UST
Umhverfisstofnun

Samantekt á rituðum heimildum um jarðfræði Austur-Skaftafellssýslu (og annarra svæða við jaðar Vatnajökuls)

Unnið af Skaftafellsþjóðgarði
apríl 2007

Helga Davids

Samantekt á rituðum heimildum um jarðfræði Austur-Skaftafellssýslu
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Þakkarorð

Kærar þakkir fá Kvískerjasjóður fyrir að gera þetta verkefni fjárhagslega mögulegt, Helgi Björnsson, Helgi Torfason og Finnur Pálsson fyrir ráðgjöf við upphaf verkefnisins og Þorvarður Árnason fyrir að auðvelda heimildavinnslu með því að benda á forritið EndNote. Síðast en ekki síst fá Hrafnhildur Hannesdóttir og Páll Imsland kærar þakkir, Hrafnhildur fyrir samvinnu og gagnkvæm skipti á heimildum og Páll Imsland fyrir ráðgjöf og að leyfa mér að nota "spjaldaskrá" sína með upplýsingum um eldri greinir um jarðfræði Austur-Skaftafellssýslu.

1. Efnisyfirlit

1.1 Myndaskrá

2. Inngangur

Nauðsynlegt er að gera samantekt á jarðfræðiheimildum um Skaftafellsþjóðgarð til að geta:

- lagt mat á verndargildi ákveðinna jarðminja

- veitt nemendum og fræðimönnum sem vilja leggja stund á jarðfræðirannsóknir innan þjóðgarðsins nauðsýnlegar upplýsingar.

Unnið er að gerð verndaráætlunar fyrir Skaftafellsþjóðgarð. Til að geta lagt mat á verndargildi jarðminja á svæðinu, þurfa vissar grunnupplýsingar að vera til staðar. Nauðsynlegt er að taka saman yfirlit um jarðminjar í þjóðgarðinum, kortleggja þær og lýsa þeim með tilliti til verndunar.

Á hverju ári koma inlendir og erlendir nemendur og fræðimenn í þjóðgarðinn til að gera rannsóknir á jarðfræði hans. Oft vita þeir ekki nákvæmlega hvað hefur verið rannsakað áður og komið hefur fyrir að þeir stunduðu rannsóknir á fyrirbærum sem höfðu verið ítarlega könnuð áður. Þar að auki er brýnt að starfsmenn þjóðgarðsins hafi gott yfirlit yfir þær rannsóknir sem hafa verið gerðar til að geta bent fræðimönum eða nemendum á þau svæði eða jarðfræðifyrirbæri sem þarfnast frekari athugunar.

Sótt var um styrk úr Kvískerjasjóði til að kortleggja jarðminjar í Skaftafellsþjóðgarði og úthlutaði sjóðurinn 500.000 krónur í þetta verkefni.

Vorið 2006 héldu Ragnar Frank Kristjánsson og skýrsluhöfundur fund með jarðfræðingunum Helga Björnssyni, Helga Torfasyni og Finni Pálssyni í Öskju, náttúrufræðahúsi Háskóla Íslands til að ræða verkefnið. Einnig var rætt við Pál Imsland. Niðurstaða úr fundunum var að upphafleg áætlun um að kortleggja jarðminjar í þjóðgarðinum væri of dýr í framkvæmd og of tímafrek. Þess í stað var ákveðið að gera ítarlega samantekt á rituðum heimildum um jarðfræði í Austur-Skaftafellssýsla, án þess að birta niðurstöðurnar í kortaformi.

Þorvarður Árnason, forstöðumaður Háskólaseturs á Höfn lagði til að forritið EndNote yrði notað til að safna og flokka heimildirnar. Starfsmaður hans, Hrafnhildur Hannesdóttir lét höfund þessarar skýrslu hafa þær heimildir í té sem hún hafði þegar tekið saman um jarðfræði Vatnajökuls.

Við söfnun á heimildum var lögð aðaláhersla á Austur-Skaftafellssýslu, þ.e.a.s. svæðið frá Skeiðarárjökli austur í Lón og voru teknar saman heimildir um bæði jaðarsvæði Vatnajökuls og sjálft jökulhvelið. Stefnt var að því að gera samantektina á heimildum um þetta svæði nokkurn veginn tæmandi. Einnig voru teknar saman heimildir um önnur jaðarsvæði hringinn í kringum Vatnajökul en er sú samantekt ekki eins yfirgripsmikil og samantektin fyrir Austur-Skaftafellssýslu.

Ekki voru einungis skráðar heimildir um jarðfræði út af fyrir sig; einnig var safnað heimildum um byggðasögu, samgöngur, ferðalög, gróður og dýralíf, ásamt ferðabókum, ferðahandbókum, ljósmyndabókum og slíku, sem innihalda oftar en ekki landslagslýsingar og tilvitnanir í jarðfræðifyrirbæri.

Forritið EndNote býður upp á þann möguleika að flokka heimildir eftir lykilorðum. Nauðsynlegt er að vanda sig vel þegar lykilorð eru skráð. Við skráningu á heimildum er greinin sjálf oft ekki fyrir hendi, aðeins títill hennar. En títill á grein lýsir innihaldi greinarinnar ekki alltaf nógu vel, sem hefur í för með sér að lykilorðin eru í sumum tilfellum illa valin. Stundum er ógerlegt að nota ákveðin lykilorð til að leita að heimildum í safninu. Þegar lykilorðið "Skaftafell" er til dæmis slegið inn, birtast ekki einungis heimildir um svæðið "Skaftafell", heldur einnig heimildir um "*Skaftafell*ssýslu" almennt; þegar lykilorðið "Hólá" er slegið inn, birtast einnig greinar sem "Nic*hola*s" hefur samið, og svo framvegis.

Stundum má finna samantekt (abstract) á ákveðinni grein á veraldarvefnum. Hægt er að vista slíkar samantektir í Endnote og birtast þær skálettraðar þegar heimildirnar eru prentaðar. Samantektir eru oftast á ensku og hafa þær ekki verið þýddar. Forritið EndNote býður einnig upp á þann möguleika að vista pdf-skjöl og myndir. Í sumum tilfellum er hægt að finna greinar í pdf-formi á veraldarvefnum og er þá hægt að vista slík skjöl í EndNote.

Birtist þá táknið  ef um pdf-skjal er að ræða, og  ef um mynd eða kort er að ræða.

Teknar voru saman alls 1764 heimildir. Í skýrslunni sem hér liggur fyrir hafa heimildirnar verið flokkaðar eftir svæðum. Sumar heimildir fjalla um fleiri en eitt svæði og koma því oftar en einu sinni fyrir. Sumar heimildir eru ekki tengdar ákveðnu svæði en frekar ákveðnu jarðfræðifyrirbæri, eins og "jökulhlaupi úr þverdal", "eldgos undir jökli", "öskulögum" , "möttulstrók" eða "landslagi undir jökli". Slíkar heimildir birtast ekki þegar leitað er að heimildum um ákveðin svæði. Þess vegna var ákveðið að flokka heimildirnar bæði eftir ákveðnum svæðum og eftir ákveðnum efnisorðum. Skýrslan sem hér liggur fyrir samanstendur úr þremur hlutum:

I: Yfirlit yfir jarðfræðirannsóknir sem hafa verið gerðar í Austur-Skaftafellssýslu. Upplýsingar um rannsóknir sem hafa verið gerðar á ákveðnum svæðum hafa verið settar inn á kort og loftmyndir af viðkomandi svæðum. Hver jökull er tekinn fyrir einn og sér; byrjað er á Skeiðarárjökli og svo er farið austur með Vatnajökli að Eystrahorni. Í lokin er gefið yfirlit um jarðfræðirannsóknir sem varða Suðausturland í heild sinni (3. kafli).

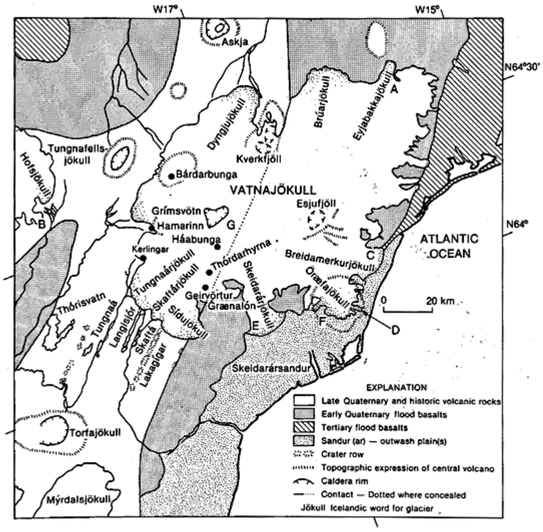
II: Samantekt á heimildum um jarðfræði Austur-Skaftafellssýslu og annarra svæða við jaðar Vatnajökuls, sem sýnir heimildirnar flokkaðar eftir landssvæðum. Byrjað er á Skeiðarárjökli og svo er farið rangsælis í kringum Vatnajökul, þangað til komið er að Vestur-Skaftafellssýslu. Að lokum er sjálfur Vatnajökull tekinn fyrir (4. kafli).

III: Samantekt á heimildum um jarðfræði Austur-Skaftafellssýslu og annarra svæða við jaðar Vatnajökuls, sem sýnir heimildirnar flokkaðar eftir efnisorðum (5. kafli).

I: yfirlit yfir jarðfræðirannsóknir í Austur-Skaftafellssýslu

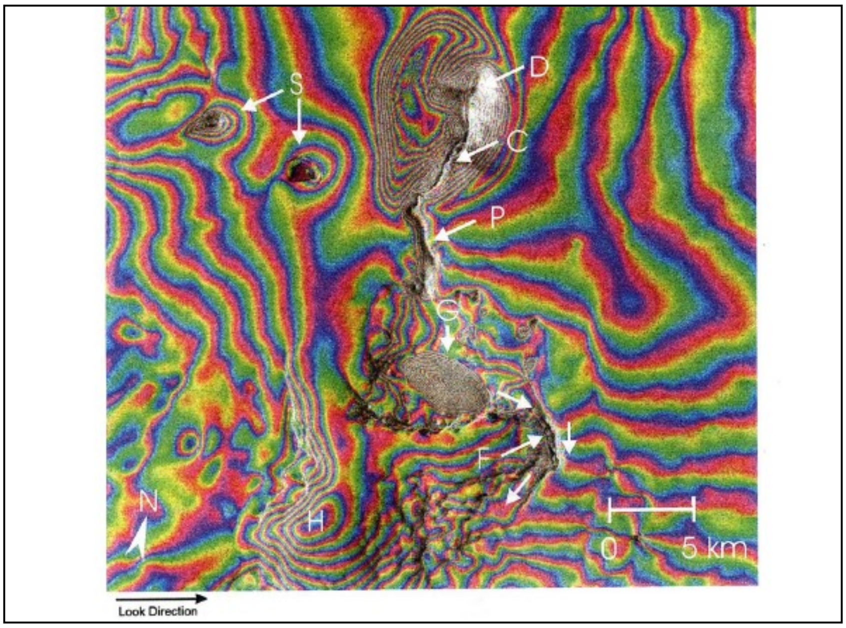
3. Yfirlit yfir jarðfræðirannsóknir í Austur-Skaftafellssýslu

3.1 Vatnajökull: rannsóknir á jökulhettunni



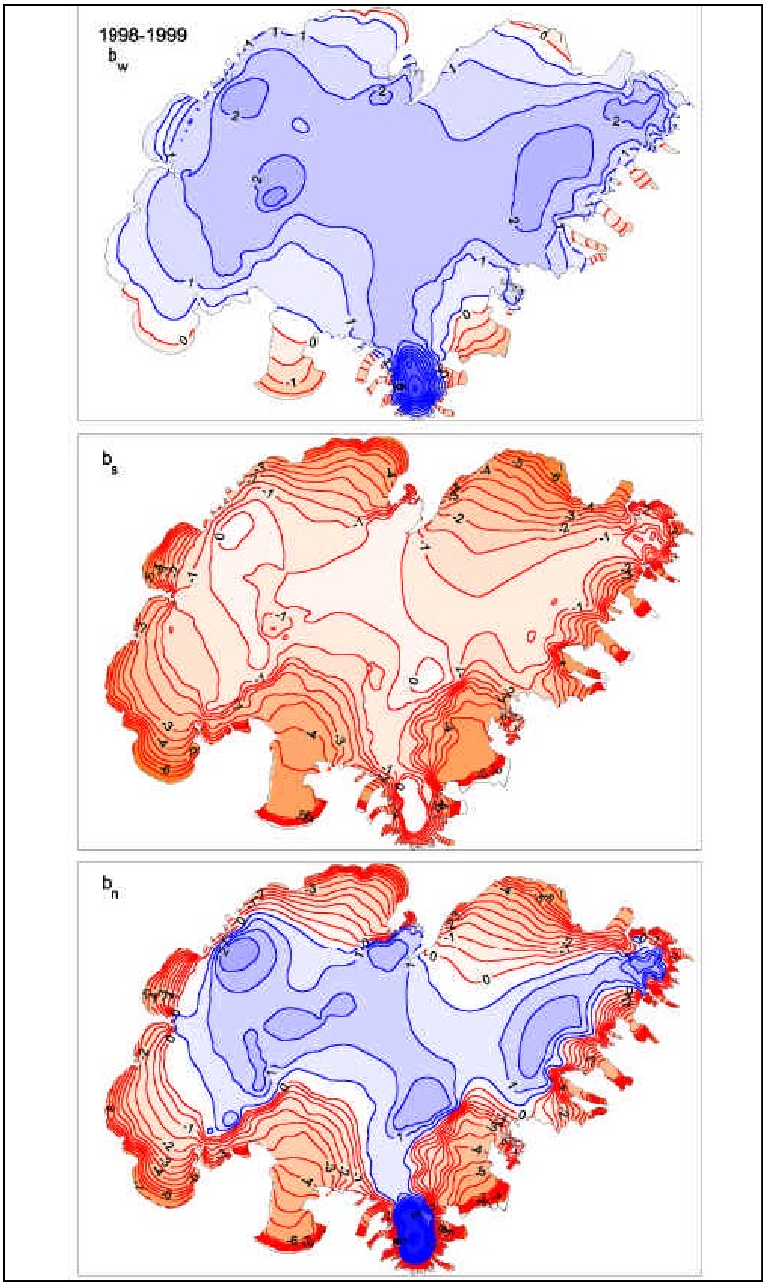
Lengi hafa verið stundaðar reglubundnar rannsóknir á Vatnajökli. Jöklarannsóknafélagið (JÖRFI), sem var stofnað árið 1950 hefur staðið fyrir fjölmörgum rannsóknarferðum á jökulinn og rekur nokkra skála á jökulhettunni. Einnig hafa fjölmargir erlendir vísindamenn, einkum Bretar, skipulagt rannsóknarleiðangra og sinnt rannsóknarstörfum á Vatnajökli. Erfitt er að gera tæmandi lista yfir þær rannsóknir sem hafa verið gerðar á Vatnajökli í gegnum tíðina en hér fylgir listi yfir þau rannsóknarsvið sem hafa fengið mesta athygli vísindamanna:

1- **jökulsporðabreytingar, mælingar á legu jökulsporða, síðan 1932**
2- **bylgjuvíxlmælingar úr gervitunglum (SAR) eru notaðar til að meta stærð jökla og umfang jöklabreytinga undanfarin 300 ár; SAR-mælingar eru einnig notaðir til að gera kort af þrívíðri hreyfingu jökla (sjá mynd 1)**



Mynd 1: Bylgjuvíxlmynd sem sýnir gosstöðina í Gjálp 1996 (C-D), Grímsvötn (G), Háabunga (H) og Skaftárkatlar (S); Myndin sýnir stöðuna 1.-2. janúar 1997 (úr: Björnsson 2001, bls, 63).

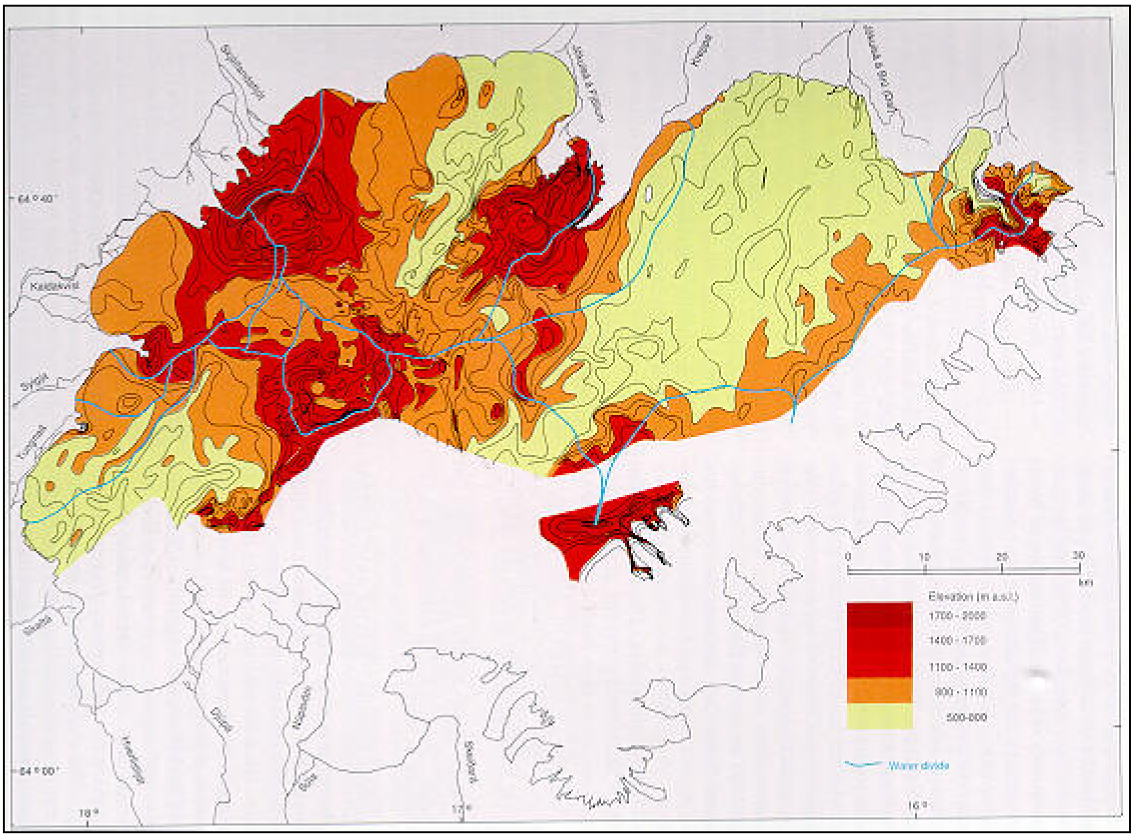
3- eldgos undir jökli, samspil eldgosa og jökla
4- mælingar á vatnshæð og jöklabúskap Grímsvatnasvæðis síðan 1953
5- jarðskjálftamælingar
6- veðurathuganir
7- tengsl veðurþátta eins og sólgeislunar, loftraka, lofthita og vindhraða við leysingu á yfirborði jökuls
8- jöklabúskapur (ákoma, leysing), sjá mynd 2.



Mynd 2: Jöklabúskapur Vatnajökuls 1998-1999 . Afkoma er mæld sem þykkt í metra vatns(ígildis) . Bw = vetrarafkoma; Bs = sumarafkoma; Bn = afkoma jökulársins

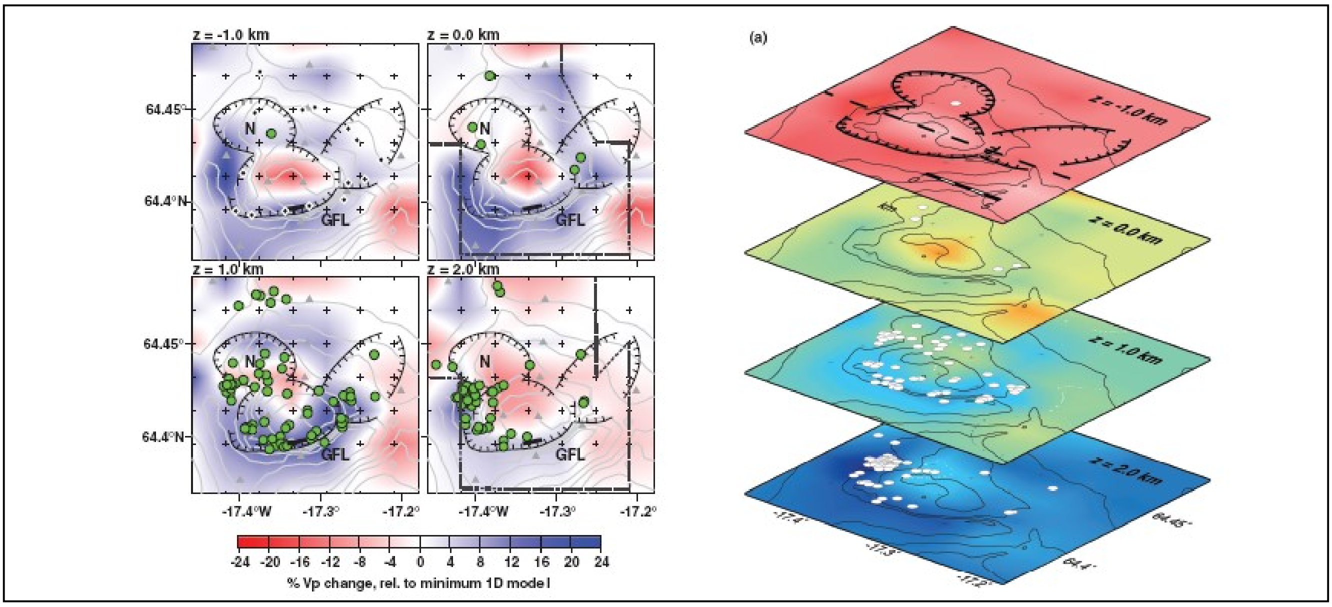
9- vatnafræði
10- hvernig jökullinn bregst við loftslagsbreytingum

11- kortlagning á yfirborði og botni jökla með íssjármælingum, síðan 1976; landslag undir jöklinum (sjá mynd 3)



Mynd 3: Landslag undir Vatnajökli samkvæmt íssjármælingum (http://www.i.is/~mmh/gos/images/grunur.jpg)

12- þyngdarmælingar; síðan 1988 hafa farið fram þyngdarmælingar á megineldstöðvum í eystra gosbeltinu til að kanna byggingu eldstöðvanna (sjá mynd 4)



Mynd 4: Bygging eldstöðvar í Grímsvötnum á mismunandi dýpi samkvæmt þyngdarmælingum (Alfaro et al. 2007).

13- djúpborun; rannsóknir á öskulögum í ískjörnum

14- jökulhlaup, áhrif jarðhita á jökla og myndun lóna undir jöklum (sérstaklega Grímsvötn og Skaftárkatlar); bæði jökulhlaup tengd eldvirkni og jökulhlaup úr jökulstífluðum þverdölum. Með kortlagningu á þykkt jökla og landslagi undir þeim má rekja feril vatns í jökulhlaupum. Slíkar rannsóknar hafa mikið gildi fyrir almannavarnir og mannvirkjagerð í nágrenni jökla

15- framhlaup skriðjökla

16- jökulminjar við sporða skriðjökla sem teygja sig niður frá Vatnajökli; bæði jökulminjar sem tengjast jökulhlaupum og jökulminjar sem tengjast framhlaupi, framskriði og hopi skriðjökla

17- myndun jaðarlóna

18- möttulstrókur undir norðvesturhluta Vatnajökuls; heitur reitur (sjá mynd 5)

19- landrek

20- landris á jaðarsvæðum Vatnajökuls í kjölfar bráðnunar jökulsins

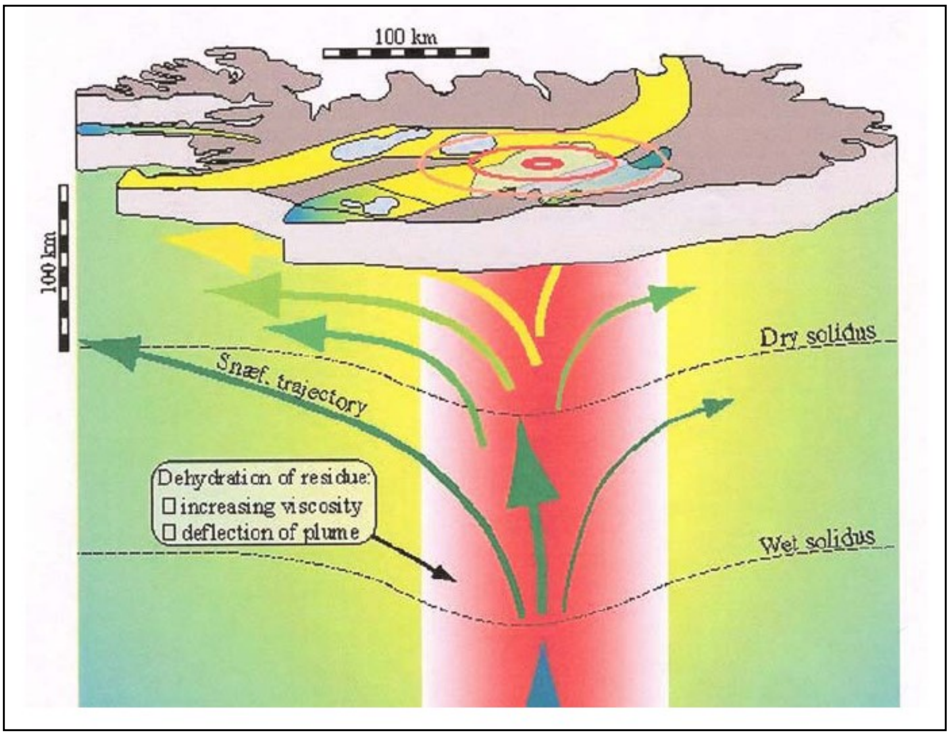
21- jöklunarsaga

22- eldstöðvakerfi undir Vatnajökli og við jaðar hans

23- gróðurframvinda, fugla- og skordýralíf á jökulskerjum

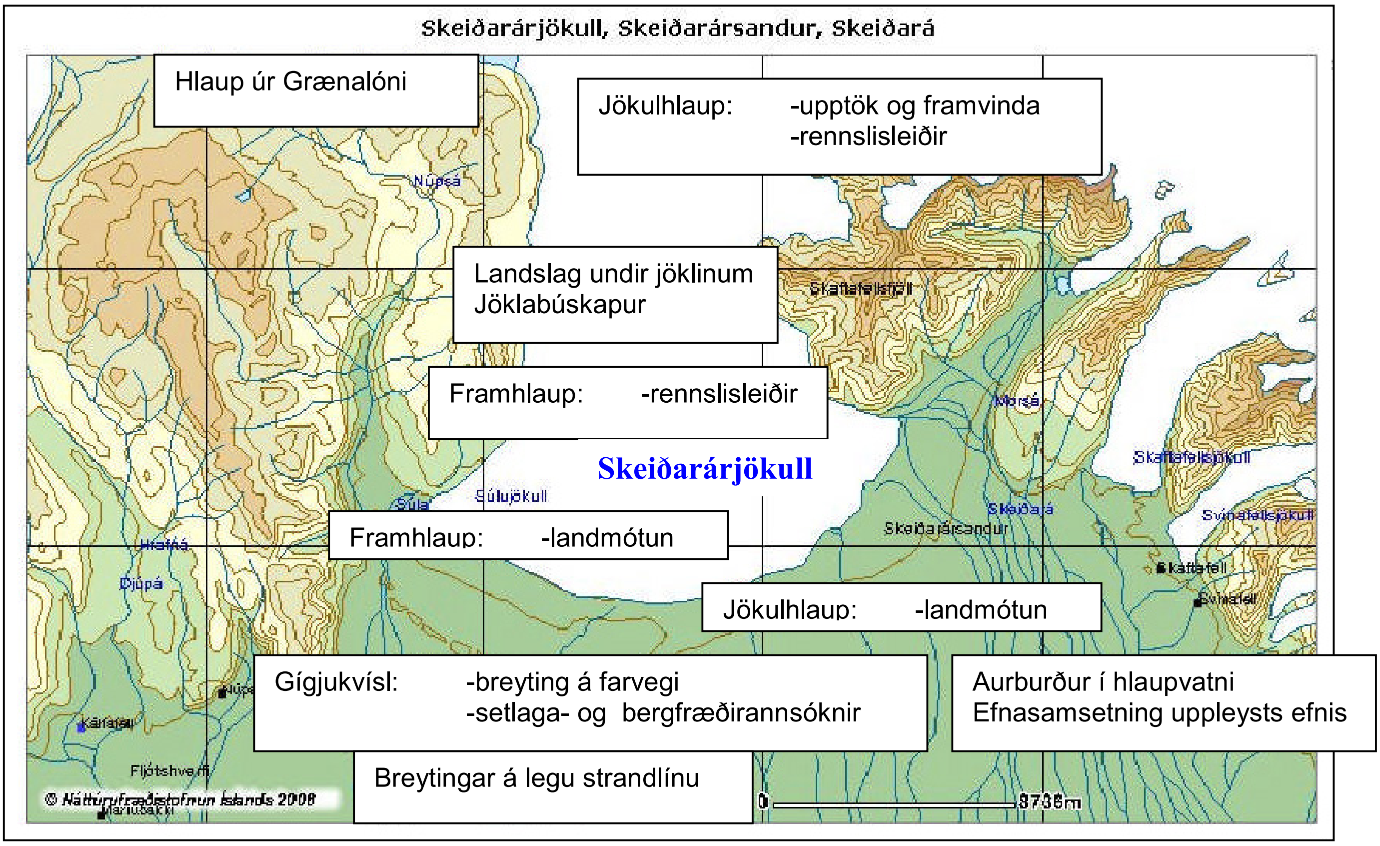
24- sérstæð lífkerfi í jarðhitasvæðum

JÖRFÍ gaf árið 2000 út skýrslu, "Vatnajökull. Rannsóknir, ferðalög og skipulag" í tengslum við fyrirhugaða stofnun Vatnajökulsþjóðgarðs. Í þessari skýrslu má finna áhugaverðar upplýsingar um starfsemi JÖRFÍ og rannsóknir sem félagið hefur staðið fyrir (Guðmundsson 2000). Einnig má finna gagnlegar upplýsingar um rannsóknir á Vatnajökli á heimasíðu Helga Björnssonar: http://www.hi.is/page/helgib

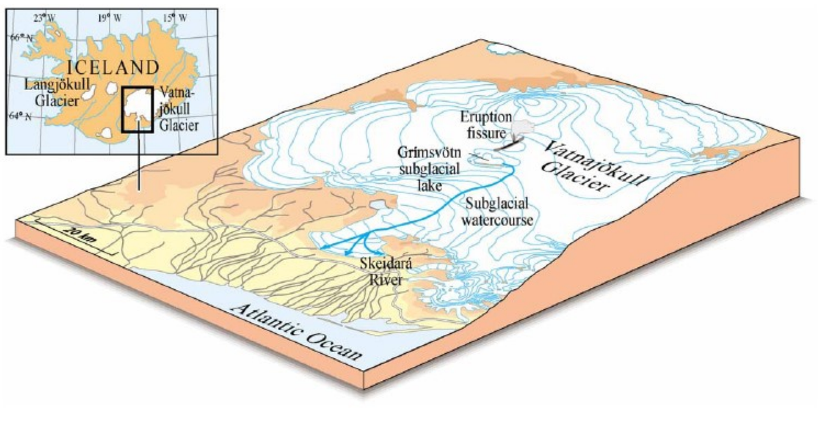


Mynd 5: Möttulstrókur undir norðvestanverðum Vatnajökli og rekbelti (Trønnes 2004).

3.2 Skeiðarárjökull, Skeiðarársandur, Skeiðará



Skeiðarárjökull og Skeiðarársandur hafa verið viðfangsefni gríðarlega margra og umfangsmikilla rannsókna, sérstaklega eftir að eldgosið í Gjálp árið 1996 og jökulhlaupið í Skeiðará sem fylgdi í kjölfar þess hafa sett svæðið á heimskortið. Rannsóknir hafa aðallega beinst að tvenns konar stórviðburðum sem hafa átt sér stað með reglulegu millibili í gegnum tíðina, **jökulhlaupum** og **framhlaupi jökulsins**. Jökulhlaup undan Skeiðarárjökli geta komið til með tvennum hætti, annars vegar stíflar Skeiðarárjökul fyrir þverdal við Grænafjall og myndast þar lón (Grænalón) sem hleypur reglulega, þegar vatnið í lóninu hefur náð ákveðinni hæð. Hins vegar valda jarðhiti og eldgos í m.a. Grímsvötnum og Bárðarbungu reglulega jökulhlaupum í Skeiðará. Skeiðarárjökull er svokallaður framhlaupsjökull, sem skríður reglulega fram um langar leiðir. Sem dæmi má nefna að Skeiðarárjökull hljóp fram um meira en 1 kílómeter árið 1991.



Mynd 6: Rennslisleiðir hlaupvatns úr Grímsvötnum (Gíslason 2002)

Aðallega hefur verið rannsökuð upptök og framvindu jökulhlaupa úr jaðarlóni (Grænalóni) og háhitasvæðum (m.a. Grímsvötnum), rennslisleiðir hlaupvatns í, undir og á yfirborði jökuls (sjá mynd

6), efnasamsetningu aurburðar í hlaupvatni, rof og landmótun af völdum jökulhlaupa, framhlaup Skeiðarárjökuls og landmótun á jaðarsvæði jökulsins í kjölfar þess, hop og framskrið Skeiðarárjökuls í gegnum aldirnar, jöklabúskapur og landslag undir jöklinum.

Sérstaklega Bretar hafa verið duglegir að rannsaka Skeiðarárjökul og Skeiðarársand. Doktorsnemar frá Háskólanum í Newcastle upon Tyne, í Staffordshire og Keele hafa undir handleiðslu Dr. Andy Russell og Dr. Fiona Tweed og með aðstóð sjálfboðaliða á vegum Earthwatch-samtakanna rannsakað jökulhlaup og áhrif þeirra á mótun landslags við jökuljaðarinn, sem og framhlaup jökulsins.

Pólskir vísindamenn (P. Molewski, L Andzejewski og E Wisniewski) frá háskólanum í Torun hafa rannsakað landmótun við jaðar Skeiðarárjökuls og annarra íslenskra skriðjökla á árunum 1993, 1995 og 1996.

JÖRFI og vísindamenn á vegum Orkustofnunar (m.a. Oddur Sigurðsson, Ingibjörg Kaldal) og jarðvísindastofnunar Háskóla Íslands (m.a. Helgi Björnsson, Finnur Pálsson, Sverrir Guðmundsson, Freysteinn Sigmundsson og Magnús Tumi Guðmundsson) hafa lagt áherslu á að rannsaka jöklabúskap, útbreiðslu jökulsins, eldgos undir jökli og landslagið undir jöklinum

Reglulega hafa verið birtar niðurstöður úr jökulsporðamælingum í tímaritinu Jökli (Eyþorsson 1963; Rist 1984; Sigurdsson 1998-2006).

Stutt yfirlit yfir helstu rannsóknir sem tengjast Skeiðarárjökli, Skeiðarársandi og Skeiðará:

Jökulhlaup úr háhitasvæðum:
-upptök og framvinda jökulhlaupa
-Rennslisleiðir vatns, bæði í, undir og á yfirborði jökuls á meðan á jökulhlaupi stendur
-Útbreiðsla, rennsli, aurburður, uppleyst efni í hlaupvatni Skeiðarár og jarðhitasvæðis; mæling rennslis með geislavirku jóði
-uppruni aurburðar í hlaupvatni Skeiðarár og dreifing þess um hafið
-Efnasamsetning uppleysts efnis í hlaupvatni
-Setflutningar og rof við flóð
-eðjustraumasetmyndun í landgrunnsbrekkunni af völdum jökulhlaupa
-Setmyndun í jöklinum á meðan jökulhlaup varir
-Rof undir jökli af völdum jökulhlaupa

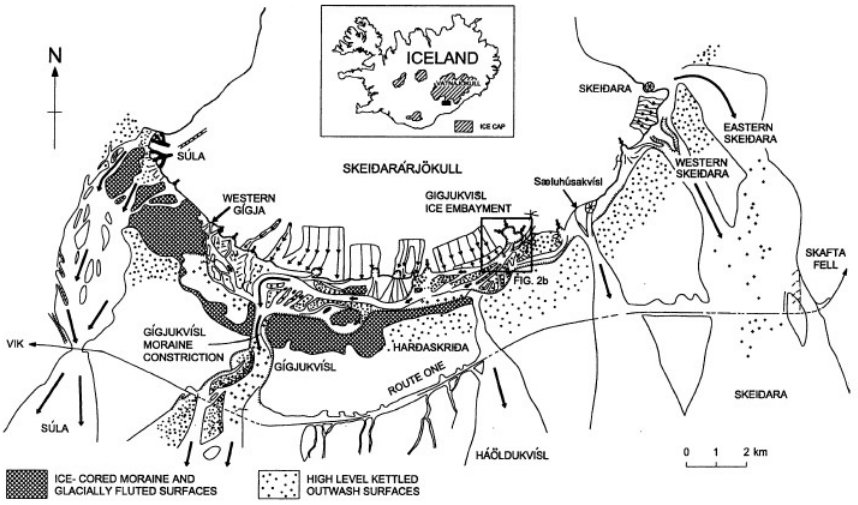
Jökulhlaup úr jaðarlóni:
-Rennslisleiðir hlaupvatns úr Grænalóni

Framhlaup Skeiðarárjökuls:
-Rennslisleiðir vatns á meðan jökullinn hleypur fram
-þversnið í gegnum setlög við jökuljaðarinn sem hafa myndast við framhlaup og hop jökulsins og túlkun þeirra setlaga
-mótun landslags við sporð framhlaupsjökuls: setmyndun, jökulgarðar, jökulkambar (kame)
-hlaup sem tengjast framhlaupi jökuls og áhrif þeirra á mótun landslags við jökulsporðinn

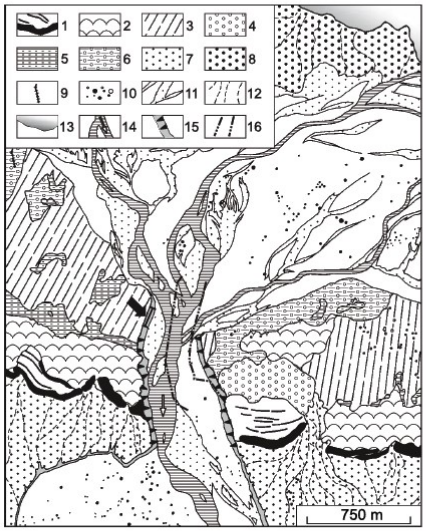
Hættan sem stafar af jökulhlaupum:
-afleiðingar eldgosa og jökulhlaupa fyrir vega-/brúargerð
-viðbrögð við hættunni

Landmótun í kjölfar jökulhlaupa:
-rof og landmótun á jaðarsvæði jökulsins í kjölfar jökulhlaupa
-Ummerki eftir ísjaka í sandinum

-Setlaga- og kornastærðagreining og bergflokkun til að útskýra minna strandrof á Breiðamerkursandi eftir Skeiðarárhlaup ´96
-setlaga- og bergfræðirannsóknir við Gígjukvísl
-breytingar á farvegi Gígjukvíslar í kjölfar Skeiðarárhlaups ´96
-breytingar á legu strandlínu í kjölfar Skeiðarárhlaups ´96
-Samanburður á aurburði í Skeiðarárhlaupum 1972 og 1976
-Efnasamsetning aurburðar í jökulhlaupum 1972 og 1976



Mynd 7: Kort af Skeiðarárjökli: rennslisleiðir hlaupvatns, jökulkembar (dökkt), jökulker (doppótt); Mynd fengið úr Russell (2001).



Mynd 8: Landmotunarkort fyrir svæðið í kringum Gígjukvísl (Molewski 2005)

Landmótun almennt:
-Landmótunarkort (sjá myndir 7 og 8)
-Myndun jökulkera
-Myndun malarása
-efnaveðrun setlaga á Skeiðarársandi
-könnun á þykkt setlaga á Skeiðarársandi með skjálftamælingum
-könnun á tilvist grafins íss í aur við jökulsporðinn með viðnámsmælingum

Vatnafræði (Skeiðarársandur)
-Efnasamsetning og rennslisleiðir grunnvatns á Skeiðarársandi

Setmyndun í og undir jöklinum, jökulrof:
-Undirkælt vatn og ísmyndun undir sporðum skriðjökla, setmyndun úr undirkældu vatni

Jöklabúskapur:
-Vöktun og kortlagning á jöklabúskap með landupplýsingakerfi (LUK), fjarkönnun og GPS (ákomusvæði, jafnvægislína, leysingasvæði, skriðhraði, yfirborð jökulsins, mat á rúmmál íssins)
- ísflæði og breytingar á yfirborði jökuls nálægt gossvæðinu

Sögulegt yfirlit:
-hopunarsaga Skeiðarárjökuls
-saga jökulhlaupa/eldgosa
-lýsing á Skeiðarárhlaupum 1939, 1954, 1972, 1976, 1996 og 1998

Loftslagsbreytingar:
-mómýri undan Skeiðarárjökli

Aldursgreining jökulminja:
-aldursgreining jökulminja m.a með fléttum og geislakolsaðferð

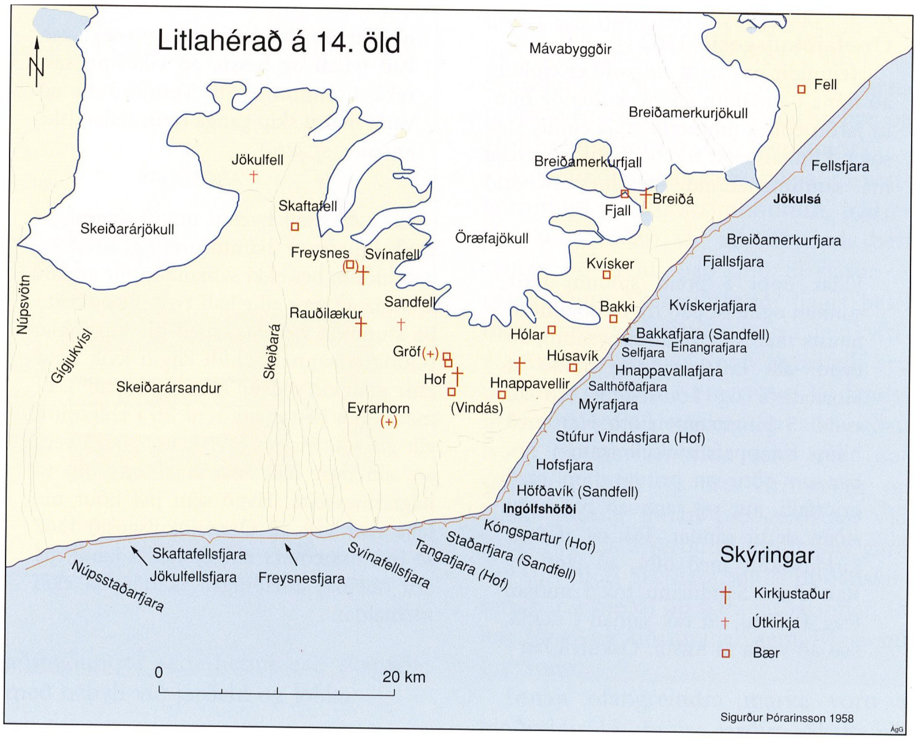
Landslag undir jöklinum:
-Könnun á landslaginu undir jöklinum með þyngdarmælingum og rafsegulmælingum

3.3 Öræfi, Öræfasveit; ekki skilgreint nánar

Eldgos í Öræfajökli og jökulhlaup í kjölfar þess hafa sett mark sitt á landslag og byggðaþróun í Öræfasveit. Eftir að landið var numið hefur Öræfajökull gosið tvisvar, fyrst árið 1362 og svo aftur 1727. Ösku- og vikurfallið ásamt jökulhlaupi í kjölfar gossins 1362 eyðilögðu alla byggð í Öræfasveit. Það kemur því ekki á óvart að flestar rannsóknir sem hafa verið gerðar í Öræfum hafa beinst að Öræfajökli.

Tveir fræðimenn, Tore Prestvik og Hjalti J. Guðmundsson hafa rannsakað jarðfræði Öræfasveitar ítarlega. Prestvik hefur á tímabilinu 1976-1985 rannsakað bergfræði gosbergs frá kvarter-tímabilinu í Öræfum og Guðmundsson hefur árið 1998 unnið doktorsritgerð við háskólann í Edinburgh um jöklabreytingar á Hólósen (nútíma) og þróað öskulagatímatal fyrir Öræfasveit. Annar doktorsnemi frá sama háskóla, R.G. Bingham, hefur árið 1998 rannsakað jökulhlaup í Öræfum.

Eins og sjá má á mynd 9 var blómleg byggð í Öræfasveit (þá kölluð Litlahérað eða "hérað milli sanda") áður en Öræfajökull gaus 1362. Sigurður Þórarinsson og Flosi Björnsson á Kvískerjum hafa skrifað greinar um Öræfajökulsgos og áhrif þeirra á byggð í "sveitina milli sanda".



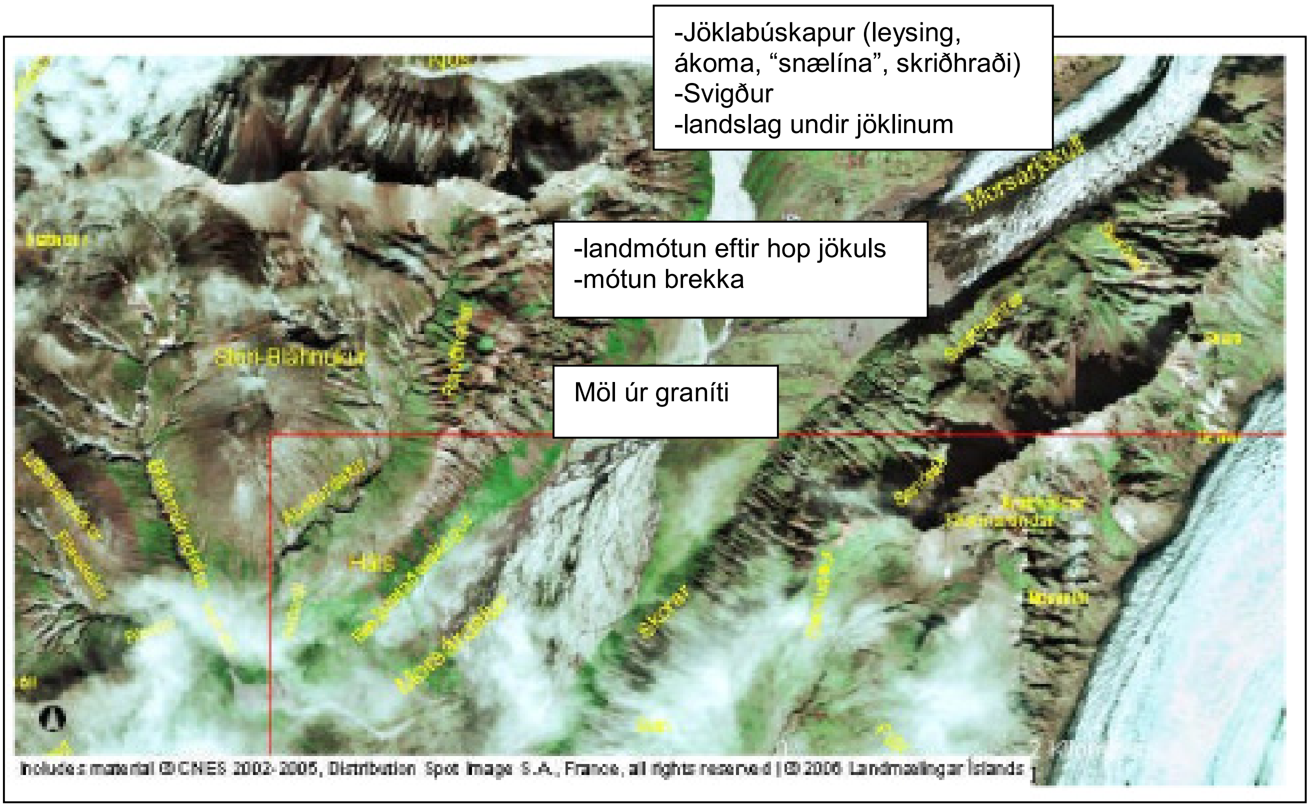
Mynd 9: Bæir og kirkjur í Öræfasveit á 14. öld, áður en Öræfajökulsgos 1362 lagði sveitina í eyði (Þórarinsson 1958).

Bresku sjálfboðaliðasamtökin Brathay Exploration Group, sem undirbúa ferðir fyrir unglinga og skólahópa, hafa frá 1953 til 1994 skipulagt fjölda af "rannsóknaleiðangrum" til Íslands og kannað m.a. dýralífið í þjóðgarðinum í Skaftafelli (1973-1978), fuglalífið í Öræfum og á Suðausturlandi almennt (1965-1975), fuglalífið í Ingólfshöfða (1978) og landslagsbreytingar í Öræfasveit (1969). Samtökin hafa gefið út rannsóknaskýrslur um hvern leiðangur en óljóst er hvert vísindalegt gildi þessara skýrslna er.

Aðrar rannsóknir hafa m.a. beinst að:

-efnafræði jökulvatns í Öræfum (Anna María Ágústsdóttir 1990: 4. árs ritgerð við H.Í.)
-landslaginu undir jöklinum með þyngdarmælingum og rafsegulmælingum (m.a. Helgi Björnsson, Finnur Pálsson)

3.4 Morsárjökull, Morsárdalur, Morsá, Skaftafellsfjöll



Morsárjökull, Morsárdalur, Morsá, Skaftafellsfjöll

Morsárjökull er falljökull sem fellur fram af þverhníptum hömrum og í hlýju veðri má stundum heyra drunur þegar fönn og ís steypast niður í háum jökulfossum. Fönnin kemur aðallega úr tveimur giljum og safnast saman neðan við jökulfossinn, þéttist í ís og skriður áfram sem jökull niður að jökullóni. Lón þetta myndaðist þegar jökullinn fór að hopa á 20. öld. Eftir miðjum jöklinum liggur urðarrönd og beggja megin við hana eru skárar eða svigður. Þessar svigður má bera saman við árhringi í tré enda er hver svigða mynduð á einu ári. Sigurður Þórarinsson beindi athygli að þessum svigðum (“ogives”) í Morsárjökli árið 1952 og skrifaði grein í tímaritinu Jökli um þær. Á næstu árum, frá 1953 til 1954, kom hópur vísindamanna og nemenda frá háskólanum í Nottingham (m.a. Jack Ives og Cuchlaine King) í Skaftafell til að rannsaka þessar svigður í Morsárjökli. Þeir könnuðu einnig jöklabúskap Morsárjökuls, mældu ákomu, leysingu og ísflæði og framkvæmdu sporðmælingar.

Árið 1989 unnu vísindamenn og nemendur tveggja háskóla í Liverpool við rannsóknir í Morsárdal. Þeir könnuðu m.a. samband milli jöklabreytinga og breytinga á farvegi Morsár og skoðuðu hvernig samsetning og lögun malar breytist þegar farið er niður með Morsá.

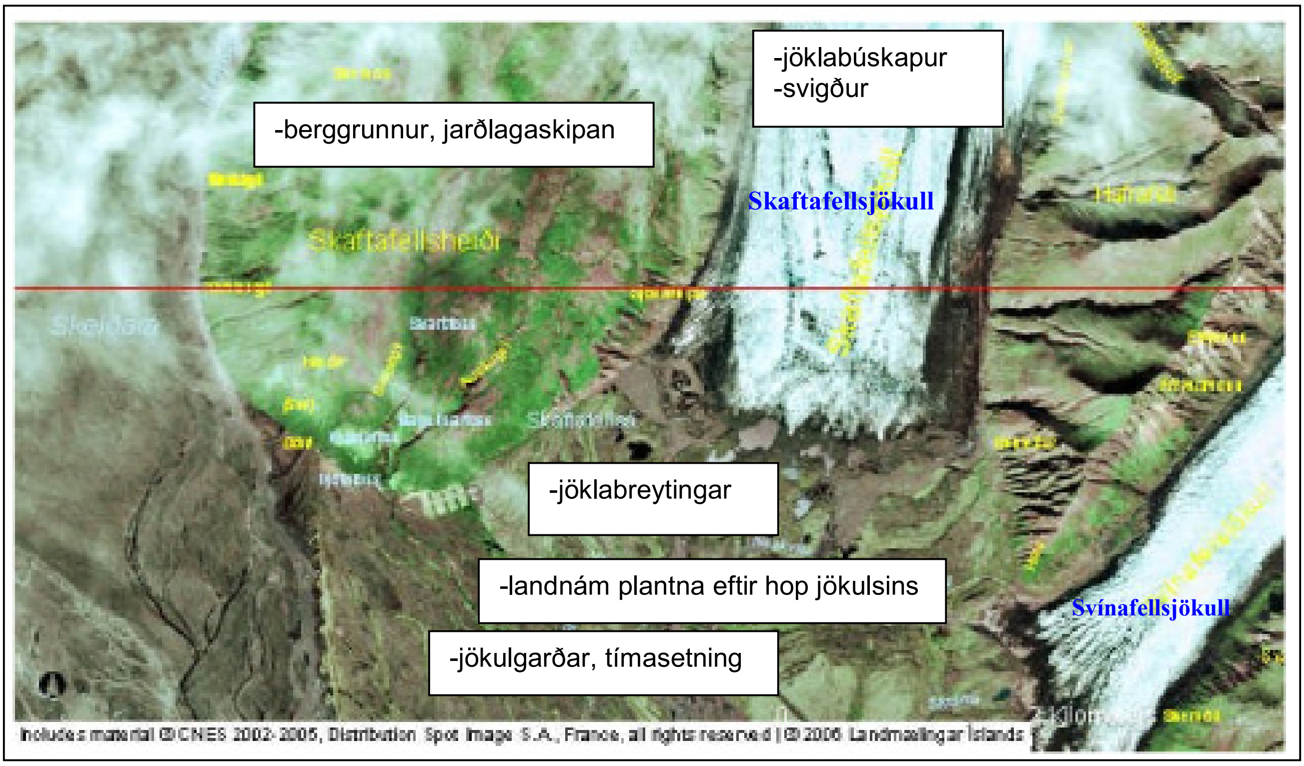
Árið 1998 rannsakaði Hjalti J. Guðmundsson breytingar á sporði Morsárjökuls (og annarra jökla í Öræfum) á Hólósen tímabilinu og dró af þeim ályktanir um loftslagsbreytingar á þeim tíma. Hann skoðaði jökulminjar (sérstaklega jökulgarða) við jökuljaðarinn og notaði aldursgreiningu með hjálp öskulaga til að fá upplýsingar um jöklabreytinga.

Danskur vísindamaður Arne Noe-Nygaard gerði nokkrar rannsóknir á Íslandi á árunum 1950-1952. Hann hafði aðallega áhuga á að kanna eldgos undir jökli og útkulnaðan jarðhita en vann einnig eitt rannsóknaverkefni í Morsárdal, þar sem hann skoðaði möl úr graníti sem jökullinn hafði flutt í dalinn.

Franskur doktorsnemi Marie Chenet frá Háskólanum í Paris er að vinna doktorsverkefni í Morsárdal. Hún rannsakar hvernig landslagið breytist sem hefur komið undan jöklinum eftir því sem hann hefur hopað og skoðar sérstaklega hvernig brekkurnar í dalnum mótast.

Reglulega hafa verið birtar niðurstöður úr jökulsporðamælingum í tímaritinu Jökli (Eyporsson 1963; Rist 1984; Sigurdsson 1998-2006).

3.5 Skaftafell, Skaftafellsjökull



Við Skaftafellsjökul hefur aðallega þrennt verið rannsakað:

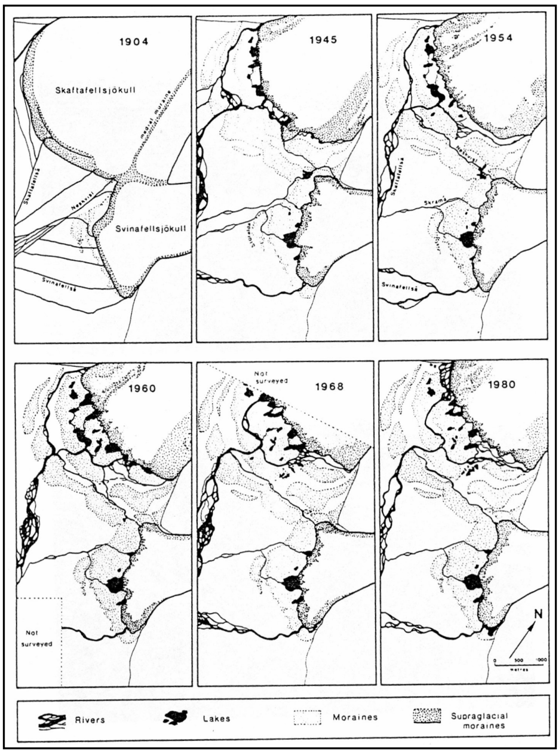
1-Landnám plantna á svæðinu við jökuljaðarinn
2-Jöklabreytingar í gegnum tíðina
3-Jökulgarðar og aðrar jökulmenjar við sporð jökulsins

1-Landnám plantna á svæðinu við jökuljaðarinn
Svæðið við Skaftafellsjökul er kjörið til að fylgjast með landnámi plantna og gróðurframvindu á svæðum sem hafa nýlega komið undan jöklinum. Sænski náttúrufræðingurinn A. Persson rannsakaði árið 1964 gróðurinn við sporð Skaftafellsjökuls og landi hans C. Lindroth rannsakaði ári seinna gróðurframvindu, loftslag auk dreifingar og fjölda skordyra á svæðinu framan við jökulinn. Hólmfríður Þorsteinsdóttir skoðaði árið 2005 breytingar á gróðri fyrir framan Skaftafellsjökul á tímabilinu 1986-2004 og birti niðurstöðurnar í BS-ritgerð sinni.

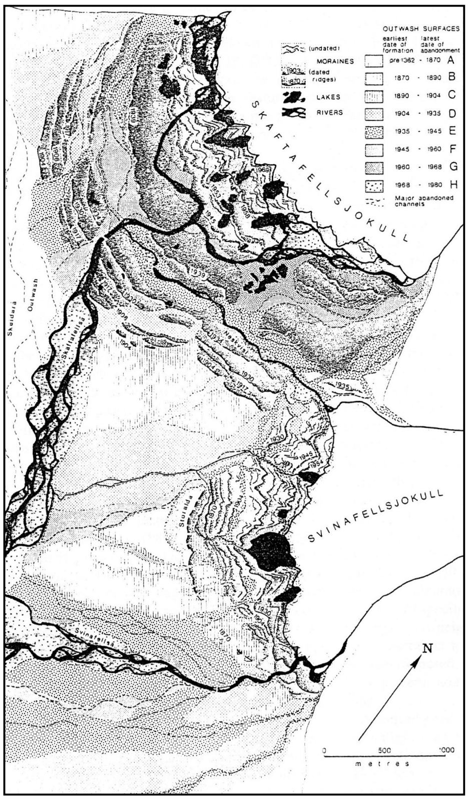
2-Jöklabreytingar í gegnum tíðina
Breytingar á sporði Skaftafellsjökuls í gegnum tíðina hafa verið viðfangsefni nokkurra rannsókna. Árið 1952 rannsakaði Svíinn Gunnar Hoppe ásamt Jóni Jónssyni jökulminjar, sérstaklega jökulruðning, við jaðar nokkurra skriðjökla á Suðausturlandi (frá Lambatungnajökli í austri til Skaftafellsjökuls í vestri). Á árunum 1953-1954 gerði rannsóknahópur frá háskólanum í Nottingham undir handleiðslu Jack Ives og Cuchlaine King sporðmælingar á Skaftafellsjökli. Hópurinn rannsakaði einnig svigður í Skaftafellsjökli, jöklabúskap og mældi ákomu, leysingu og ísflæði. Sigurður Þórarinsson ritaði árið 1956 grein í Jökul um breytingar á sporðum Skaftafells-, Svínafells- og Kvíarjökla. Eins og áður kom fram, rannsakaði Hjalti J. Guðmundsson árið 1998 ítarlega hvernig staða á sporðum allmargra skriðjökla í Öræfum hefur breyst á Hólósen-tímabilinu. Bretarnir Alan Thompson (1986 og 1988) og Philip Marren (2002) gerðu einnig rannsóknir á sporðbreytingum Skaftafellsjökuls og tímasetti jökulgarðana við jaðar Skaftafellsjökuls (sjá mynd 12).

3-Jökulgarðar og aðrar jökulminjar við sporð jökulsins

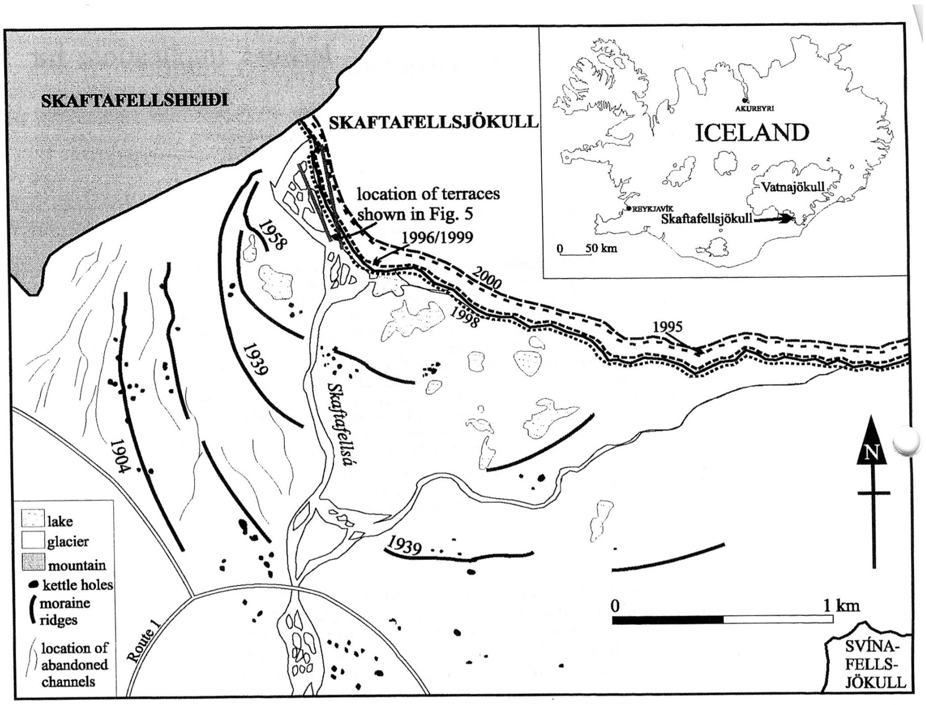
Jökulgarðarnir við sporð Skaftafellsjökuls hafa verið rannsakað ítarlega. Árið 1986 notaði Alan Thompson loftmyndir og kort til að fá upplýsingar um hop og framskrið Skaftafells- og Svínafellsjökuls á 20. öld og tveimur árum seinna kannaði hann ásamt A. Jones hvaða áhrif jöklabreytingar hafa á landslagsmótun (sjá myndir 10 og 11). Árið 2002 gerði Philip Marren enn frekari rannsóknir á jöklabreytingum og áhrifum þeirra á mótun sanda. Úr þessum rannsóknum kom fram að jökulsár flæmast yfirleitt um sandinn þegar jökullinn skríður fram en byrja að grafa sig niður þegar jökullinn hopar.



Mynd 10: Landslagsbreytingar framan við Skaftafellsjökul samfara hörfun hans á þessari öld. Byggt á korti Herforingjaráðsins frá 1904 og á loftmyndum (Thompson 1988, bls. 19).



Mynd 11: Ársettir jökulgarðar og aurar myndaðir af Svínafellsjökli og Skaftafellsjökli (Thompson 1988, bls. 22).



Mynd 12: Tímasettir jökulgarðar framan við Skaftafellsjökul (Marren 2002, bls. 76).

Árið 1952 rannsakaði Svíinn Gunnar Hoppe ásamt Jóni Jónssyni jökulminjar, sérstaklega jökulruðning, við jaðar nokkurra skriðjökla á Suðausturlandi (frá Lambatungnajökli í austri til Skaftafellsjökuls í vestri).

Árið 1989 gerðu vísindamenn og nemendur tveggja háskóla í Liverpool margvíslegar rannsóknir við Skaftafellsjökul (Morse og Hunt 1989). Þeir rannsökuðu m.a. jarðeðlisfræðilega eiginleika jökulruðnings, jarðskrið, jarðvegsmyndun og prufuðu tvær aðferðir til að aldurgreina jökulminjar (með fléttum og Schmidt-hammer aðferð).

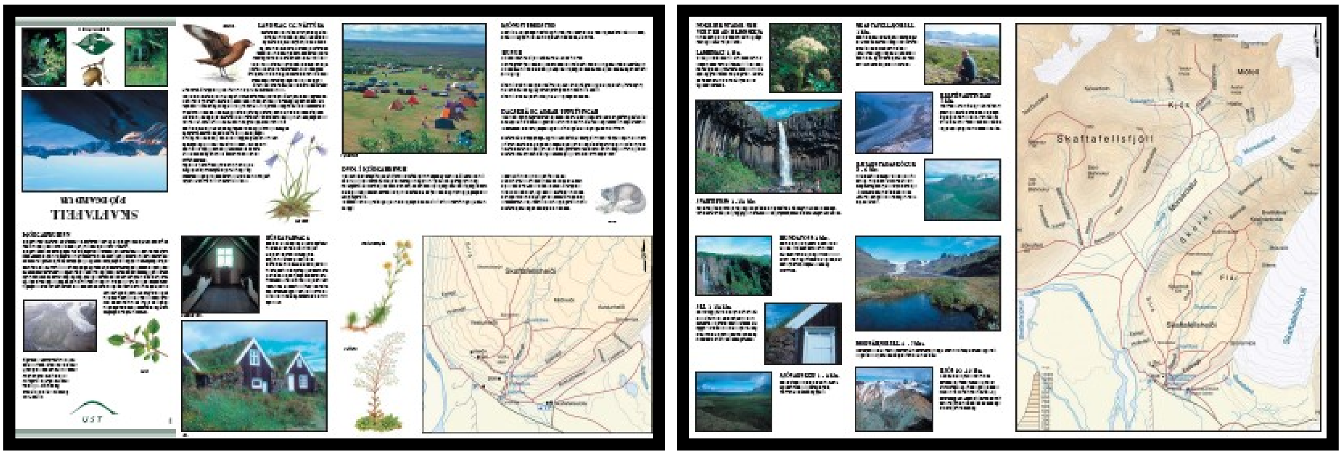
Áðurnefndur Philip Marren rannsakaði einnig hvaða áhrif vatnsmagn og tíðni í jökulám hafa á landmótun og setmyndun. Hann rannsakaði atburði sem gerast sjaldan en hafa gríðarlega aukningu í vatnsmagni í för með sér (jökulhlaup og framhlaup) og atburði sem eru mjög tíðir en leiða einungis til lítilsháttar aukningar í vatnsmagni (venjulega leysingu) og skoðaði hvernig þessir mismunandi atburðir koma fram í setlagastaflanum (Marren 2005).

Matthew Roberts kannaði árið 2002 undirkælt vatn undir sporðum skriðjökla, ísmyndun og setmyndun í jöklinum úr undirkældu vatni, bæði við Skeiðarárjökul og Skaftafellsjökul (Roberts, Tweed, Russell, Knudsen, Lawson, Larson, Evenson, Björnsson 2002).

Berggrunnurinn í Skaftafelli hefur verið rannsakaður ítarlega en gögnin hafa aldrei birst, nema að mjög litlu leyti. Jóhann Helgason hefur, með aðstoð Robert Duncan, á tímabilinu 1987-2001 safnað gríðarlegu magni af upplýsingum um berggrunn, bergsegulstefnu og jöklunarsögu Skaftafells, Hafrafells og Svínafells auk þess sem hann hefur látið aldursgreina bergsýni með K-Ar aðferðinni (Helgason og Roberts 1992; Helgason 2001; Helgason og Duncan 2001). Markmið með þessum rannsóknum var að kortleggja jarðlagaskipan svæðisins og að gera jarðfræðikort.

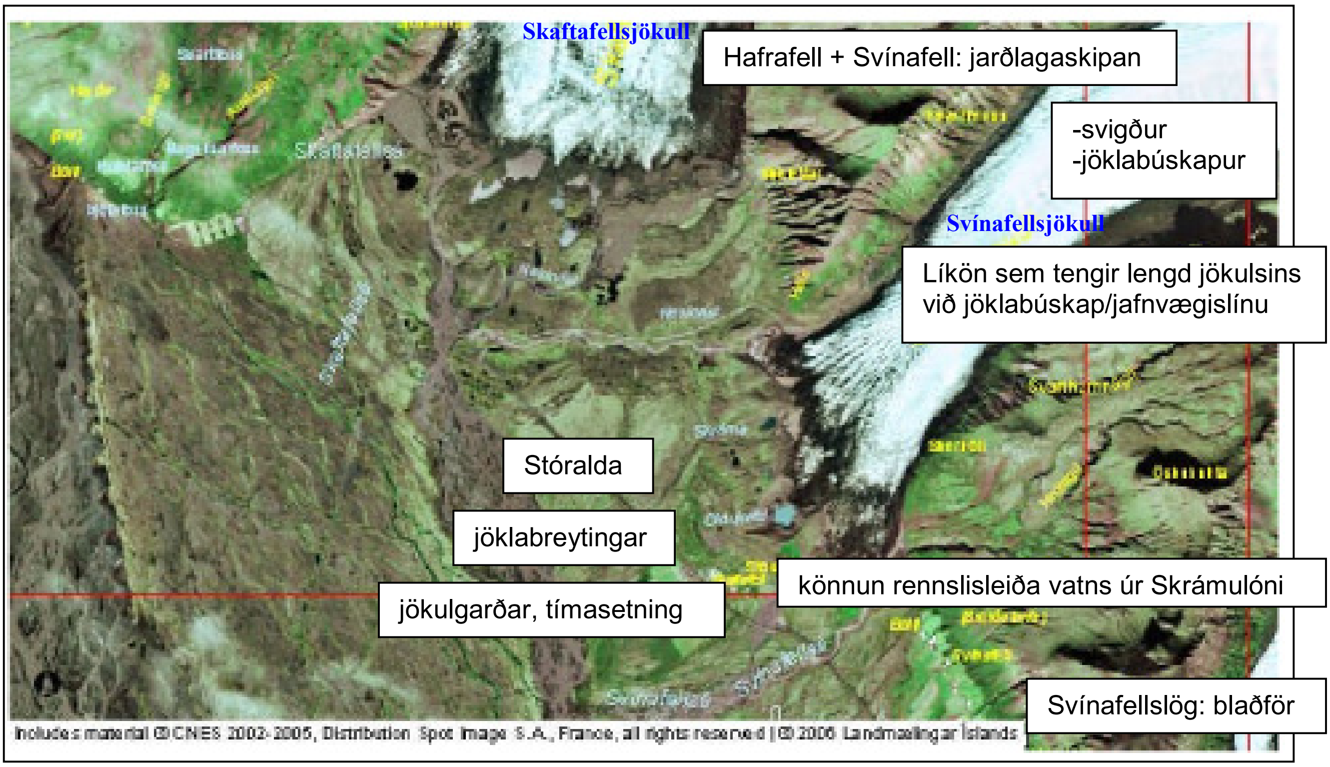
Árið 1989 rannsökuðu vísindamenn og nemendur tveggja háskóla í Liverpool mýri í Skaftafellsheiði, til að finna út hvort þar væri að finna geislavirkt efni frá kjarnorkuslysinu í Tsjernobyl árið 1986. Ef svo væri, þá væri hægt að nota lög með geislavirka efninu til aldursgreiningar (Morse og Hunt 1989).

Árið 2004 gaf Umhverfisstofnun út bækling með upplýsingum um sögu, gróður, fuglalíf, jarðfræði og gönguleiðir í Skaftafelli (sjá mynd 13).



Mynd 13: Bæklingur UST um þjóðgarðinn í Skaftafelli.

3.6 Svínafellsjökull, Svínafell, Hafrafell, Svínafellslög, Stóralda



Svínafellsjökull
Svínafellsjökull hefur lengi hopað minna en flestir aðrir skriðjöklar á Suðausturlandi, því hann á upptök sín hátt upp í Öræfajökli, þar sem ákoma er mikil. Beggja megin við urðarrönd sem liggur eftir miðjum jöklinum eru skárar eða svigður ("ogives", sbr. við Morsárjökul).

Reglulega hafa verið birtar niðurstöður úr jökulsporðamælingum í tímaritinu Jökli (Eyporsson 1963; Rist 1984; Sigurdsson 1998-2006).

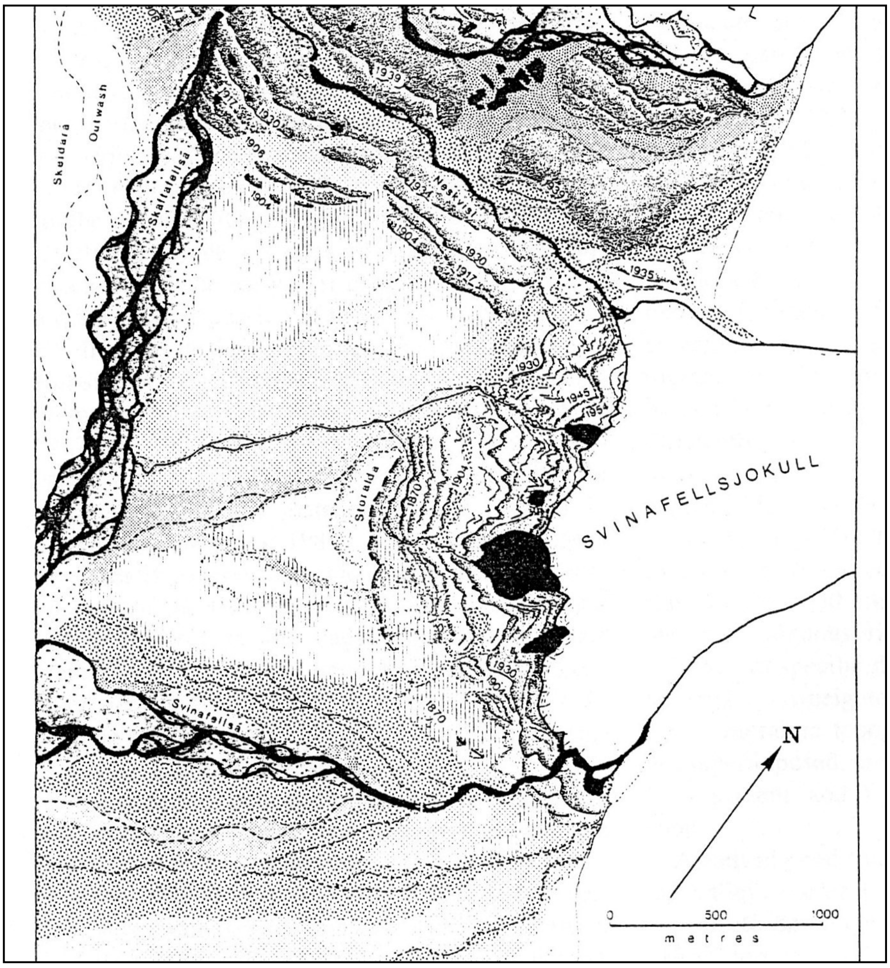
Árið 1952 rannsakaði Svíinn Gunnar Hoppe ásamt Jóni Jónssyni jökulminjar, sérstaklega jökulruðning, við jaðar nokkurra skriðjökla á Suðausturlandi (frá Lambatungnajökli í austri til Skaftafellsjökuls í vestri).

Árið 1953 birti Sigurður Þórarinsson grein í Jökli um svigður á Svínafellsjökli í Öræfum.

Á árunum 1953-1954 gerði rannsóknahópur frá háskólanum í Nottingham undir handleiðslu Jack Ives og Cuchlaine King sporðmælingar á Svínafellsjökli. Hópurinn rannsakaði einnig svigður í Svínafellsjökli, jöklabúskap og mældi ákomu, leysingu og ísflæði.

Sigurður Þórarinsson ritaði árið 1956 grein í Jökul um breytingar á sporðum Skaftafells-, Svínafells- og Kvíarjökla.

Árið 1986 notaði Alan Thompson loftmyndir og kort til að fá upplýsingar um hop og framskrið Skaftafells- og Svínafellsjökuls á 20. öld. Tveimur árum seinna birti hann grein í Jökli um sögulega þróun í landslagsmótun við jaðar Svínafells- og Skaftafellsjökuls (sjá mynd 14).



Mynd 14 Ársettir jökulgarðar og aurar myndaðir af Svínafellsjökli og Skaftafellsjökli (Thompson 1988, bls. 22).

Árið 1989 gerðu vísindamenn og nemendur tveggja háskóla í Liverpool margvíslegar rannsóknir við Svínafellsjökul. Þeir könnuðu m.a. jarðeðlisfræðilega eiginleika jökulruðnings, jarðvegsmyndun í jökulgörðum, jöklabreytingar, frostveðrun, uppleyst efni og aurburð í Svínafellsá, áhrif veðurfars á leysingu, breytingar á farvegi Svínafellsár, vatnshæð í jaðarlónum, rennsli í Neskvísl, jarðskrið og gerðu tilraunir með tvær aðferðir til að aldursgreina jökulminjar (með fléttum og með svk. Schmidt-hammer aðferðinni).

Árið 1998 könnuðu vísindamenn á vegum Raunvísindastofnunar Háskóla Íslands (Finnur Pálsson, Helgi Björnsson og Eyjólfur Magnússon) rennslisleiðir vatns úr Skrámulóni, undir sporð Svínafellsjökuls

Árið 1998 rannsakaði Hjalti J. Guðmundsson breytingar á sporði Svínafellsjökuls (og annarra jökla í Öræfum) á Hólósen tímabilinu og dró af þeim ályktanir um loftslagsbreytingar á þeim tíma. Hann skoðaði jökulminjar (sérstaklega jökulgarða) við jökuljaðarinn og notaði aldursgreiningu með hjálp öskulaga til að fá upplýsingar um jöklabreytingar.

Árið 2003 notuðu tveir hollenskir jarðfræðingar upplýsingar um jöklabreytingar margra skriðjökla í Evrópu (þ.a.m. Svínafellsjökuls) til að gera líkan sem gerir það kleift að reikna út jafnvægislínu og jöklabúskap ákveðins jökuls á sögulegum tíma.

Reglulega hafa verið birtar niðurstöður úr jökulsporðamælingum í tímaritinu Jökli (Eyporsson 1963; Rist 1984; Sigurdsson 1998-2006).

Svínafell, Hafrafell

Vísindamenn og nemendur frá tveimur háskólum í Liverpool rannsökuðu árið 1989 basaltlögin í Hafrafelli til að fá upplýsingar um bergfræði og gossögu Öræfajökuls. Hópur frá sömu háskólanum skoðaði hvort hægt væri að nota svokallaða “Schmidt-hammer” aðferð, sem gengur út frá því að ákveða aldur bergs á grundvelli veðrunarstigs þess, til að aldursgreina jökulminjar eins og jökulgarða. Þeir prufuðu aðferðina m.a. í Svínafellsfjöllum og báru niðurstöðurnar saman við niðurstöður úr aldursgreiningum með fléttum. Jóhann Helgason hefur, með aðstoð Robert Duncan, á tímabilinu 1987-2001 safnað gríðarlegu magni af upplýsingum um berggrunn, bergsegulstefnu og jöklunarsögu Skaftafells, Hafrafells og Svínafells auk þess sem hann hefur látið aldursgreina bergsýni með K-Ar aðferðinni. Árið 1996 héldu þeir erindi á vorráðstefni Jarðfræðifélags Íslands um jarðlagaskipan Svínafells.

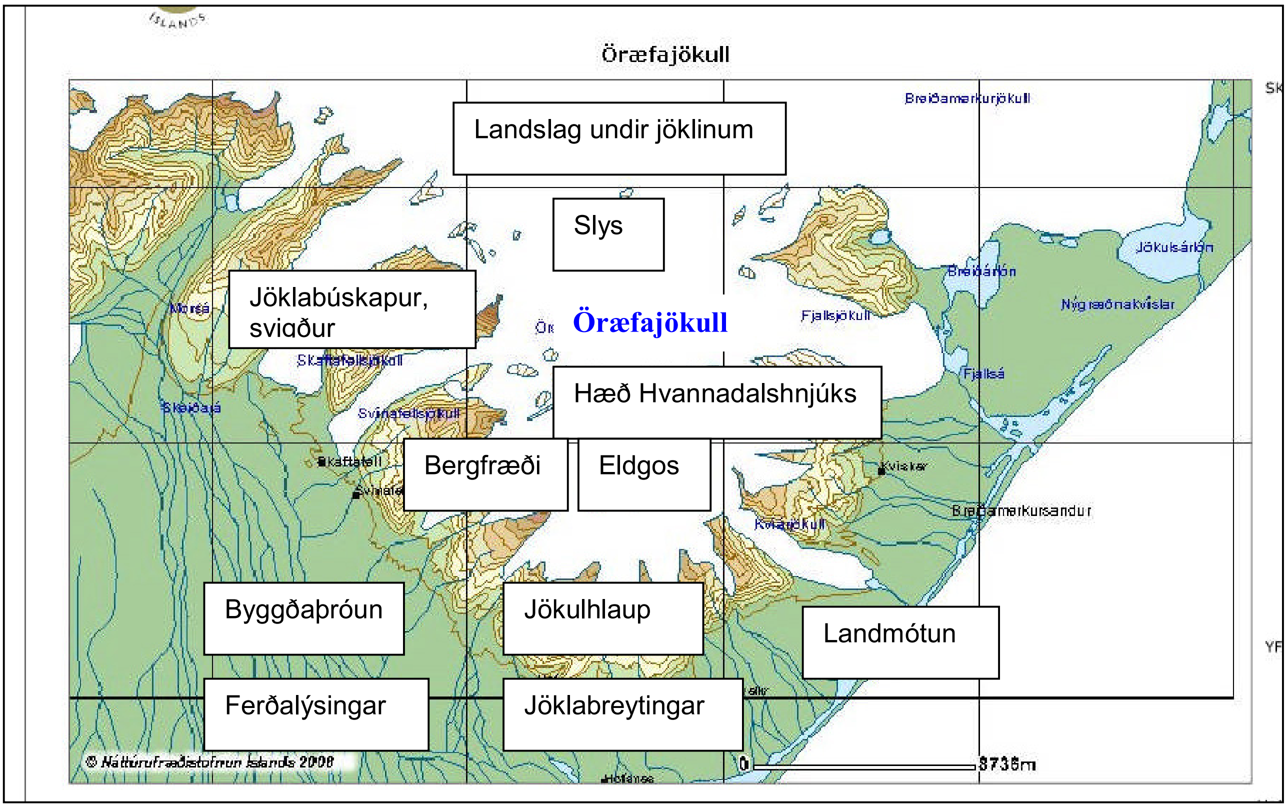
Svínafellslög

Neðarlega í Svínafellsfjalli er um 120 m þykkt lag af fínkornuðum sandsteini sem hefur sest til í stöðuvatni, á hlýskeiði ísaldar. Setlögin fylla dal sem hefur grafist niður í basalthraunlög og teljast vera milli 780.000 og 500.000 ára gömul. Víða í sandsteininum má finna blaðför af elri, víði, birki, reyni, bláberja- og krækiberjalyng, grösum og burknum. Þessar plöntuleifar veita okkur mikilvægar upplýsingar um loftslagið á þeim tíma þegar setlögin mynduðust. Sigurður Þórarinsson (Þórarinsson 1963) og Eyþór Einarsson (Einarsson 1987) skrifuðu greinar um þessi merku sandsteinslög.

Stóralda

Stóralda er hár, forn jökulgarður sem hefur verið ýtt upp af Svínafellsjökli fyrir um það bil 2500 árum. Árið 1956 rannsakaði Sigurður Þórarinsson Stóröldu og tímasetti hana. Vísindamenn og (doktors)nemendur frá tveimur háskólum í Liverpool rannsökuðu árið 1989 jarðvegsmyndun í Stóröldu (Morse og Hunt 1989) . Hópur nemenda í jarðeðlisfræði gerði árið 2003 þyngdarmælingar við Stóröldu til að finna eðlismassa hennar.

3.7 Öræfajökull



Öræfajökull

Öræfajökull er virk eldkeila sem hefur gosið tvisvar eftir landnám, fyrst árið 1362 og svo aftur 1727. Gosið 1362 var mesta vikurgos sem orðið hefur á Íslandi á sögulegum tíma. Ösku- og vikurfallið ásamt jökulhlaupi í kjölfar gossins eyðilögðu alla byggð í Öræfasveit. Sveitin hét áður Litla Hérað eða Hérað milli Sanda en eftir gosið fékk hún nafnið Öræfi. Gosið 1727 olli ekki jafnmiklu tjóni. Á norðvesturbrún Öræfajökulsöskjunnar rís Hvannadalshnúkur, hæsti tindur Íslands. Ósamkomulag er um nákvæma hæð tindsins, sem er talin vera 2119 m (samkvæmt eldri mælingum) eða 2111 m (samkvæmt mælingum sem voru gerðar árið 2004).

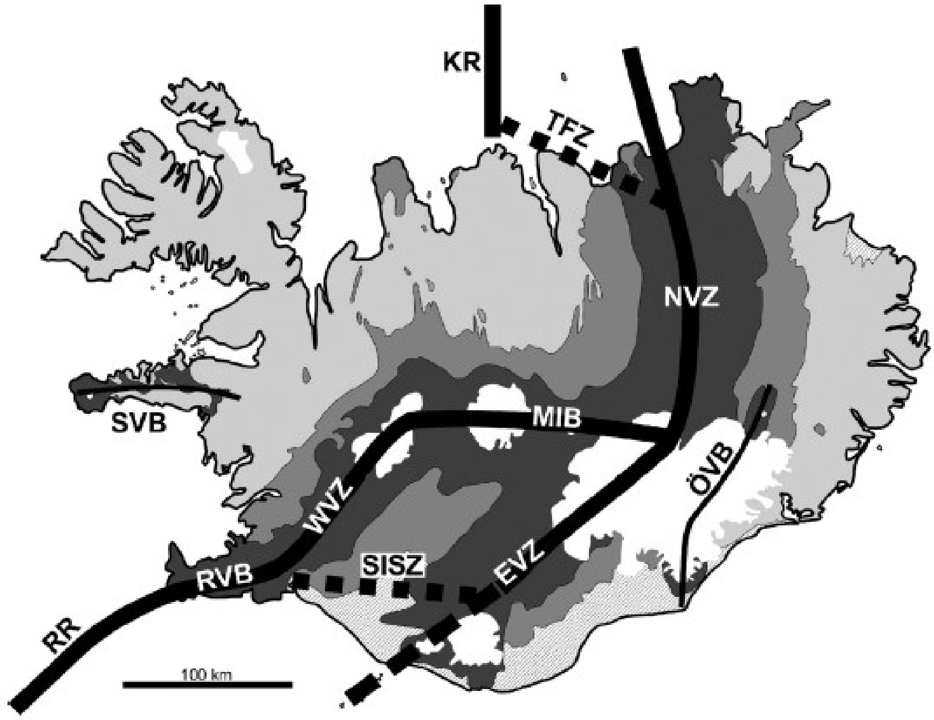
Öræfajökull hefur fengið verðskuldaða athygli vísindamanna og ferðalanga í gegnum tíðina. Flestar greinar sem hafa verið skrifaðar um Öræfajökul fjalla um eftirfarandi 11 atriði:

1- Jökulhlaup í kjölfar eldgosa
2- Eldgos í Öræfajökli
3- Bergfræði Öræfajökuls
4- Landmótun við sporð skriðjökla
5- Hæð Hvannadalshnjúks
6- Slys á Öræfajökli
7- Byggðaþróun í Öræfasveit
8- Ferðalýsingar
9- Landslag undir jöklinum
10- Jöklabreytingar
11- Jöklabúskapur, svigður

1- Jökulhlaup í kjölfar eldgosa
Frásögn Síra Einars Hálfdánarsonar er ágæt samtímaheimild um hlaupið úr Öræfajökli 1727 (Hálfdánarson 1918-1920). Bretinn Bingham hefur rannsakað hvaða áhrif jökulhlaupin sem fylgdu í kjölfar Öræfajökulsgosanna 1362 og 1727 hafi haft á mótun landslags við fjallsræturnar. Hann kortlagði svæðin við jaðar Fall- og Kotárjökla og reyndi að útskýra jökulminjar við þá jökulsporða með því að bera þær saman við hliðstæðar jökulminjar sem mynduðust í kjölfar Skeiðarárhlaups 1996 (Bingham 1998). Í Náttúrufræðingnum birtist grein eftir Sigurð Björnsson á Kvískerjum um hlaup sem hefur hugsanlega átt sér stað árið 1598 (Björnsson 1951). Upplýsingar um jökulhlaup úr Öræfajökli má einnig finna í ritinu “Skaftafell og Öræfi”, sem Hið íslenska náttúrufræðifélag hefur gefið út (Einarsson et al. 1987) og í tveimur alfræðiritum sem Ari Traustu Guðmundsson hefur samið, “Íslandseldar” og “Íslenskar eldstöðvar” (Guðmundsson 1986, 2001).

2- Eldgos undir Öræfajökli
Sigurður Þórarinsson gerði grein fyrir Öræfajökulsgosi 1362 í riti Náttúrfræðistofnunar Íslands, Acta Naturalia Islandica (Þórarinsson 1957). Í bókinni “Vatnajökull” eftir Jón Eyþórsson er að finna lýsing á eldvirkni í Öræfajökli í gegnum tíðina (Eyþórsson 1960). Í ofangreindum bókum eftir Ara Trausta Guðmundsson, “Íslandseldar” og “Íslenskar eldstöðvar”, má einnig finna ítarlega lýsingu á gossögu Öræfajökuls (Guðmundsson 1986, 2001). Sharma, Self, Blake og Larsen rannsökuðu Öræfajökulsgos 1362 ítarlega og könnuðu m.a. gosefna, gosferli og gosgufur í kvikunni (Sharma, Self, Blake, Larsen 2004). Þorvaldur Þórðarson og Guðrún Larsen sömdu ítarlega yfirlitsgrein um eldvirkni á Íslandi á sögulegum tíma og gerðu í henni Öræfajökli góð skil (Þórðarson, Larsen 2007). Selbekk og Trønnes rannsökuðu bergfræðileg einkenni líparíts sem hefur hlaðist upp í Öræfajökulsgosinu 1362 (Selbekk og Trønnes, óprentuð grein).

3- Bergfræði Öræfajökuls
Á áttundi og níundi áratugunum gerði Norðmaðurinn Tore Prestvik nokkrar rannsóknir á bergfræðilegum einkennum gosbergs úr Öræfajökli (Prestvik 1976, 1979, 1980, 1982; einnig 2001). Á níunda áratugnum birtust nokkrar greinar eftir Pál Þór Imsland um bergfræði og sögu Öræfajökuls (Imsland 1987, 1988, 1989; einnig 2005, 2006). Jóhann Helgason og Robert Duncan rannsökuðu jarðlagaskipan, bergsegulstefnu og jöklunarsögu Skaftafells og Svínafells við rætur Öræfajökuls og aldursgreindu bergið (Helgason og Duncan 1996). Olgeir Sigmarsson, Michel Condomines og Serge Fourcade rannsökuðu eldstöðvakerfi á Íslandi sem liggja utan virka gosbeltisins, þ.e.a.s. Snæfellsjökul og Öræfajökul. Þeir könnuðu efnasamsetningu gosefna til að geta dregið ályktanir um uppruna kvikunnar (Sigmarsson, Condomines og Fourcade 1992). Í Bulletin of Volcanology birtist grein eftir Olgeir Sigmarsson, H.R. Karlsson og Guðrún Larsen sem fjallar aðallega um nýleg eldgos í Gjálp og Grímsvötnum (1996 og 1998) en í henni er einnig greint frá eldstöðvakerfinu Öræfajökli og efnasamsetningu kvikunnar úr henni (Sigmarsson, Karlsson og Larsen 2000). Öræfajökull og Snæfell teljast liggja á sama gosbelti, sem nú er næstum því kulnað og er kallað Öræfajökuls gosbelti (sjá mynd 15). Hards, Kempton, Thompson og Greenwood rannsökuðu efnasamsetningu gosefna Snæfells og breytingar á henni í gegnum tíðina til að geta dregið ályktanir um eðli Öræfajökuls gosbeltisins (Hards, Kempton, Thompson og Greenwood 2000). Stevenson, Mcgarvie, Smellie and Gilbert gerðu rannsóknir á bergfræði Öræfajökuls og samspili íss og elds; þeir reyndu m.a. að meta þykkt íssins yfir gosopinu með því að skoða lögun og stærð gosminja (Stevenson, McGarvie, Smellie og Gilbert 2006). Selbekk og Trønnes rannsökuðu bergfræðileg einkenni líparíts sem hefur hlaðist upp í Öræfajökulsgosinu 1362 (Selbekk og Trønnes, óprentuð grein). Mynd 16 sýnir jarðvegssnið sem var tekið í Bleikafjalli; gjóskulögin sem sjást í jarðvegssniðinu hlóðust upp í Öræfajökulsgosinu 1362.



Mynd 15: Eldstöðvakerfi á Íslandi; ÖVB er Öræfajökulsgosbelti og teljast Öræfajökull, Esjufjöll og Snæfell liggja á því (Þórðarson 2007).

4- Landmótun við sporð skriðjökla
Skriðjöklar teygja sig í allar áttir niður úr Öræfajökli. Ýmsir vísindamenn hafa gert rannsóknir á landmótun við sporða þessara skriðjökla, skoðað jökulgarða og aðrar jökulminjar og gert landmótunar kort (sjá umfjöllun um einstaka skriðjökla: Svínafellsjökull, Virkisjökull, Falljökull, Kotárjökull, Stigárjökull, Hólárjökull, Kvíárjökull, Hrútárjökull, Fjallsárjökull).

5- Hæð Hvannadalshnjúks
Hvannadalshnúkur er hæsti tindur Íslands. Nokkrar tilraunir hafa verið gerðar til að mæla nákvæma hæð hans en illa hefur gengið, því fjallið er snævi þakið og snjódýptin hefur verið breytileg. Í tímaritinu Skirnir birtist árið 1906 grein sem fjallar um hæð Hvannadalshnúks (Sæmundsson 1906).

6- Slys á Öræfajökli
Árið 1953 skipulagði Jack Ives rannsóknaleiðangur til að rannsaka Morsárjökul. Þáttakendur í leiðangrinum voru kennarar og nemendur við Háskólann í Nottingham, Þegar leið að lokum dvalarinnar fórust tveir nemendur á Öræfajökli. Það var leitað að þeim dögum saman en leitin bar engan árangur. Meira en hálfri öld seinna, sumarið 2006, fannst þó hluti af viðlegubúnaði þeirra ofarlega á Skaftafellsjökli. Um þetta banaslys hafa verið skrifaðar nokkrar greinar (Kjartansson 1953; Stefánsson 1987).

7- Byggðaþróun í Öræfasveit
Úr gömlum heimildum eins og máldögum má lesa að blómleg byggð hafi verið við rætur Öræfajökuls. Öræfajökulsgos 1362 og jökulhlaup í kjölfar þess lögðu byggðina í eyði í áratugi. Ýmsir fræðimenn hafa rannsakað ummerki Öræfajökulsgosa og áhrif þeirra á byggðina við fjallsræturnar (Björnsson 1982, 1996; Þórarinsson 1957, 1959, 1979; Þorsteinsson 1992).

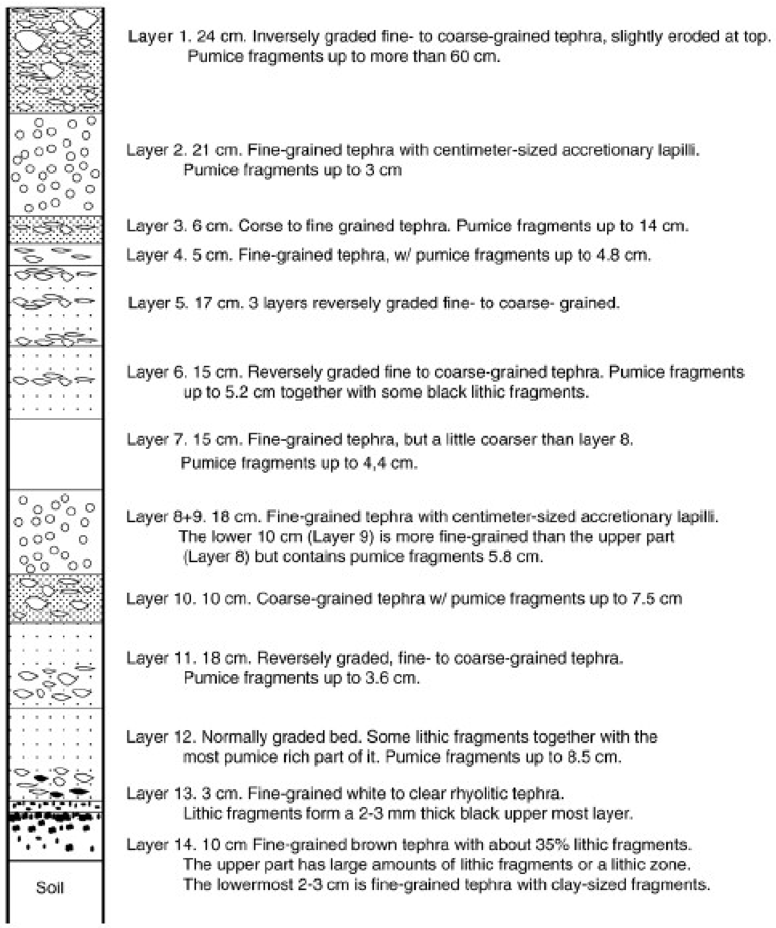
8- Ferðalýsingar
Margir hafa lýst gönguferðum á Öræfajökul í gegnum tíðina (Thoroddsen 1908-1922; St. Leger og Gall 1952; Stefánsson 1952; Arason 1959; Baldursson 1978; Guðmundsson 1978; Björnsson 1982;

Ísólfsson 1989; Schierbeck 2000). Sveinn Pálsson gekk fyrstur á Öræfajökul, árið 1794 (Björnsson 1994; Pálsson 1998).

9- Landslag undir jöklinum
Helgi Björnsson og aðrir hafa rannsakað rof af völdum jökla og kannað landslagið undir Öræfajökli og skriðjöklunum sem teygja sig niður frá honum.

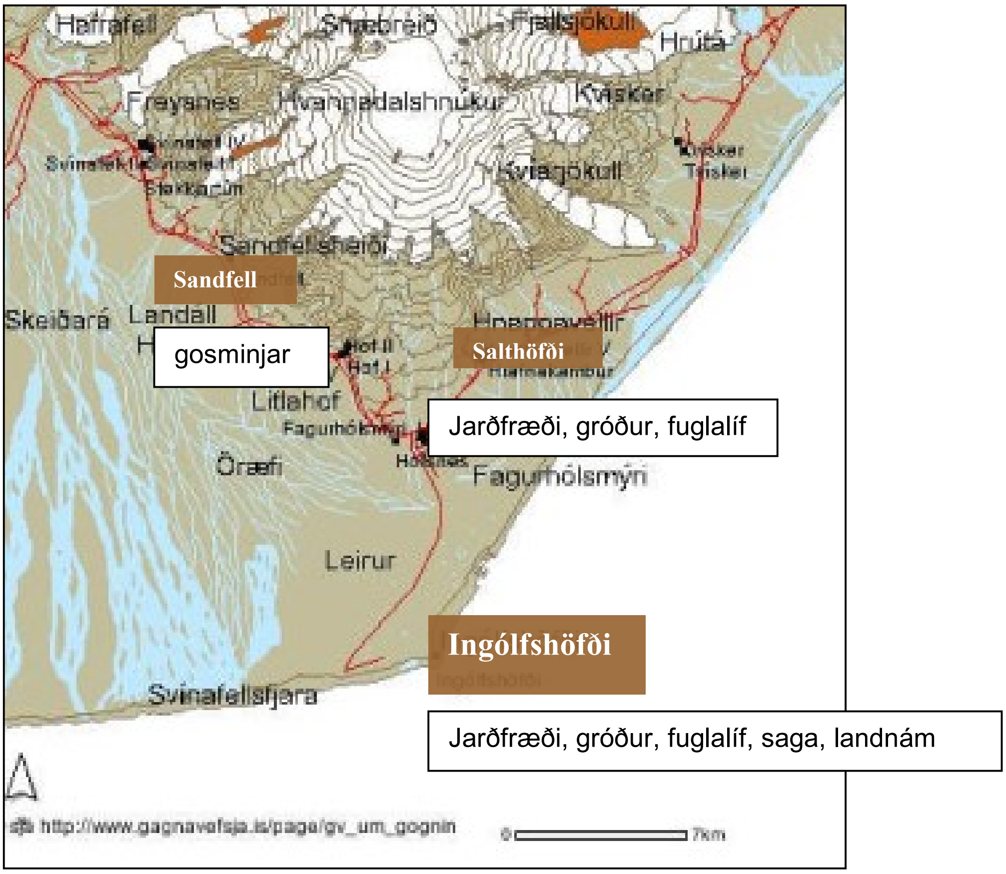
10- Jöklabreytingar
Reglulega hafa verið birtar niðurstöður úr jökulsporðamælingum við einstaka skriðjökla í tímaritinu Jökli (Eyporsson 1963; Rist 1984; Sigurdsson 1998-2006). Af þeim fjölmörgum skriðjöklum sem falla niður úr Öræfajökli hafa einungis Svínafellsjökull, Virkisjökull, Falljökull, Kvíárjökull, Hrútárjökull og Fjallsárjökull verið mældir reglulega. Engar reglulegar mælingar hafa farið fram við Stigárjökul og Hólárjökul.

11- Jöklabúskapur, svigður
Bretinn Elliston rannsakaði svigður á nokkrum skriðjöklum sem teygja sig niður frá Öræfajökli Þessar svigður má bera saman við árhringi í tré enda er hver svigða mynduð á einu ári (Elliston 1957). Magnús Tumi Guðmundsson gerði rannsóknir á jöklabúskap (ákomu og leysingu) efst á Öræfajökli (Guðmundsson 2000).



Mynd 16: Jarðvegssnið tekið á Bleikafjalli, 4 km austan við öskju Öræfajökuls; gjóskulögin í sniðinu hlóðust upp í Öræfajökulsgosinu 1362 (Úr Selbekk, óprentuð grein).

3.8 Sandfell, Ingólfshöfði, Salthöfði



Sandfell
Árið 1974 birtist grein eftir Flosa Björnsson á Kvískerjum í Náttúrufræðingnum um gosminjar upp af Sandfellsfjalli.

Salthöfði
Salthöfði er klettarani umlukinn votlendi. Höfðinn er líklega gígtappi eða leifar af goshrygg og er hluti af hamrabelti sem teygir sig frá Fagurhólsmýri að Hnappavöllum. Í votlendinu sem umlýkur höfðann vaxa sjáldgæfar starategundir og þar er fjölskrúðugt fuglalíf. Í tilefni friðlýsingar Salthöfða og Salthöfðamýra birtu Kvískerjabræðurnir Hálfdán og Sigurður Björnsson grein um svæðið í tímaritinu Týli (Hálfdán og Sigurður Björnsson, 1978).

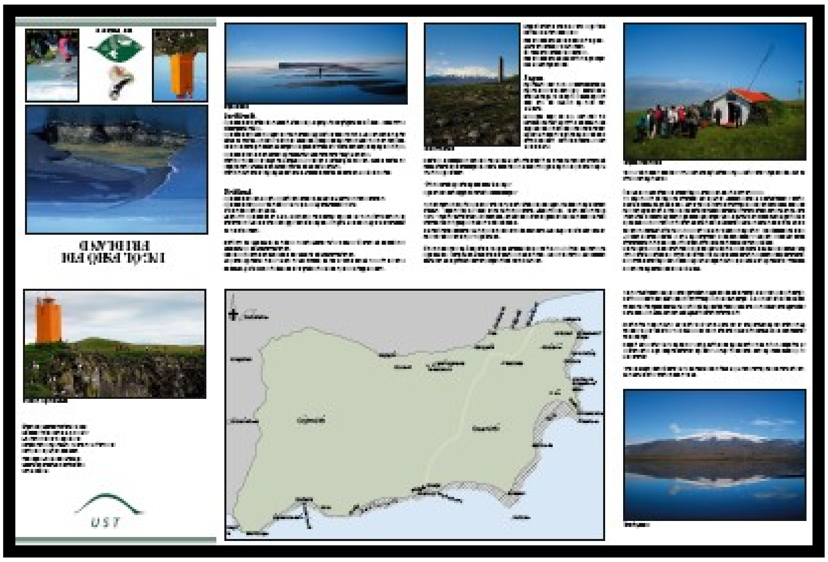
Ingólfshöfði
Ingólfshöfði er þverhníptur móbergs- og grágrýtishöfði, sem stendur í sjó fram. Höfðinn er svokallað standberg (eða brimklif) sem er mótaður af sjávarrofi. Í sunnan- og austanverðum Ingólfshöfða eru samfelld fuglabjörg, þar sem áragrúi af sjófuglum verpir, einkum langvía, álka, fýll og lundi. Landnámsmaðurinn Ingólfur Árnason lenti þar þegar hann kom til landsins. Flestar heimildir sem fundust um Ingólfshöfða varða landnám, gróður og fuglalíf frekar en jarðfræði. Þýski jarðfræðingurinn Emmy Mercedes Todtmann lýsti árið 1934 ferð sinni um Ingólfshöfða í tímariti Félags Íslandsvina í Þýskalandi (Todtmann 1934). Heimamennirnir Hálfdán og Sigurður á Kvískerjum sem og Páll Þorsteinsson hafa skrifað ítarlegar og fróðlegar greinar um gróður, fuglalíf, landnám, sögu, sjóróður, menningarminjar, skipbrot, fuglaveiðar og fleira á Ingólfshöfða (Hálfdán Björnsson 1950; Sigurður Björnsson 1984; Páll Þorsteinsson 1978). Bresku sjálfboðaliðasamtökin Brathay Exploration Group, sem undirbúa ferðir fyrir unglinga og skólahópa skipulögðu nokkra rannsóknarleiðangra í Öræfi til að

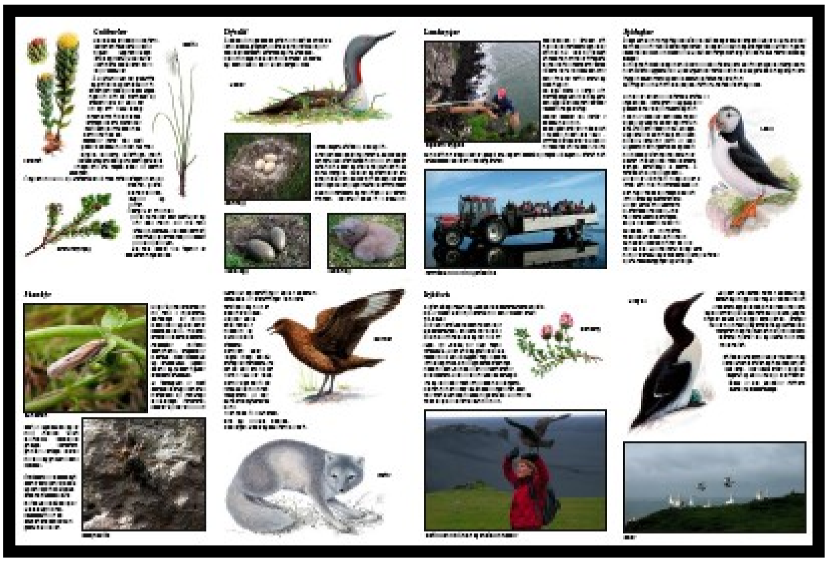
kanna fuglalífið og gera fuglatalningar. Árin 1962, 1967 og 1969 var aðallega lögð áherslu á það að kanna stofnstærð skúms á Suðausturlandi; árin 1965-68 var gerð úttekt á fuglalífinu almennt í Öræfum. Niðurstöður úr þessum rannsóknum á fuglalífinu voru teknar saman í skýrslu sem kom út árin 1973-1975 (1973-75 Review of Ornithological Studies in S.E.Iceland). Einnig var fuglalífið í Ingólfshöfða kannað ítarlega (Ingolfshofdi, Iceland, Conservation Report. 1978 Collier (F.S.No 33) 57 bls.). Árið 2005 birtist grein eftir Sigurð Hannesson í austfirska tímaritinu "Glettingur"; Sigurður tók viðtal við nafna sinn ferðaþjónustubóndann Sigurð Bjarnason, sem hefur um árabil skipulagt fuglaskoðunarferðir út í höfðann (Hannesson 2005).

Í eftirfarandi bókum má finna almennar upplýsingar um Sandfell, Salthöfða og Ingólfshöfða, þ.a.m. upplýsingar um jarðfræði:

- Björnsson, Sigurður 1979: Öræfasveit. Árbók 1979. Reykjavík, Ferðafélag Íslands.
- Guðmundsson, Snævarr 1999: Þar sem landið rís hæst. Reykjavík, Mál og Menning.
- Guttormson, Hjörleifur 1993: Við rætur Vatnajökuls. Byggðir, fjöll og skriðjöklar. Árbók 1993. Reykjavík, Ferðafélag Íslands.
- Guttormsson, Hjörleifur og Oddur Sigurðsson 1997: Leyndardómar Vatnajökuls. Víðerni, fjöll og byggðir. Stórbrotin náttúra, eldgos og jökulhlaup. Reykjavík, Fjöll og firnindi.

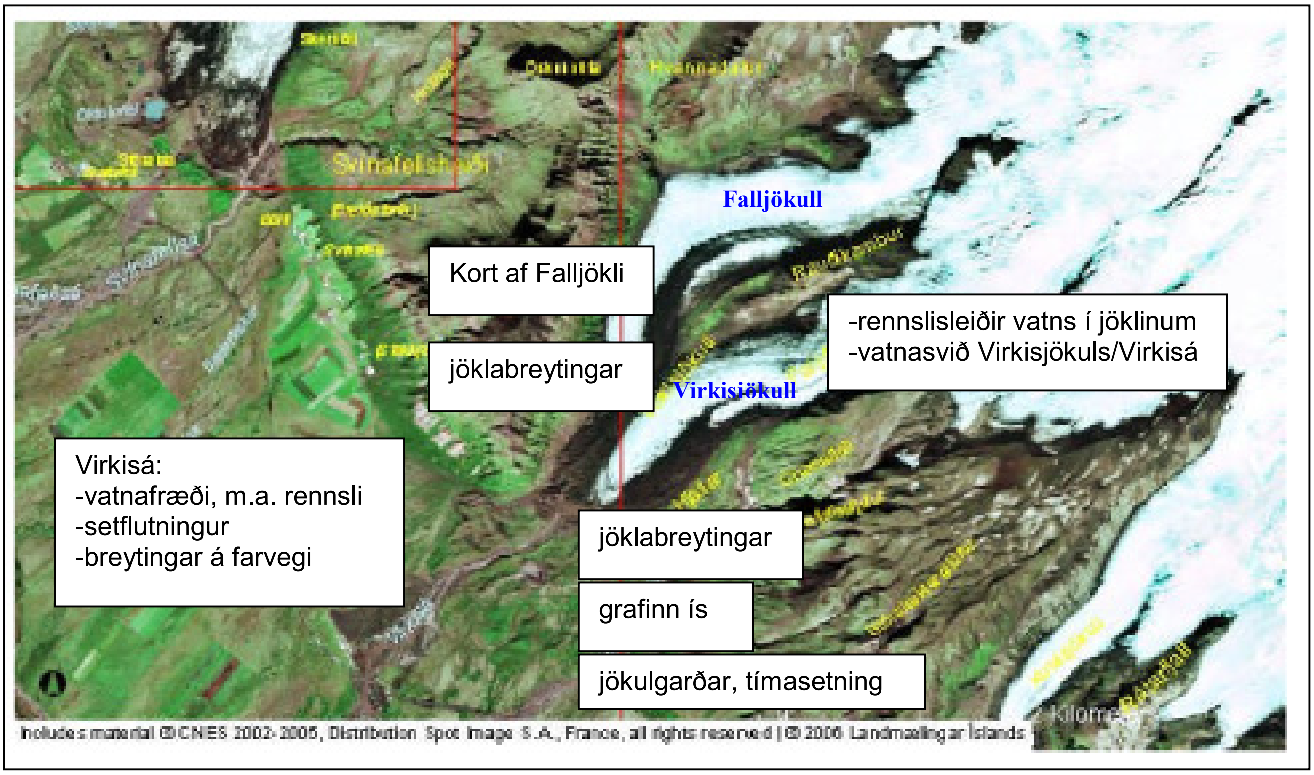
Árið 2006 gaf Umhverfisstofnun út bækling um friðlandið í Ingólfshöfða, með upplýsingum um jarðfræði, sögu, gróður og fuglalíf (sjá mynd 17).





Mynd 17: Bælingur UST um friðlandið í Ingólfshöfða.

3.9 Virkisjökull, Virkisá, Falljökull



Virkisjökull
Árið 1998 rannsakaði Hjalti J. Guðmundsson breytingar á sporði Virkisjökuls (og annarra jökla í Öræfum) á Hólósen tímabilinu og dró af þeim ályktanir um loftslagsbreytingar á þeim tíma. Hann skoðaði jökulminjar (sérstaklega jökulgarða) við jökuljaðarinn og notaði aldursgreiningu með hjálp öskulaga til að fá upplýsingar um jöklabreytingar.

J. Everest og T. Bradwell gerðu árið 2003 könnun á tilvist grafins íss í aur við sporð Virkisjökuls með viðnámsmælingum.

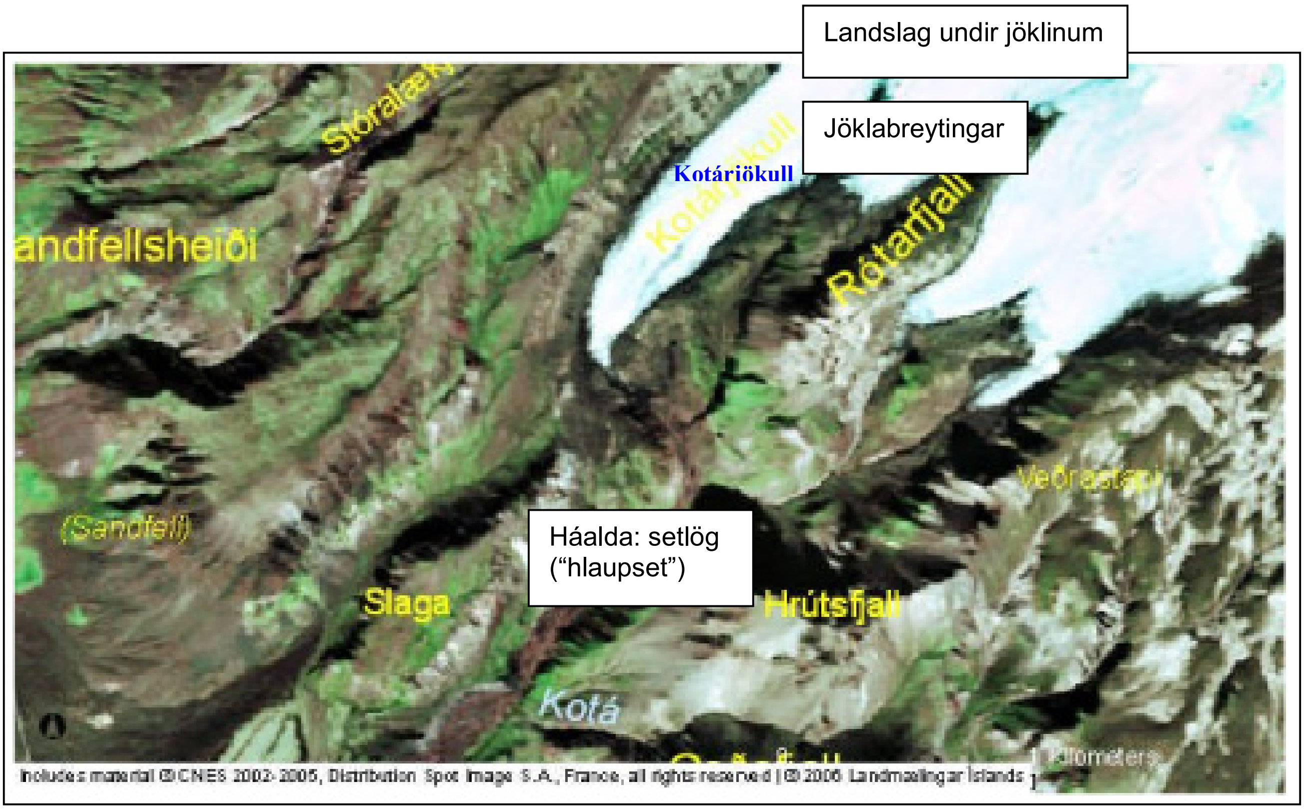
Reglulega hafa verið birtar niðurstöður úr jökulsporðamælingum í tímaritinu Jökli (Eyporsson 1963; Rist 1984; Sigurdsson 1998-2006).

Virkisá
Árið 1998 rannsökuðu A.P. Nicholas og G.H. Sambrook Smith vatnafræði, setflutning og breytingar á farvegi Virkisár. Spænskir vísindamenn (M.C. Dominguez, A. Eraso, með aðstoð Sveins Jónssonar) könnuðu árið 1992 rennslisleiðir vatns í Virkisjökli, vatnasvið Virkisár og rennsli í Virkisá.

Falljökull
Bresku sjálfboðaliðasamtökin Brathay Exploration Group, sem undirbúa ferðir fyrir unglinga og skólahópa, kortlögðu árið 1968 Falljökul og svæðin við sporð jökulsins. Grein um leiðangurinn eftir leiðangursstjórann E. A. Escritt birtist í Jökli árið 1972.

Reglulega hafa verið birtar niðurstöður úr jökulsporðamælingum í tímaritinu Jökli (Eyporsson 1963; Rist 1984; Sigurdsson 1998-2006).

3.10 Kotárjökull, Kotá, Háalda



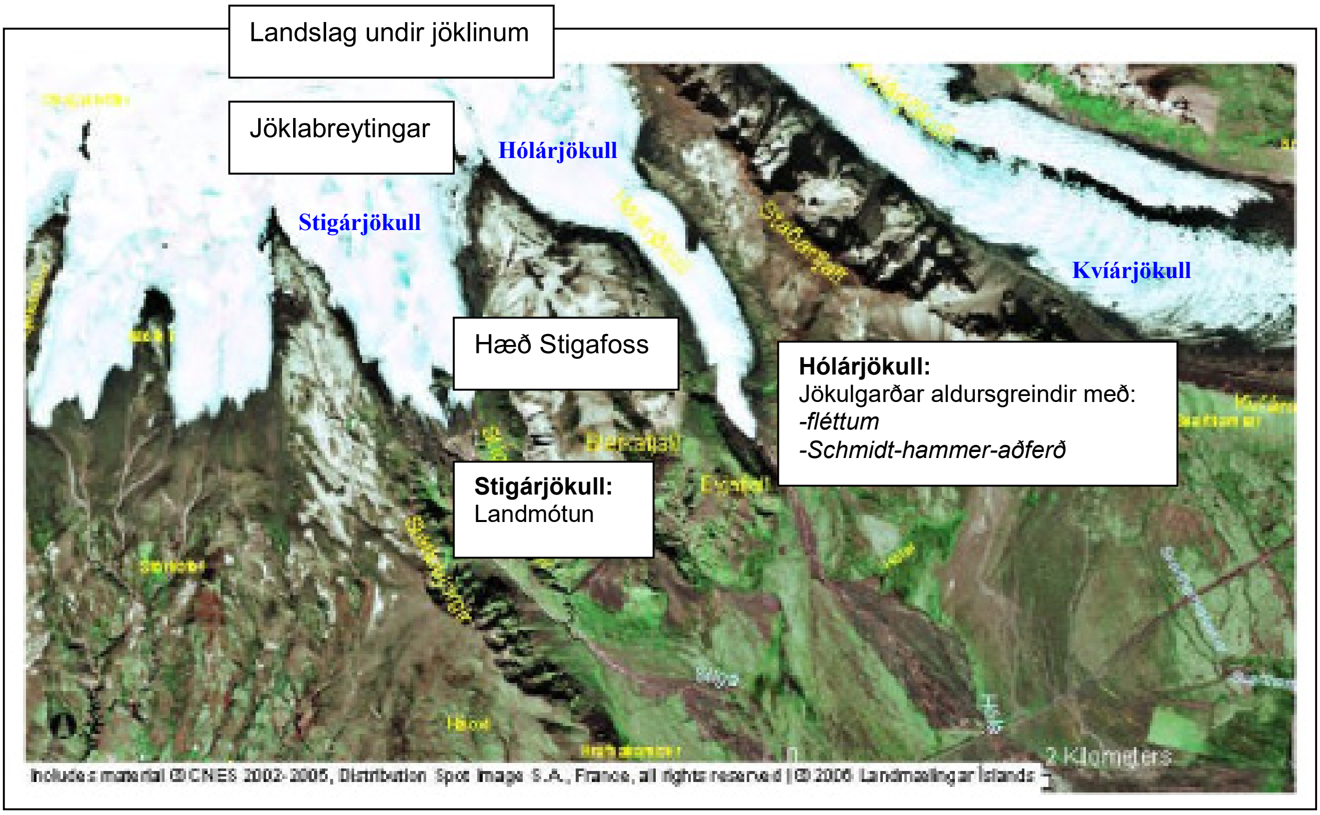
Kotárjökull, Kotá
Árið 1998 rannsakaði Hjalti J. Guðmundsson breytingar á sporði Kotárjökuls (og annarra jökla í Öræfum) á Hólósen tímabilinu og dró af þeim ályktanir um loftslagsbreytingar á þeim tíma. Hann skoðaði jökulminjar (sérstaklega jökulgarða) við jökuljaðarinn og notaði aldursgreiningu með hjálp öskulaga til að fá upplýsingar um jöklabreytingar.

Engar sporðmælingar virðast hafa verið gerðar á Kotárjökli.

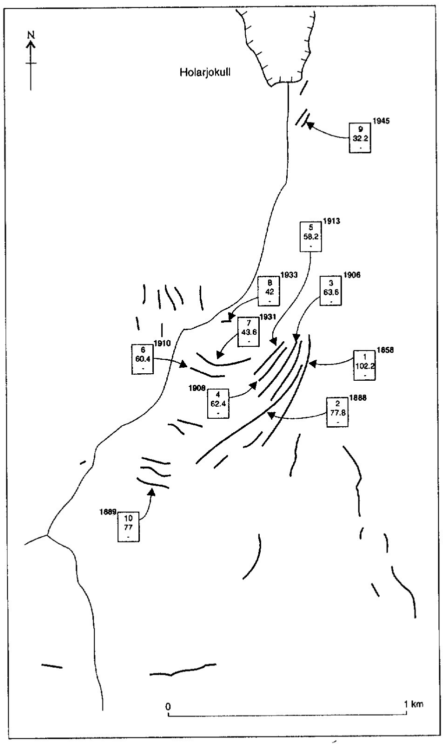
Háalda
Háalda er stór jökulgarður vestan Kotár. Í henni eru jökulker, för eftir ísjaka sem bárust fram undan Kotárjökli með hlaupi sem fylgdi Öræfajökulsgosinu 1727.

Fáar heimildir fundust um Háöldu. Árið 1989 rannsakaði R. Smith frá Háskólanum í Liverpool setlög í sniði við Kotá. Um "hlaupset" er að ræða, sem urðu til í hlaupum sem fylgdu í kjölfar Öræfajökulsgosa 1362 og 1727. Árið 2006 fékk Matthew J. Roberts styrk úr Kvískerjasjóði til að rannsaka jökulhlaup af völdum eldgosa í Öræfajökli og í tengslum við þetta verkefni kannaði hann svæðið við Háöldu.

3.11 Stigárjökull, Stigá, Hólárjökull, Hólá



Engar reglulegar sporðmælingar virðast hafa verið gerðar á Stigárjökli og Holárjökli en á korti sem Sigurður Þórarinsson hefur teiknað árið 1956 eftir gömlum kortum og (loft)myndum má sjá hversu mikið Stigár- og Hólárjöklar hafa hopað frá 1904 til 1945 Þórarinsson 1956, bls. 9, 11).



Mynd 18: Jökulgarðar við sporð Hólárjökuls; við hvern jökulgarð eru upplýsingar um aldur hans og stærð fléttna sem vaxa á honum (úr Evans 1999).

Helgi Björnsson og aðrir hafa rannsakað rof af völdum jökla og kannað landslagið undir Vatnajökli og skriðjöklunum sem teygja sig niður frá honum, þar á meðal Stigárjökli og Holárjökli.

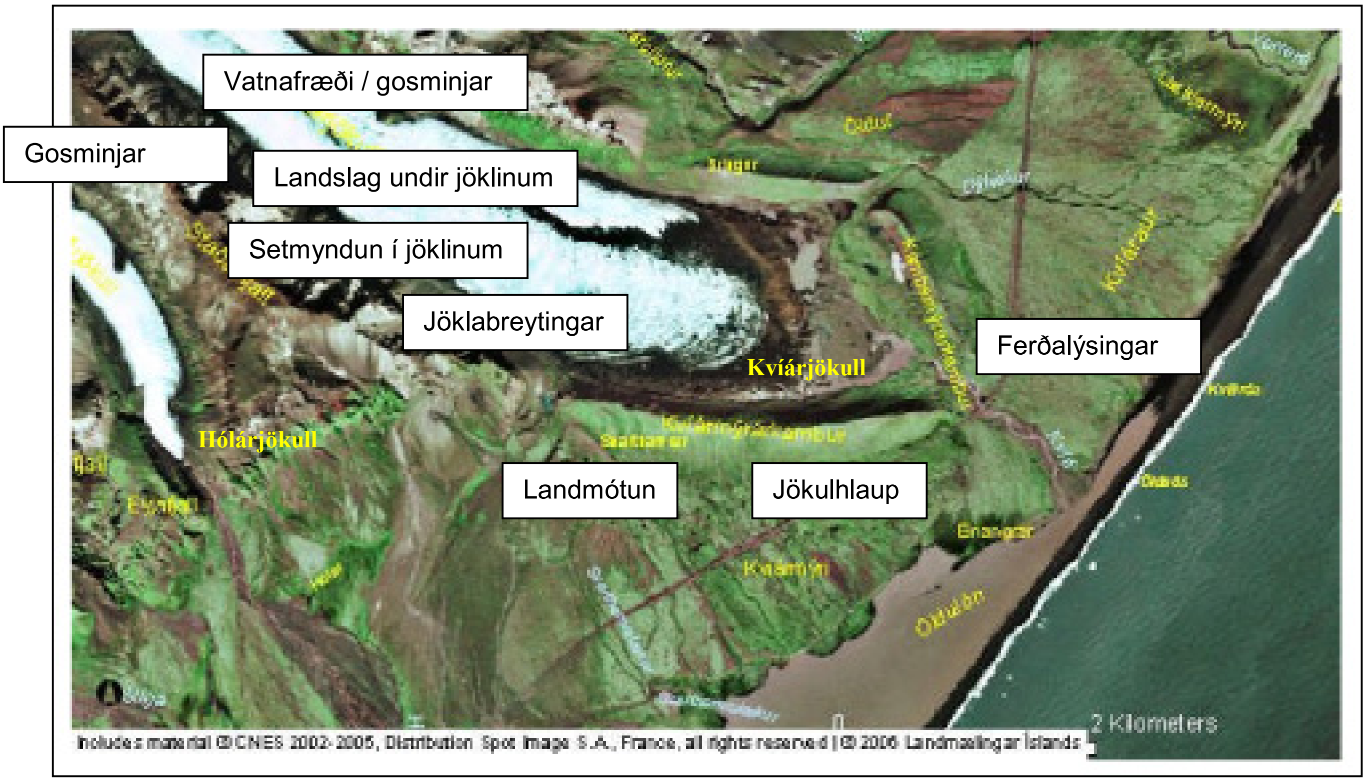
Stigárjökull, Stigá

Sigurður Björnsson hefur skrifað grein í Skaftfelling um foss í Stigá, Stigafoss, sem er talinn vera með hæstu fossum landsins (Sigurður Björnsson, 1989). Breskir jarðfræðingar hafa rannsakað jökulminjar við Stigá sem líkjast jökulgarði. Við nánari athugun kom í ljós að aðeins neðri hluti hryggjarins er jökulgarður en að efri hluti hans á uppruna sinn að rekja til grjóthruns vegna frostveðrunar (Harris, Tweed og Knudsen 2004).

Hólárjökull, Hólá

Hópur breskra jarðfræðinga gerði samanburð á tveimur aðferðum sem eru notaðar til að aldursgreina jökulminjar: Schmidt-hammer aðferð og fléttuaðferð (sjá mynd 18). Þeir notuðu þessar aðferðir til að fá upplýsingar um hop Heinabergs-, Kvíár- og Hólárjökuls eftir að Litla Ísöldin náði hámarki sínu (D.J.A. Evans, S. Archer, D.J.H. Wilson 1999). Markmið með rannsókninni var aðallega að ákveða hvaða aðferð hentaði best.

3.12 Kvíárjökull, Kvíá, Kvíármýrarkambur



Kvíárjökull hefur lengi verið vinsælt viðfangsefni rannsókna. Rannsóknum sem hafa verið gerðar á jöklinum má skipta í sjö flokka:

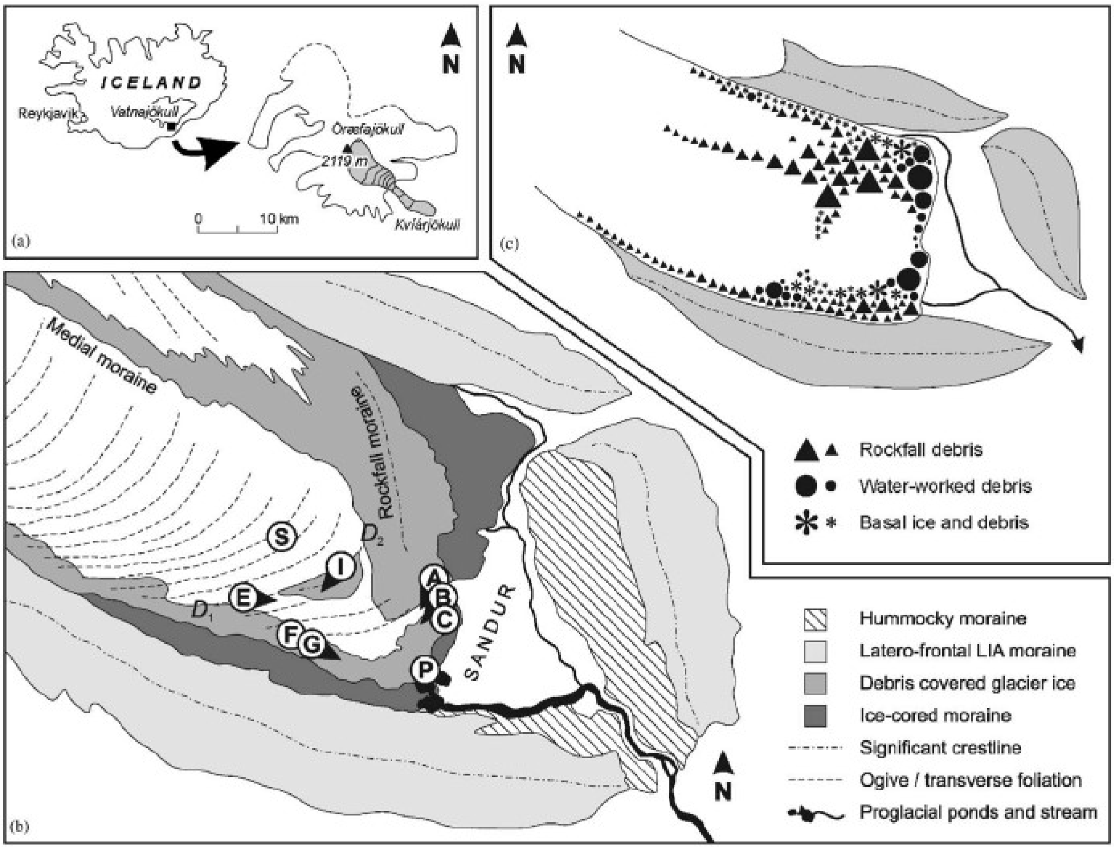
1- Jöklabreytingar
2- Gosminjar í grennd við Kvíárjökul
3- Landmótun við Kvíarjökul
4- Setmyndun í jöklinum
5- Gamlar ferðalýsingar
6- Landslag undir jöklinum
7- Vatnafræði / jöklabúskapar
8- Myndun Kvíármýrarkambs

1- Jöklabreytingar

Reglulega hafa verið birtar niðurstöður úr jökulsporðamælingum í tímaritinu Jökli (Eyporsson 1963; Rist 1984; Sigurðsson 1998-2006). Árið 1956 birti Sigurður Þórarinsson grein í tímaritinu Jökli um hop og framskrið þriggja jökla í Öræfum: Svínafellsjökuls, Skaftafellsjökuls og Kvíárjökuls (Þórarinsson 1956). Bandarískur nemi frá háskólanum í Boulder, Colorado kannaði breytingar á sporði Kvíárjökuls í lok Nútímans og skrifaði MS-ritgerð um rannsóknir sínar (Black, 1990). Árið 1998 rannsakaði Hjalti J. Guðmundsson breytinga á sporð Kvíárjökuls (og annarra jökla í Öræfum) á Hólósen tímabilinu (Nútíma) og dró úr þeim ályktanir um loftslagsbreytingar á þeim tíma. Hann skoðaði jökulminjar (sérstaklega jökulgarða) við jökuljaðarinn og notaði aldursgreiningu með hjálp öskulaga til að fá upplýsingar um jöklabreytingar. Sama ár skrifaði hann grein í Kvískerjabók um breytingar á Kvíárjökli í Nútíma (Guðmundsson 1998). Með því að bera saman loftmyndir sem voru tekna á árunum 1945, 1954, 1980 og 1998, má fá upplýsingar um hop Kvíárjökuls á seinni hluta 20. aldar (sjá mynd 20).

2- Gosminjar í grennd við Kvíárjökul
Flosi Björnsson frá Kvískerjum rannsakaði fjallendi í kringum Kvíárjökul og skrifaði greinar um gosminjar sem hafa komið í ljós við rof jökulsins.

3- Landmótun við Kvíárjökul
Svíinn Gunnar Hoppe skoðaði árið 1952 ásamt Jóni Jónssyni jökulminjar, sérstaklega jökulruðning, við jaðar nokkurra skriðjökla á Suðausturlandi, þ.a.m. Kvíárjökuls (Hoppe 1953, 2004). Árið 1984 vann L.R. Ástvaldsson lokaverkefni við H.Í. um jökulminjar við sporð Kvíárjökuls. Hann teiknaði jarðfræðikort af jaðarsvæði jökulsins, tók saman yfirlit yfir breytingar á jökulsporðinum milli áranna 1934-1982 og rannsakaði sérstaklega “katlana” í Kvíárjökli, dældir á yfirborði jökulsins. Hópur breskra jarðfræðinga gerði samanburð á tveimur aðferðum sem eru notaðar til að aldursgreina jökulminjar: Schmidt-hammer aðferð og fléttuaðferð. Þeir notuðu þessar aðferðir til að fá upplýsingar um hop Heinabergs-, Kvíár- og Hólárjökuls eftir að Litla Ísöld náði hámarki sínu (Evans, Archer, Wilson 1999). Markmið með rannsókninni var aðallega að ákveða hvaða aðferð hentaði best. D.J.A. Evans og N.Spedding könnuðu setlög við Kvíárjökul, setmyndun í jöklinum og jökulminjar við jökulsporðinn (sjá mynd 19).



Mynd 19: Mynd sem sýnir a) staðsetningu Kvíárjökuls, b) landmótun við jökulsporðinn og c) dreifng á mismunandi tegundum af jökulruðningi (úr Swift 2006, upphaflega í Evans og Spedding 2002).

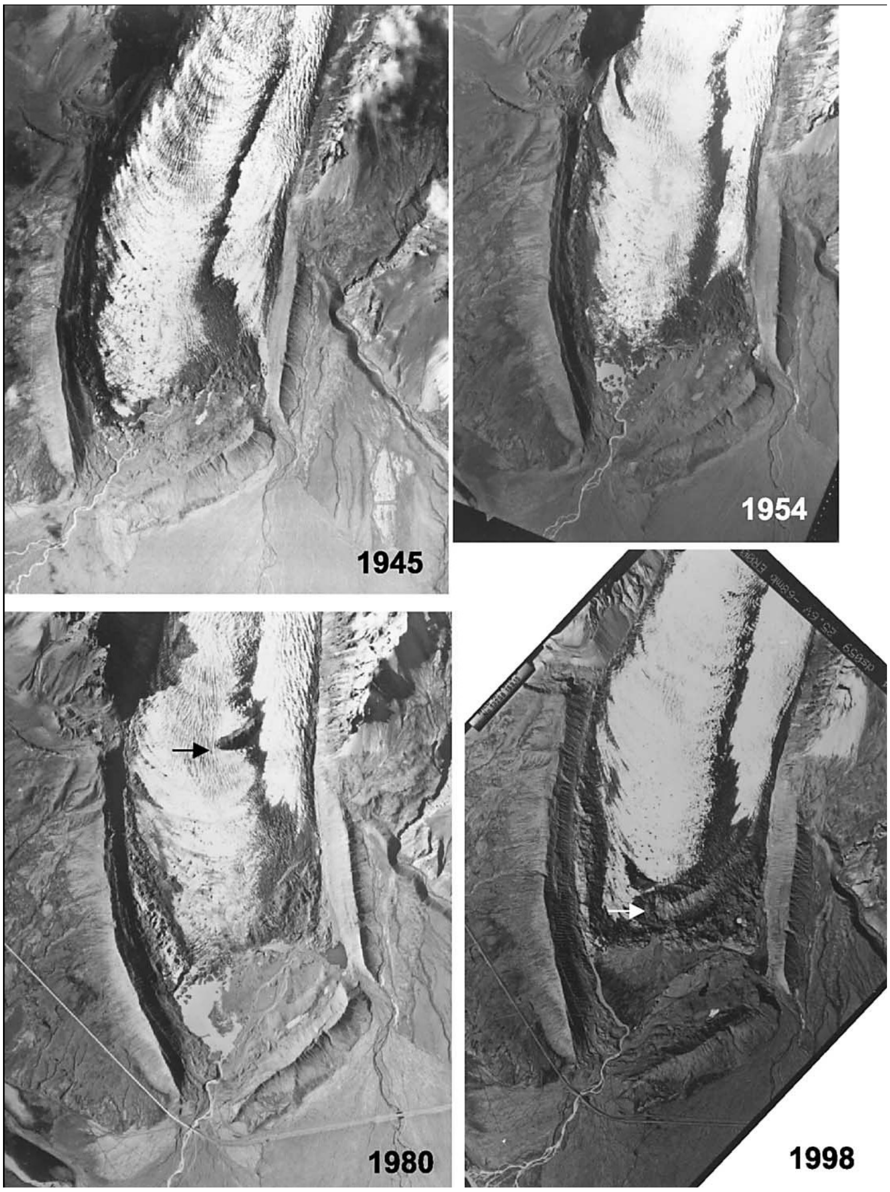
4- Setmyndun í jöklinum
T. Ebert rannsakaði undirkælt vatn við Kvíár- og Hoffellsjökul og greindi frá niðurstöðum sínum í meistararitgerð (Ebert 2003). Í íslenskum jöklum eru sum íslög sérstaklega rík af bergmylsnu. D.A. Swift, D.J.A. Evans og A.E. Fallick rannsökuðu uppruna bergmylsnu í slíkum íslögum og könnuðu hvort um setmyndun úr undirkældu vatni er að ræða eða frekar um botnurð sem er ýtt upp eftir þversprungum í jöklinum (Swift et al. 2006).

5-Gamlar ferðalýsingar
Bretinn E. Henderson ferðaðist um Ísland árin 1814 og 1815 og lýsti m.a. landslaginu við Kvíárjökul.

6- Landslag undir jöklinum
Helgi Björnsson og aðrir hafa rannsakað rof af völdum jökla og kannað landslagið undir Vatnajökli og skriðjöklunum sem teygja sig niður frá honum, þ.a.m. Kvíárjökli.

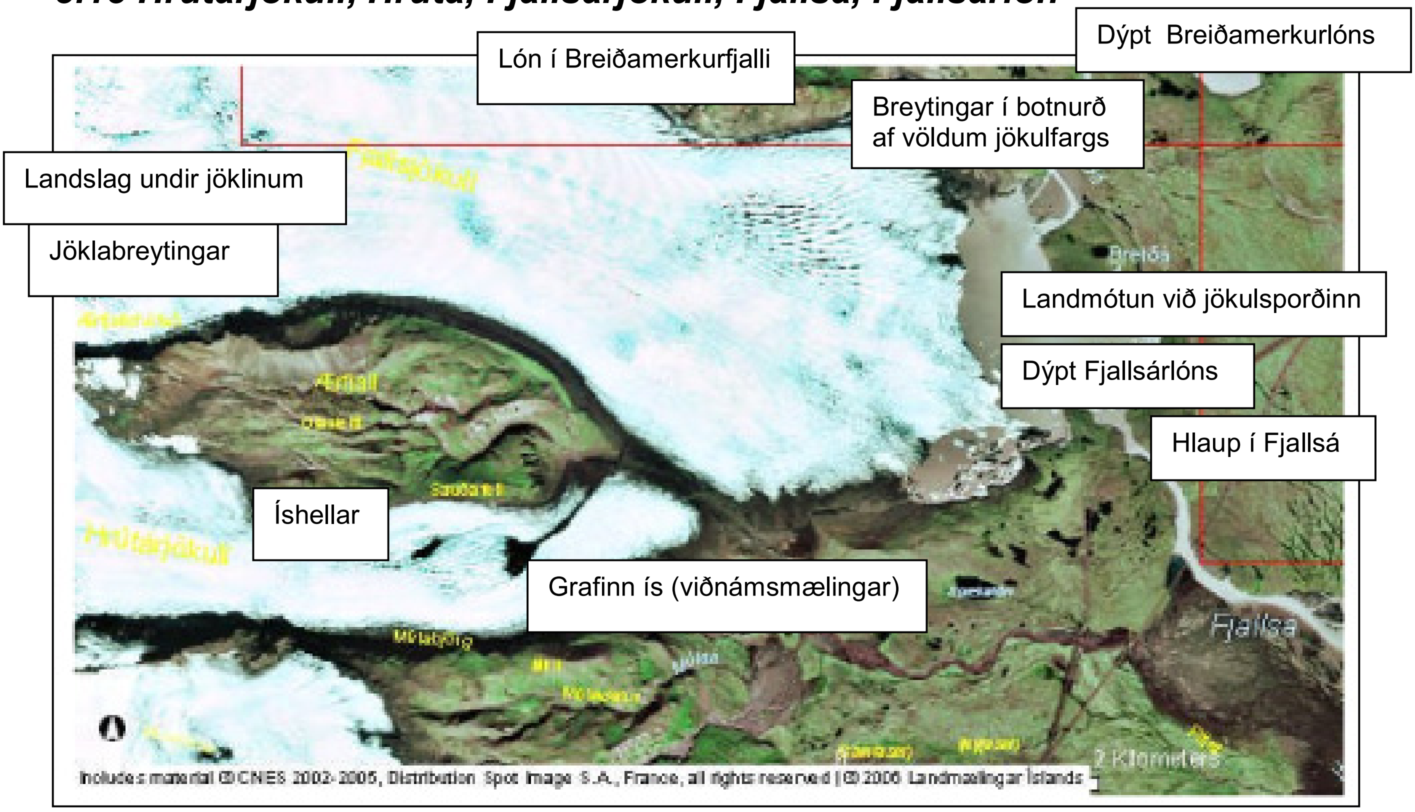
7- Vatnafræði / jöklabúskapur
Á árunum 1996-1997, 1999 og 2003-2004 skipulögðu Spánverjarnir M.C. Dominguez og A. Eraso nokkra rannsóknaleiðangra að Kvíárjökli. Þeir skoðuðu einkum vatnasvið jökulsins og könnuðu vatnafræði og jöklabúskap Kvíárjökuls. Einnig rannsökuðu þeir "katlana" í Kvíárjökli (Dominguez, Eraso og Jónsson 1999, 2002, 2003; Eraso og Dominguez 1999, 2003, 2005).

8- Myndun Kvíármýrarkambs
Í ferðabók Bretans Henderson má finna (ranga) tilgátu um myndun Kvíármýrarkambs (Henderson 1957). Kvískerjabræðurnir Flosi og Sigurður Björnssynir rannsökuðu aldur og myndun Kvíármýrarkambs og komu með nýja tilgátu um tilurð jökulöldunnar (Flosi Björnsson 1956; Sigurður Björnsson 1993). Í grein eftir Sigurð Þórarinsson um jöklabreytingar, sem birtist í Jökli árið 1956 má einnig finna umfjöllun um aldur og myndunarhátt Kvíármýrarkambs (Þórarinsson 1956).



Mynd 20: Loftmyndir sem sýna hop Kvíárjökuls milli 1945-1998 (úr Spedding og Evans 2002).

3.13 Hrútárjökull, Hrútá, Fjallsárjökull, Fjallsá, Fjallsárlón



Hrútárjökull **Fjallsárjökull**

Reglulega hafa verið birtar niðurstöður úr sporðmælingum á Hrútárjökli og Fjallsárjökli í tímaritinu Jökli (Eyporsson 1963; Rist 1984; Sigurdsson 1998-2006).

Helgi Björnsson og aðrir hafa rannsakað rof af völdum jökla og kannað landslagið undir Vatnajökli og skriðjöklunum sem teygja sig niður frá honum, þ.a.m. Hrútárjökli og Fjallsárjökli.

Hrútárjökull, Hrútá

J. Everest og T. Bradwell gerðu árið 2003 könnun á tilvist grafins íss í aur við sporð Hrútárjökuls með viðnámsmælingum.

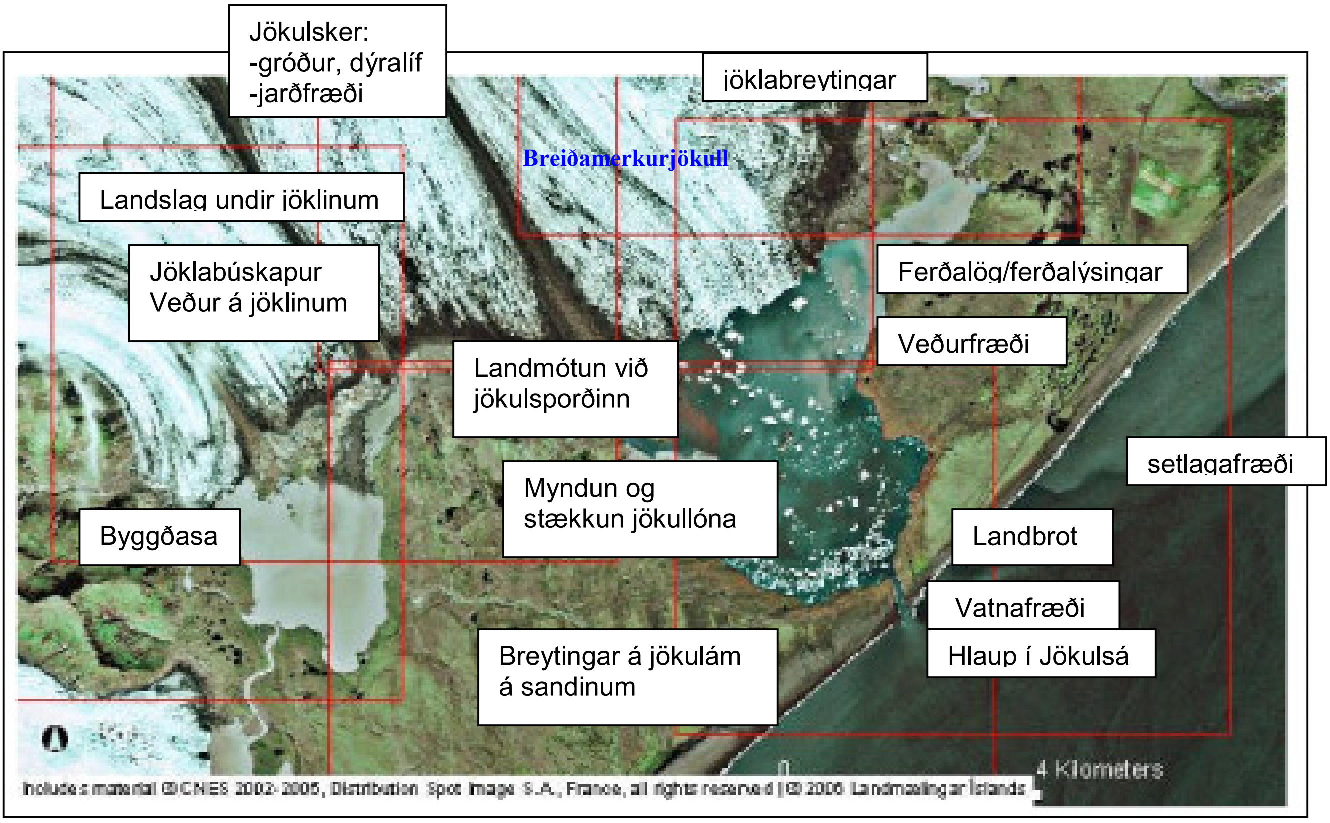
Í tímaritinu Jökli hafa birst greinar um Hrútárjökul eftir Kvískerjabræðurna Flosa og Sigurð Björnssyni. Í grein Sigurðar er vitnað í draum Guðrúnar Bjarnadóttur, sem er ágæt heimild um þær breytingar sem hafa orðið á jöklinum. Grein Flosa fjallar um "göngin" í Hrútárjökli; Flosi kannaði hellana sem Hrútá hefur skilið eftir í jöklinum og teiknaði kort af þeim.

Fjalls(ár)jökull, Fjallsá, Fjallsárlón

Árið 1970 rannsakaði R.J. Price jökulgarða við sporð Fjallsárjökuls (Price 1970). D.J.A. Evans og D.R. Twigg notuðu sögulegar heimildir, kort og loftmyndir til að rekja hop Fjallsár- og Breiðamerkurjökla og landslagsþróun framan við þessa jökla síðan 1903. Þeir gerðu einnig setfræðilegar rannsóknir við jaðar þessara tveggja jökla. Afrakstur rannsókna þeirra var röð af landmótunarkortum (sjá mynd 21) sem sýnir vel hvernig landslagið framan við þessa jökla hefur breyst í gegnum tíðina og hvernig jökullón hafa myndast og smá saman stækkað framan við báða jöklana (Evans og Twigg 2002). Greinar um dýpt Fjallsár- og Breiðárlóna birtust í Náttúrufræðingnum. Þegar jöklarnir voru stærri en nú, var jökulstíflað lón í Breiðamerkurfjalli. Úr því hljóp reglulega í Fjallsá. Jón Eyþórsson og Flosi Björnsson á Kvískerjum hafa skrifað greinar um Fjallsárhlaupin (Jón Eyþórsson 1951 og Flosi Björnsson 1955, 1962). J.K. Hart, A. Khatwa og P.

Sammonds hafa rannsakað tengsl milli kornastærðar og breytinga sem hafa átt sér stað í botnurð við Fjallsárjökul af völdum jökulfargs(Hart, Khatwa og Sammonds 2004).

3.14 Breiðamerkurjökull, Breiðamerkursandur, Breiðamerkurfjall, Breiðárlón, Breiðá



Breiðamerkurjökull og Breiðamerkursandur hafa verið viðfangsefni gríðarlega margra og umfangsmikilla rannsókna hérlendra og erlendra vísindamanna. Á landnámsöld var jökullinn miklu minni en nú er og var blómleg byggð á Breiðamerkursandi. Móleifar sem hafa fundist á sandinum og sjálft nafnið "Breiðamörk" benda til þess að sléttan framan við jökulinn hafi að miklu leyti verið skógi vaxin. Til eru margar sögulegar heimildir um bæina á Breiðamerkursandi[1] sem fóru í eyði í kjölfar Öræfajökulsgossins 1362 og af völdum framgangs Breiðamerkurjökuls og ágangs jökulvatna. Lýsingar íslenskra og erlendra ferðamanna[2] á Breiðamerkurjökli og jökulám sem falla úr honum gefa góða mynd af hopi og framskriði jökulsins og breytingum á vatnsföllum á sandinum í gegnum tíðina. Sögulegar heimildir, kort og loftmyndir gera okkar kleift að rekja myndun og stækkun jökullóna (Fjallsárlón, Breiðárlón, Jökulsárlón) sem og landmótun við jökulsporðinn. Á síðustu áratugnum hefur hröð stækkun Jökulsárlóns og mikið landbrot við brúarstæðið valdið Vegagerðinni miklum áhyggjum. Í Kvískerjabók má finna nokkrar góðar yfirlitsgreinar um bæði Breiðamerkurjökul og Breiðamerkursand með ítarlegum upplýsingum um framskrið og hop jökulsins, ísstrauma, landmótun á Breiðamerkursandi, landslag undir jöklinum, þátt vatns við gröft undir jöklinum, auk upptalningar á sögulegum heimildum (Björnsson 1998; Sigurðsson 1998).

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1 Fjall, Breiðá, Fell, hjáleigur frá Felli og seinna Brennhólar

2 m.a. Eggert Ólafsson og Bjarni Pálsson 1756, Þorvaldur Thoroddsen, Henderson 1818, Thienemann 1824, Þorsteinn Einarsson 1885, Paijkull 1866, Kålund 1873, Watts 1876, Helland 1882

Í greinum um Breiðamerkurjökul og jaðarsvæði hans er aðallega fjallað um eftirfarandi viðfangsefni:

1- Landslagið undir jöklinum
2- Jöklabreytingar
3- Landmótun
4- Setlagafræði
5- Breytingar á vatnsföllum á Breiðamerkursandi í gegnum tíðina
6- Lónin á Breiðamerkursandi (Fjallsárlón, Breiðárlón, Jökulsárlón) og stækkun þeirra í gegnum tíðina
7- Vatnafræði
8- Veðurfræði
9- Jöklabúskapur / veður á jöklinum
10- Hlaup
11- Landbrot við Jökulsárbrú
12- Jökulsker
13- Ferðalög / ferðalýsingar
14- Byggðasaga

1- Landslag undir jöklinum
Helgi Björnsson og aðrir hafa rannsakað rof af völdum jökuls og kannað landslagið undir Breiðamerkurjökli með íssjármælingum. Niðurstöður íssjármælinga birtust í nokkrum skýrslum sem Raunvísindastofnun Háskóla Íslands hefur gefið út (Björnsson 1992, á íslensku og á ensku; Björnsson 1996). Kort af landslaginu undir Breiðamerkurjökli hefur m.a. birst í Kvískerjabók og í árbók Ferðafélags Íslands 1993 (bls. 108). Einnig hefur yfirborð jökulsins verið mælt (Gavin og Williams 1993).

2- Jöklabreytingar
Reglulega hafa verið birtar niðurstöður úr sporðmælingum á Breiðamerkurjökli í tímaritinu Jökli (Eyporsson 1963; Rist 1984; Sigurðsson 1998-2006). Árið 2001 hélt Oddur Sigurðsson erindi á Vorráðstefnu Jarðfræðifélags Íslands þar sem hann gaf yfirlit yfir jöklabreytingar á Íslandi síðustu fjórar aldir (Sigurðsson 2001).

3- Landmótun
Árið 1951 gerði Jón Jónsson rannsóknir á Breiðamerkursandi (Jónsson 1951). Ári seinna rannsakaði Svíinn Gunnar Hoppe ásamt áðurnefndum Jóni Jónssyni jökulminjar við jaðar nokkurra skriðjökla á Suðausturlandi, þ.a.m. Breiðamerkurjökul (Hoppe 1953, 2004). Jón Eyþórsson skrifaði grein í Jökul um breytingar á Breiðamerkursandi, framgang jökuls og afleiðingar þeirra fyrir byggð á sandinum (Eyþórsson 1952).Vísindamenn á vegum nokkurra breskra háskóla hafa verið duglegir að rannsaka landmótun við jaðar Breiðamerkurjökuls. Á árunum 1964-1967 gerðu R.J. Price og P.J. Howarth frá Háskólanum í Glasgow rannsóknir á jöklaminjum við sporð Breiðamerkurjökuls. Þeir kortlögðu jökulgarða, sanda, malarása og aðrar jökulminjar við jökuljaðarinn og fylgdust með breytingum á landslaginu og vatnsföllum framan við jökulinn (Price, 1968, 1969, 1971, 1982; Price og Howarth 1970). Vísindamenn frá Háskóla í Durham og Loughborough, D.J.A. Evans og D.R. Twigg, notuðu sögulegar heimildir, kort og loftmyndir til að rekja hop Breiðamerkurjökuls og landslagsþróun framan við jökulinn síðan 1903. Þeir gerðu einnig setfræðilegar rannsóknir við jökulsporðinn. Afrakstur rannsókna þeirra var röð af landmótunarkortum (sjá mynd 21) sem sýnir vel hvernig landslagið framan við þessa jökla hefur breyst í gegnum tíðina og hvernig jökullón hafa myndast og smá saman stækkað (Evans, Lemmen og Rea 1999; Evans og Twigg 2002). Sömu vísindamenn hafa, ásamt starfsbræðrum sínum frá Háskólanum í Aberdeen, rannsakað jökulminjar við jaðar Tungnaárjökuls og gert nákvæmt

landmótunarkort fyrir svæðið framan við þann jökul. Landmótunarkortin hafa verið notuð sem kennsluefni og niðurstöður úr rannsóknunum við íslenska jökla hafa verið notaðar til að útskýra fornar jökulminjar sem hafa fundist á Bretlandi.

4- Setlagafræði

Árið 1986 rannsökuðu Halina Bogadóttir og aðrir berggrunn og setlög undir Breiðamerkursandi (Bogadóttir, Boulton, Tómasson og Thors 1986). D.I. Benn hefur rannsakað breytingar sem hafa átt sér stað í botnurð við Breiðamerkurjökul af völdum jökulfargs (Benn 1995; Benn og Evans 1996)

5- Breytingar á vatnsföllum á Breiðamerkursandi

Í Jökli birtist grein eftir Jón Eyþórsson um breytingar sem hafa orðið á Breiðá í gegnum tíðina (Eyþórsson 1951). Árið 1996 skrifaði Flosi Björnsson á Kvískerjum ítarlega grein í Skaftafelling um breytingar sem hafa orðið á vatnsföllum á Breiðamerkursandi (Björnsson 1996). Í sömu grein lýsir hann einnig gróðri og fuglalífi á sandinum. Upplýsingar um breytingar á jökulám á Breiðamerkursandi má einnig finna í ritinu “Skaftafell og Öræfi”, sem Hið íslenska náttúrufræðifélag hefur gefið út (Einarsson et al 1987)

6- Lónin á Breiðamerkursandi (Fjallsárlón, Breiðárlón, Jökulsárlón) og stækkun þeirra í gegnum tíðina

Vísindamenn frá Háskólanum í Glasgow, P.J. Howarth og R.J. Price, skrifuðu grein í Geographical Journal um lónin við sporð Breiðamerkurjökuls og Fláajökuls (Howarth og Price 1969). Sjá einnig “Jökulsárlón”, bls. 45-46.

7- Vatnafræði

Á Breiðamerkursandi hafa ýmsar vatnafræðilegar rannsóknir farið fram. Rannsakað hefur m.a. verið rennsli í Jökulsá, dýpt lóna á Breiðamerkursandi og áhrif sem framskrið eða framhlaup jökulsins hefur á vatnsrennsli í þeim setlögum sem jökullinn fer yfir (Boulton, Dobbie og Zatsepin 2001; Boulton og Zatsepin 2006). S. Árnason mældi árið 1998 fyrir Orkustofnun rennsli og hitastig í Jökulsá á Breiðamerkursandi. Jón Eyþórsson mældi dýpt Fjallsár- og Breiðárlóna (Eyþórsson 1951) og Flosi Björnsson mældi dýpt Breiðárlóns (Björnsson 1955).

8- Veðurfræði

Flosi Björnsson hefur birt grein í tímaritinu Veðrinu um veðurfar og snjóálag á Breiðamerkursandi (Björnsson 1977).

9- Jöklabúskapur / veður á jöklinum

Nokkrar rannsóknir hafa verið gerðar á jöklabúskap Breiðamerkurjökuls (ákomu, leysingu) og á ýmsum veðurþáttum sem hafa áhrif á ákomu og leysingu, eins og t.d. vindeðlisfræði, hitastig, úrkomu, gufun, lögun á yfirborði jökuls, endurvarp sólgeislunar o.sl. (Lister 1953; Kaltenbrock og Obleitner 1999; Obleitner 2000; Denby og Snellen 2002; Parmhed, Oerlemans og Grisogono 2004; Soderberg og Parmhed 2006).

10- Hlaup

Sigurður Björnsson á Kvískerjum birti greinar í Jökli um hlaup sem varð í Jökulsá á Breiðamerkursandi árið 1927 og tengist hugsanlega eldgosi í Esjufjöllum (Björnsson 1977, 1978).

11- Landbrot

Við Jökulsárlón hefur verið mikið landbrot af völdum sjávar. Lónið hefur farið ört stækkandi og nú skilur að aðeins mjó landræma lónið og sjóinn að. Ef svo heldur fram sem horfir mun bráðum vegi og raflínu stafa hætta af landbroti. Til að fylgjast með þessari þróun, hefur Vegagerðin frá árinu 1991 til dagsins í dag staðið fyrir árlegum mælingum á umfangi landbrots.Vísindamenn á vegum Vegagerðarinnar og aðrir hafa gert rannsóknir á stækkun Jökulsárlóns (Guðmundsson, Björnsson, Pálsson og Berthier 2005, 2006) og landbrot við brúna yfir Jökulsá á Breiðamerkursandi (Jóhannesson 1994, 1995, 2004; Jóhannesson og Sigurðarson 2005). Páll Þór Imsland hefur rakið orsakir og eðli núverandi ástands og komið með tillögu um framtíðarlausn á vandanum (Imsland 2000, á íslensku og á ensku; Blaðamaður 2002). Starfsmenn Orkustofnunar gerðu kornastærðargreiningar og flokkuðu sýni af Skeiðarár- og Breiðamerkursandi eftir bergtegundum til að finna út af hverju strandrof við Jökulsá á Breiðamerkursandi hefur verið minna eftir Skeiðarárhlaup 1996 (Harðardóttir, Víkingsson, Pálsson 2006).

12- Jökulsker

Heimamenn og aðrir hafa skipulagt nokkra rannsóknaleiðangra til að kanna jökulskerin í Breiðamerkurjökli (m.a. Esjufjöll, Mávabyggðir, Kárasker, Bræðrasker). Aðaláherslan var lögð á að rannsaka gróður, fuglalíf og skordýralíf í skerjunum sem hafa fengið að þróast í friði fyrir ágangi manna og búfjár. Í greinunum sem birtust um skerin má þó einnig finna nokkrar athuganir um jarðfræði þeirra (Björnsson og Ólafsson 1986; Eyþór Einarsson 1987; Bjarni Diðrik Sigurðsson 2005).

13- Ferðalög / ferðalýsingar/samgöngur

Jökulárnar á Breiðamerkursandi hafa lengi verið verulegir farartálmar og samgöngur um sandinn hafa verið erfiðar fram á 20. öld. Þegar mikið var í ánum, var oft einungis leiðin yfir jökulinn ferðamönnum fær. Margir íslenskir og erlendir ferðamenn hafa lýst ferðalögum og svaðilförum um sandinn og yfir jökulinn. Á. Óla lýsti árið 1944 ferð sem Ferðafélag Íslands skipulagði um Öræfasveit (Óla 1944). Páll Þorsteinsson skrifaði bók um samgöngur í Skaftafellssýslum og tileinkaði ferðum yfir Jökulsá á Breiðamerkursandi og Breiðamerkurjökul sérkafla (Þorsteinsson 1985). Þorbjörg Arnórsdóttir lýsir síðustu ferðinni sem var farin yfir Breiðamerkurjökul á vefsíðunni http://www.thorbergur.is. Einnig eru til nokkrar heimildir um (bana)slys sem urðu á Breiðamerkursandi og Breiðamerkurjökli í gegnum tíðina (m.a. Eyþórsson 1953).Í Framkvæmdafréttum Vegagerðarinnar birtist yfirlit um brýrnar sem hafa verið reistar á Breiðamerkursandi á 20. öld (Þorvaldsson 2004).

14- Byggðasaga

Nokkrir heimamenn (og aðrir) hafa tekið saman upplýsingar um byggð á Breiðamerkursandi á landnámsöld og fram eftir öldum og lýsa hvernig hún hefur eyðst af völdum Öræfajökulsgosa og ágangs Breiðamerkurjökuls og jökulánna (Jón Eyþórsson 1952; Flosi og Sigurður Björnsson á Kvískerjum, Helgi Björnsson 1998; Egill Jónsson 2004; Fjölnir Torfason 2005). Í ritinu "Skaftafell og Öræfi" má einnig finna upplýsingar um sögu byggðar á Breiðamerkursand (Einarsson et al 1987).

Á næstu blaðsíðu má finna þrjár myndir úr grein Evans og Twigg 2002, sem sýna myndun og stækkun lóna við sporð Breiðamerkurjökuls og landmótun á Breiðamerkursandi. Fyrsta myndin sýnir svæðið eins og það leit út í ágúst 1945, önnur myndin sýnir stöðuna í ágúst 1965 og þriðja myndin í ágúst 1998.

Mynd 21: Landmótun við sporð Breiðamerkur- og Fjallsárjökla árin 1945, 1965 og 1998 (Evans og Twigg 2002).

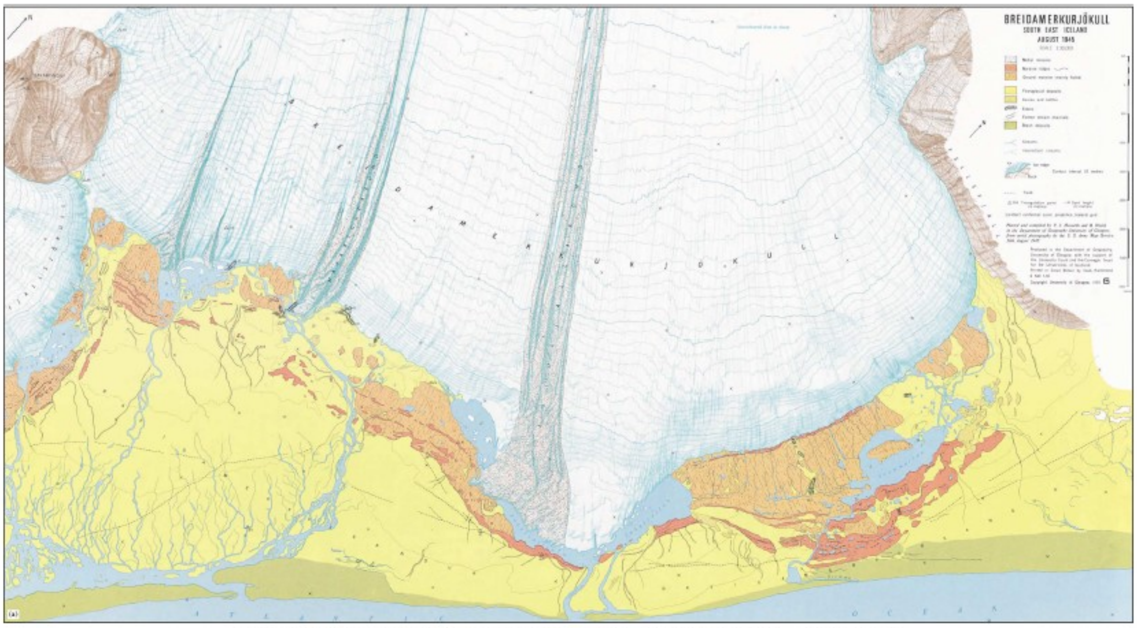


Fig. 6. Smaller scale reproductions of the 1:30,000 maps of Breiðamerkurjökull and part of Fjallsjökull for 1945, 1965 (Howarth and Welch, 1969a, b) and 1998 (Evans and Twigg, 2000).

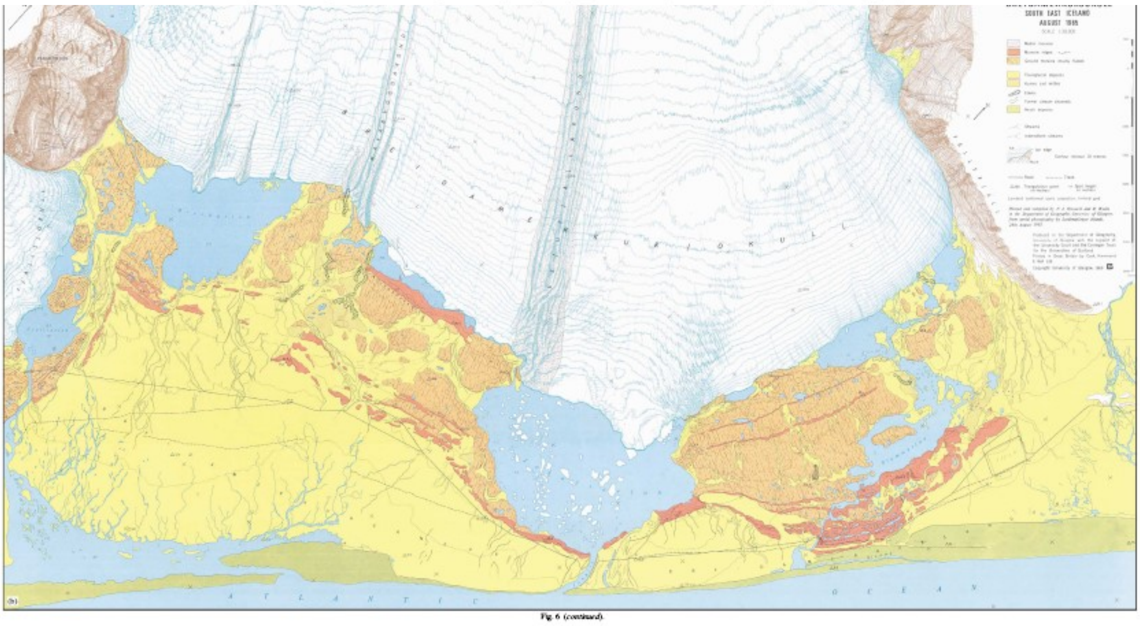


Fig. 6 (*continued*).

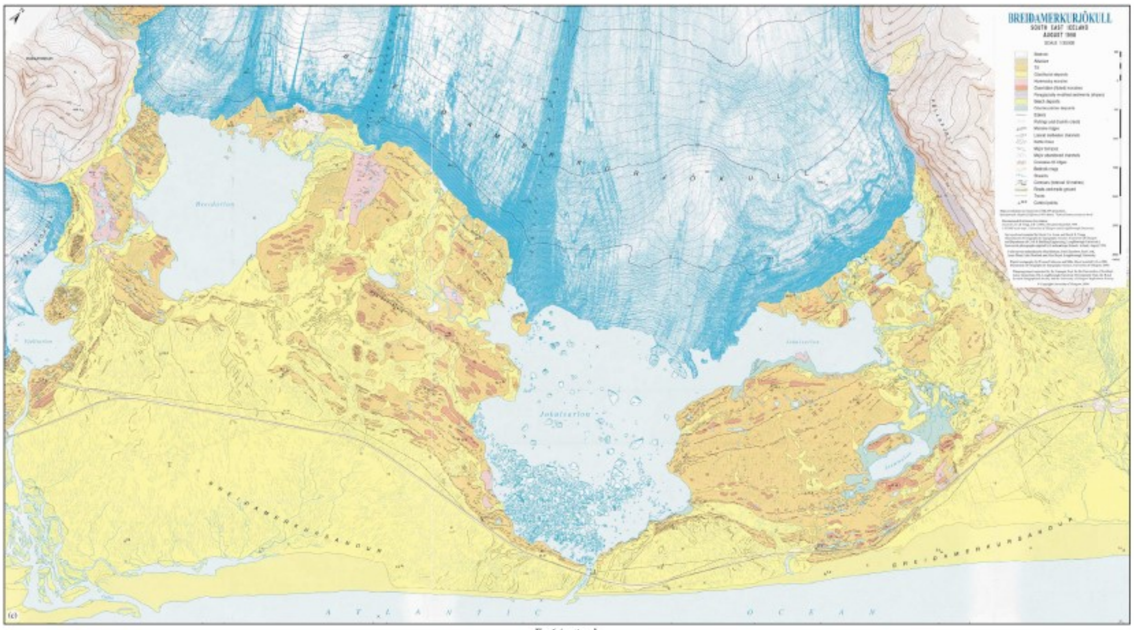
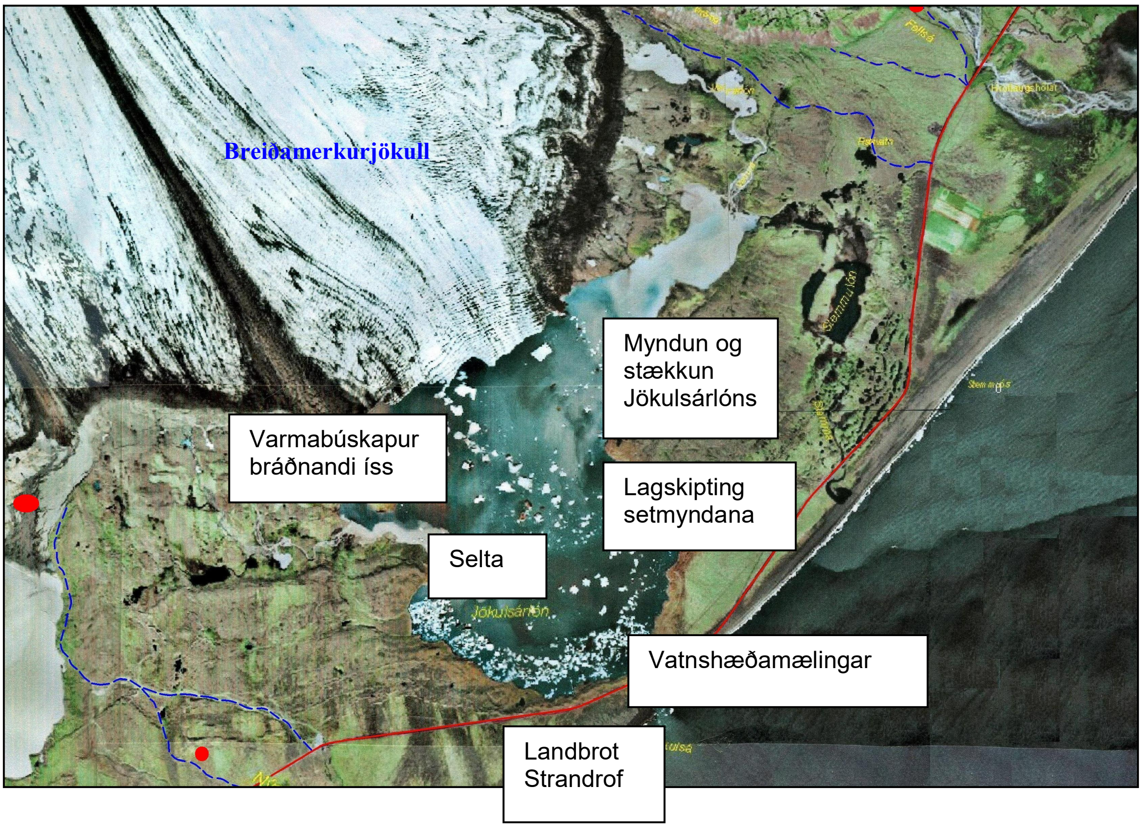


Fig. 6 (*continued*).

3.15 Jökulsárlón



Jökulsárlón er jökullón við sporð Breiðamerkurjökuls, sem byrjaði að koma í ljós upp úr 1930. Undir Breiðamerkurjökli er djúpur jökulgrafinn dalur, sem nær allt að 300 m niður fyrir sjávarmál. Þegar loftslagið fór að hlýna, snemma á 20. öld, byrjaði Breiðamerkurjökull að hopa og myndaðist lón í lægð sem kom í ljós framan við jökulinn. Lónið hefur farið ört stækkandi og nú er það orðið svo stórt, að aðeins mjó landræma skilur lónið og sjóinn að. Ef svo heldur fram sem horfir mun bráðum vegi og raflínu stafa hætta af landbroti. Til að fylgjast með þessari þróun, hefur Vegagerðin frá árinu 1991 til dagsins í dag staðið fyrir árlegum mælingum á umfangi landbrots. Á mynd 22 sést glögglega hvernig Jökulsárlón hefur myndast og stækkað í gegnum tíðina.

Við Jökulsárlón hefur aðallega verið rannsakað :

1-myndun lónsins og breytingar á lóninu í gegnum tíðina
2-hætta sem stafar af stækkun lónsins:
- **-landbrot við brýrnar**
- **-framkvæmdir til að koma í veg fyrir rof**
- **-strandrof og strandvarnir**
- **-vatnshæðarmælingar**

1-myndun lónsins og breytingar á lóninu í gegnum tíðina
Nokkrir vísindamenn hafa rannsakað tilurð Jökulsárlóns og breytingar á lóninu í gegnum tíðina. Guðmundur Kjartansson skrifaði tvær greinar um myndun lónsins (í Náttúrufræðingnum 1957 og í Fold og vötn 1980) og Flosi Björnsson á Kvískerjum tíndi saman upplýsingar um Jökulsá á Breiðamerkursandi og Jökulsárlón (Flosi Björnsson 1993). Þrír vísindamenn á vegum Raunvísindastofnunar Íslands, Helgi Björnsson, Finnur Pálsson og Eyjólfur Magnússon, tóku saman skýrslu um breytingar á Jökulsárlóni 1934-1998 og í Jökli birtist grein eftir þá um stækkun lónsins (Björnsson, Pálsson, Guðmundsson 1999, 2001). Sverrir Guðmundsson, Helgi Björnsson, Finnur

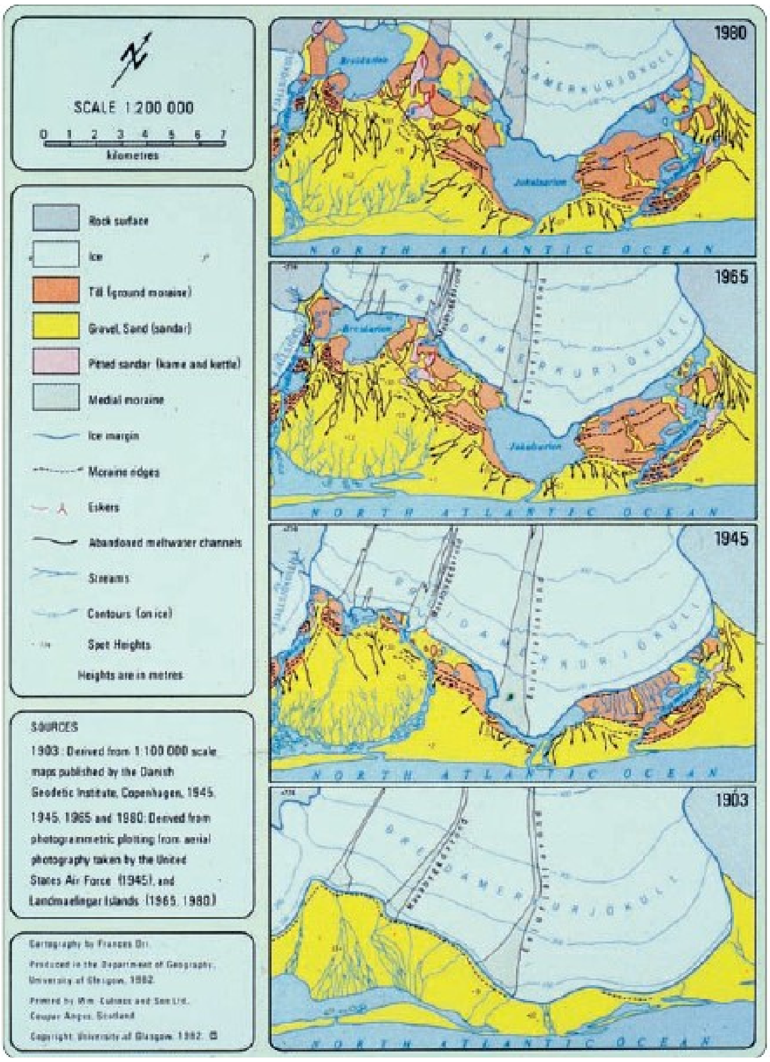
Pálsson og E. Berthier hafa haldið erindi um stækkun Jökulsárlóns á 20. öld við Opinn Háskóla árið 2006 og á ráðstefnu um strandrof og strandvarnir sem var haldin á Höfn í Hornafirði árið 2005.

2-hætta sem stafar af stækkun lónsins

Til að fylgjast með rof við Jökulsárbrú, hefur Vegagerðin frá árinu 1991 til dagsins í dag staðið fyrir árlegum mælingum á umfangi landbrots.Vísindamenn á vegum Vegagerðarinnar og aðrir hafa gert rannsóknir á stækkun Jökulsárlóns (Guðmundsson, Björnsson, Pálsson og Berthier 2005, 2006) og landbrot við brúna yfir Jökulsá á Breiðamerkursandi (Jóhannesson 1994, 1995, 2004; Jóhannesson og Sigurðarson 2005). Páll Þór Imsland hefur samið nokkrar skýrslur og blaðagreinar um hættuna á Breiðamerkursandi. Í þeim lýsir hann núverandi ástandi á Breiðamerkursandi og þróun Jökulsárlóns í gegnum tíðina. Hann gerir grein fyrir orsökum þessar þróunar og gerir tillögu að framtíðarlausn á vandanum (Imsland 2000, á íslensku og á ensku; Blaðamaður 2002). Starfsmenn Orkustofnunar gerðu kornastærðargreiningar og flokkuðu sýni af Skeiðarár- og Breiðamerkursandi eftir bergtegundum til að finna út af hverju strandrof við Jökulsá á Breiðamerkursandi hefur verið minna eftir Skeiðarárhlaup 1996 (Harðardóttir, Víkingsson, Pálsson 2006). S. Árnason mældi árið 1998 fyrir Orkustofnun rennsli og hitastig í Jökulsá á Breiðamerkursandi. S. Zóphóníasson og R. Freysteinsdóttir, einnig á vegum Orkustofnunar, gerðu vatnshæðarmælingar í Jökulsárlóni á Breiðamerkursandi 1991-1998 (Zóphóníasson og Freysteinsdóttir 1999).

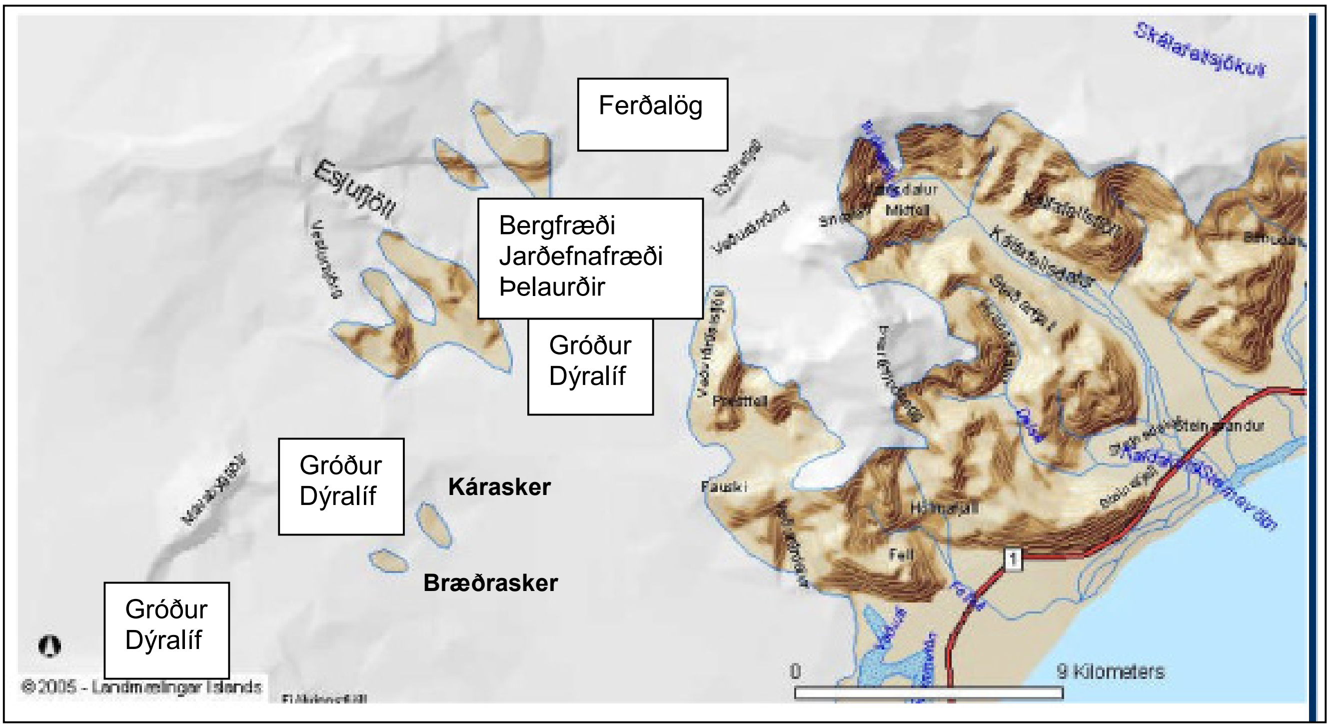
Einnig hafa nokkrar rannsóknir verið gerðar sem tengjast ekki beint myndun og stækkun lónsins eða landbroti við Jökulsárbrú. Má þar nefna:

-rannsókn á lagskiptingu setmyndana undir Jökulsárlóni (Boulton 1982)
-rannsókn á seltu í Jökulsárlóni (Kjartansson 1957)
-rannsókn á varmabúskap bráðnandi íss í Jökulsárlóni (Landl, Björnsson, Kuhn 2003)
-rannsókn á því, hversu hratt jökullinn kelfir og hvaða þættir stjórna hraðanum (van der Veen 2002)



Mynd 22: breytingar á Breiðamerkurjökli, Breiðamerkursandi, Jökulsárlóni og Jökulsá frá 1903 til 1980 (Price 1982)

3.16 Esjufjöll, Mávabyggðir, Kárasker



Esjufjöll, Mávabyggðir, Kárasker og Bræðrasker eru jökulsker í Vatnajökli, norðan og norðvestan við Breiðamerkurjökul. Þar hafa gróður og dýralíf fengið að þróast í friði fyrir ágangi manna og búfjár og eru þess vegna talin “upprunaleg”. Flestar rannsóknir sem hafa verið gerðar í skerjunum hafa því aðallega beinst að gróðri og dýralífi en einungis að litlu leyti að jarðfræði.

Esjufjöll

Talið er að Esjufjöll tengjast Öræfajökli og Snæfelli; þau teljast liggja í miðju gamals gosbeltis sem nú er næstum því kulnað og er kallað Öræfajökuls gosbelti. Uppbygging Esjufjalla bendir til að þau séu hluti af megineldstöð, sem ís hefur rofið sundur. Norður af fjallgörðunum er sporöskjulaga lægð sem er líklega ísfyllt askja. Árið 1927 varð hlaup í Jökulsá á Breiðamerkursandi sem hugsanlega tengist eldgosi í Esjufjöllum (Sigurður Björnsson 1977, 1978). Fredrik Holm, R. Trønnes, Karl Grönvold og Halldór Karlsson hafa rannsakað uppruna líparíta í Öræfajökuls gosbeltinu (Holm et al. 2004) og þeir hafa einnig kannað bergfræði og jarðefnafræði eldstöðvarinnar í Esjufjöllum (Holm et al. 2004). N. Eyles vann við jöklarannsóknir á Suðausturlandi og rannsakaði m.a. þelaurðir (rock glaciers) í Esjufjöllum. Í Esjufjöllum hafa verið gerðar margvíslegar rannsóknir á gróðri, landnámi plantna, gróðurframvindu, dýralífi og sérstaklega skordýralífi (Hálfdán Björnsson 1951, 1979, 1997; Bjarni Diðrik Sigurðsson 2005). Einnig eru til nokkrar lýsingar á “Esjufjallaferðum og Esjufjallagöngum”, ferðalögum í Esjufjöll (Jón Eyþórsson 1951, 1960-61;Valur Jóhannesson 1975; Jón E. Ísdal 1978; Árni Reynisson 1985 og Sigurður Sigurðarson 1989).

Mávabyggðir

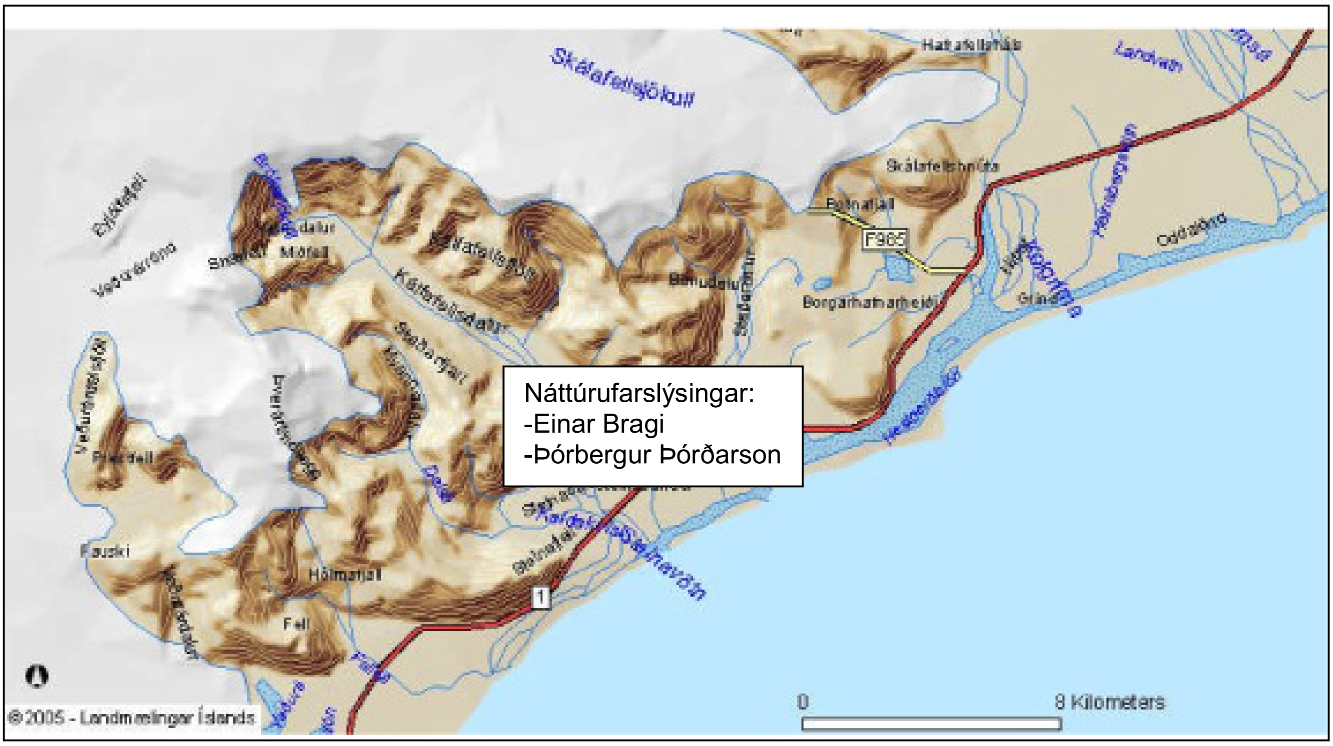
Kvískerjabræður rannsökuðu gróður, dýralíf og jarðfræði í Mávabyggðum og árið 1951 birtist grein eftir Hálfdáni Björnssyni í Náttúrufræðingnum um athuganir þeirra.

Kárasker, Bræðrasker

Kvískerjabræður könnuðu gróður og dýralíf í Káraskeri og lýstu staðháttum (þ.a.m. jarðfræði) þar (Hálfdán Björnsson 1958, Sigurður Björnsson 1958). Grasafræðingurinn Eyþór Einarsson rannsakaði gróður og landnám plantna í Káraskeri og Bræðraskeri og skrifaði greinar um athuganir sínar í

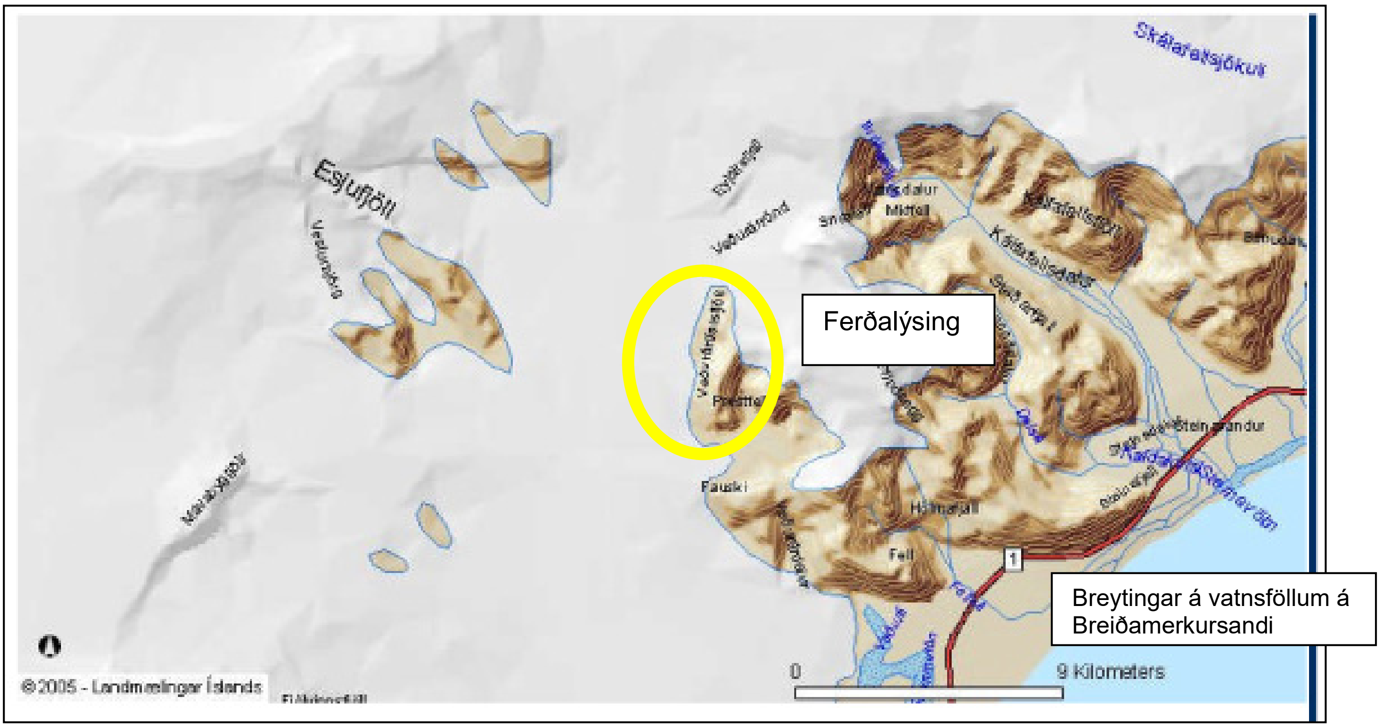
Kvískerjabók (1998), Nordecol newsletter no. 12, desember 1980 (bls. 21-22) og í Naturens verden apríl 1988 (bls. 97-111).

3.17 Suðursveit



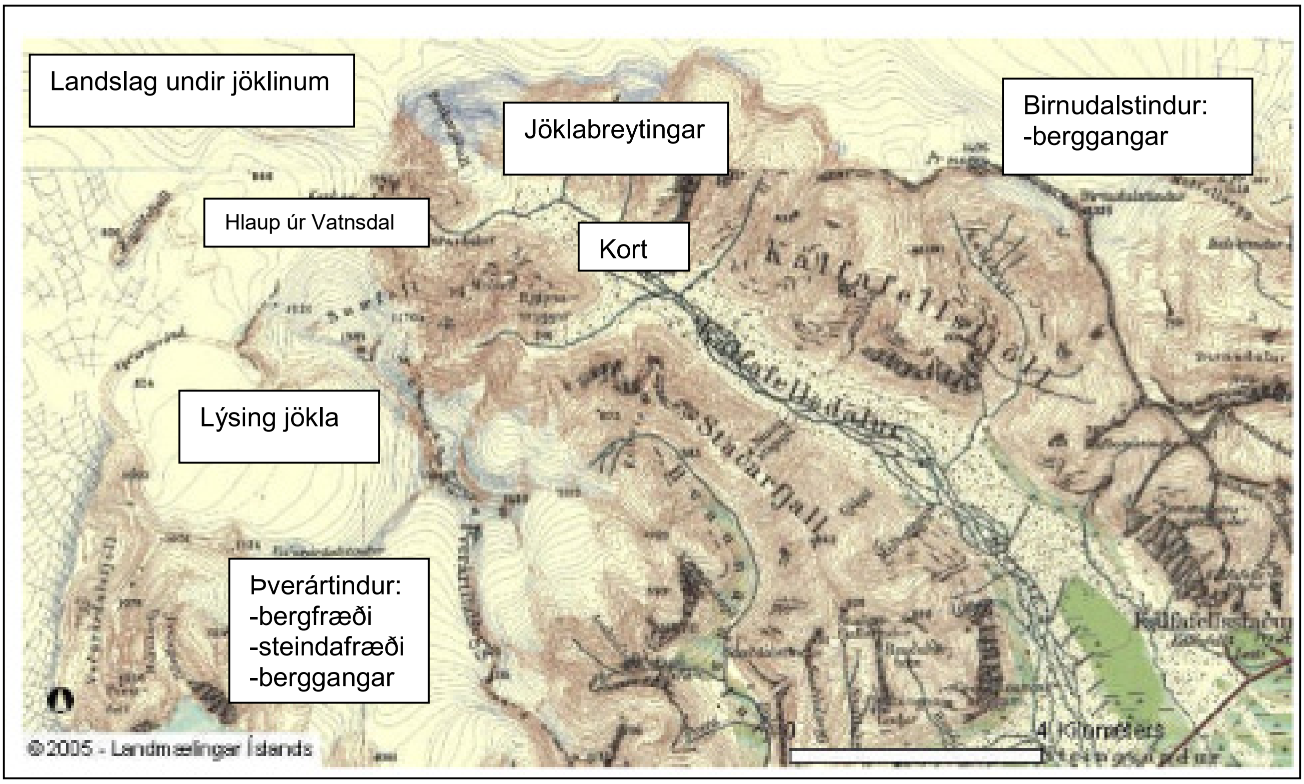
Glöggar lýsingar á landslagi og náttúrufari Suðursveitar má finna í ritum tveggja heimamanna, Einars Braga skálds og Þórbergs Þórðarsonar rithöfundar frá Hala (Einar Bragi 1973, 1973-1974; Þórðarson 1956, 1957, 1958, 1974, 1975, 1983, 1986, 1987).

3.18 Veðurárdalur, Veðurá



Breiðamerkurjökull lokar fyrir mynni Veðurárdals og í dalnum myndast lón sem hleypur stundum og tæmist. Áður fyrr skilaði hlaupvatnið sér í Veðurá, sem rann undan Breiðamerkurjökli í kverkinni vestan undir Fellsfjalli. Austast á Breiðamerkursandi sést enn gamall þurr farvegur þessarar ár. Áin rann lengi um Breiðabólstaðarós til sjávar en fór seinna að renna í Stemmulón, sem sameinaðist Jökulsárlóni arið 1991. Fáar heimildir fundust um Veðurárdal og Veðurá. Árið 1993 birtist grein í Skaftfellingi, þar sem Þorsteinn Guðmundsson lýsir ferð sinni í Veðurárdal árið 1928. Flosi Björnsson skrifaði tvær greinar um jökla milli Fells og Staðarfjalls (í Skaftafellingi 1993 og Jökli 1998) og árið 1996 birtist grein eftir hann um Breiðamerkursand, þar sem hann lýsir breytingum á vatnsföllum á sandinum í gegnum tíðina. Í grein eftir Baldur Þ. Þorvaldsson, sem birtist í Framkvæmdafréttum Vegagerðarinnar árið 2004, má einnig finna glögga lýsingu á breytingum á jökulám á Breiðamerkursandi auk samantektar um brúargerð. Í Morgunblaðinu (21. september 1990) er fjallað um ána Stemmu sem hefur þornað skyndilega upp og einnig er lýst hvernig farvegir annarra áa á Breiðamerkursandi hafa breyst í gengum aldirnar.

3.19 Brókarjökull, Kálfafellsdalur, Þverártindur, Birnudalstindur



Á Suðausturlandi eru fjölmargar útkulnaðar megineldstöðvar, til að mynda Vestra- og Eystrahorn, Kollumúlaeldstöð, Geitafellseldstöð, Hvannadalseldstöð, Skaftafellseldstöð o.fl.. Í þeim má finna fjölbreytilegar bergtegundir, eins og líparít með basaltæðum og djúpbergsinnskotum. Í fjöllunum í kringum Kálfafellsdal eru tvær útkulnaðar eldstöðvar, Þverártindur vestan við dalinn og Birnudalstindur austan við hann. Þessar eldstöðvar voru virkar á Tertíer-tímabilinu og í þeim koma djúpbergsinnskot úr gabbró, granófýr og granít í ljós. Bergfræði og höggun þessara eldstöðva hafa verið rannsakaðar ítarlega af jarðfræðingum frá Danmörku og Eistlandi.

Þverártindur

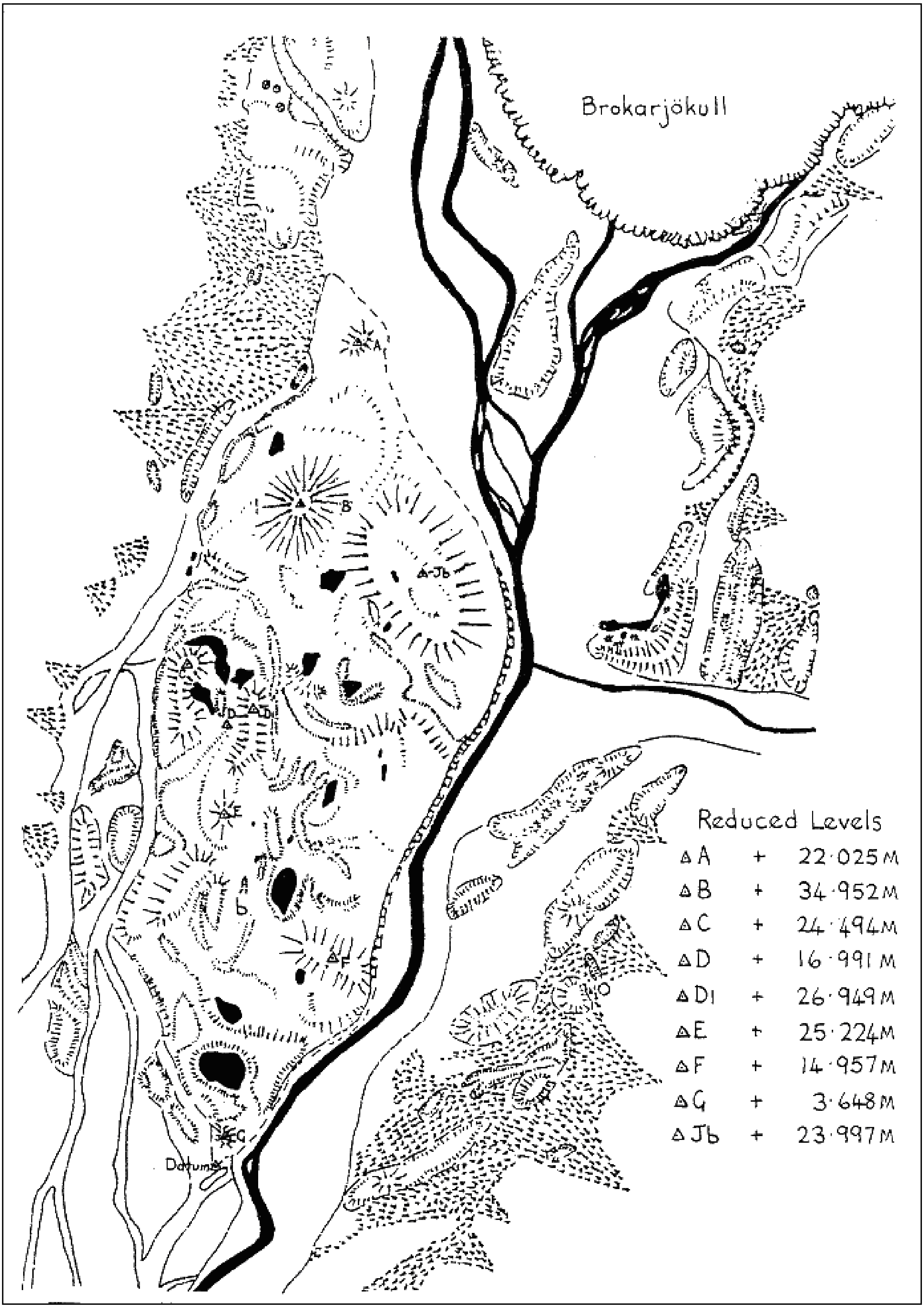
Eistneski jarðfræðingurinn Alvar Soesoo hefur rannsakað bergfræði og steindafræði djúpbergsinnskota í Þverártindi (A. Soesoo 1995, 1998). Daninn M.B. Klausen kannaði aðallega halla og þykkt berggangna í gangaþyrpingum sem tengjast fornu eldstöðinni í Þverártindi (M.B. Klausen 1995, 2004, 2006)

Birnudalstindur

Daninn M.B. Klausen rannsakaði halla og þykkt berggangna í gangaþyrpingum sem tengjast fornu eldstöðinni í Birnudalstindi (Klausen 2006).

Brókarjökull

Reglulega hafa verið birtar niðurstöður úr sporðmælingum á Brókarjökli í tímaritinu Jökli (Eyporsson 1963; Rist 1984; Sigurdsson 1998-2006). Í lok 19. aldar gekk Brókarjökull hratt fram og lokaði fyrir mynni dals sem nefnist Vatnsdalur. Þar myndaðist lón og hlaup sem komu úr þessu lóni hafa valdið miklum skemmdum á gróðurlendi. Í bókinni Jöklaveröld (2004) má finna lýsingu á þessum hlaupum. Cranleigh School skipulagði árið 1985 rannsóknaleiðangur að Brókarjökli. Unnið var m.a. að því að



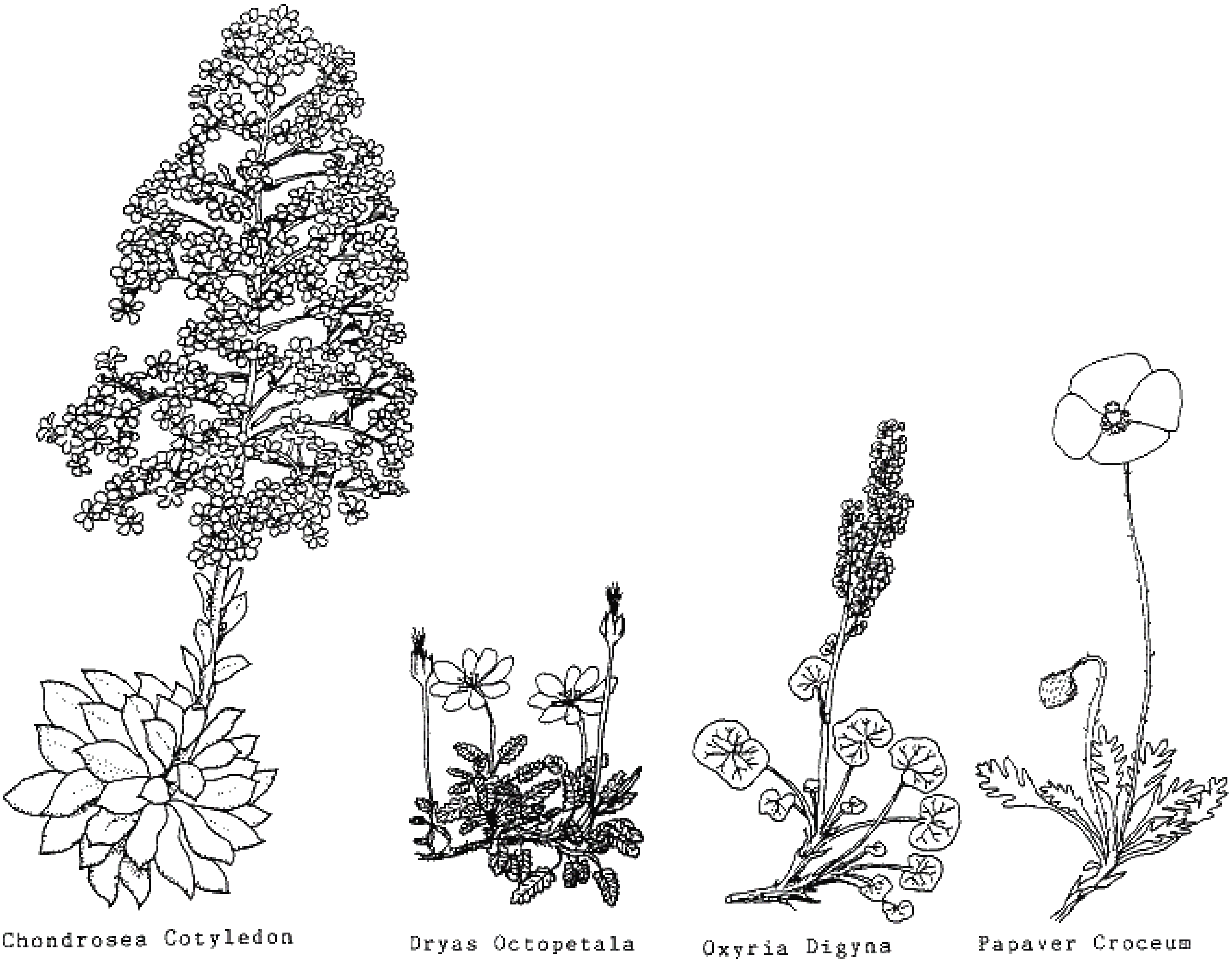
Mynd 23: Kort af svæðinu við sporð Brókarjökuls (Winser 1985).

kortleggja Brókarjökul og jaðarsvæði hans (Winser 1985; sjá mynd 23). Einnig voru gerðar kannanir á gróðri og fuglalífi í Kálfafellsdal (sjá mynd 24).

Jöklar milli Fells og Staðarfjalls

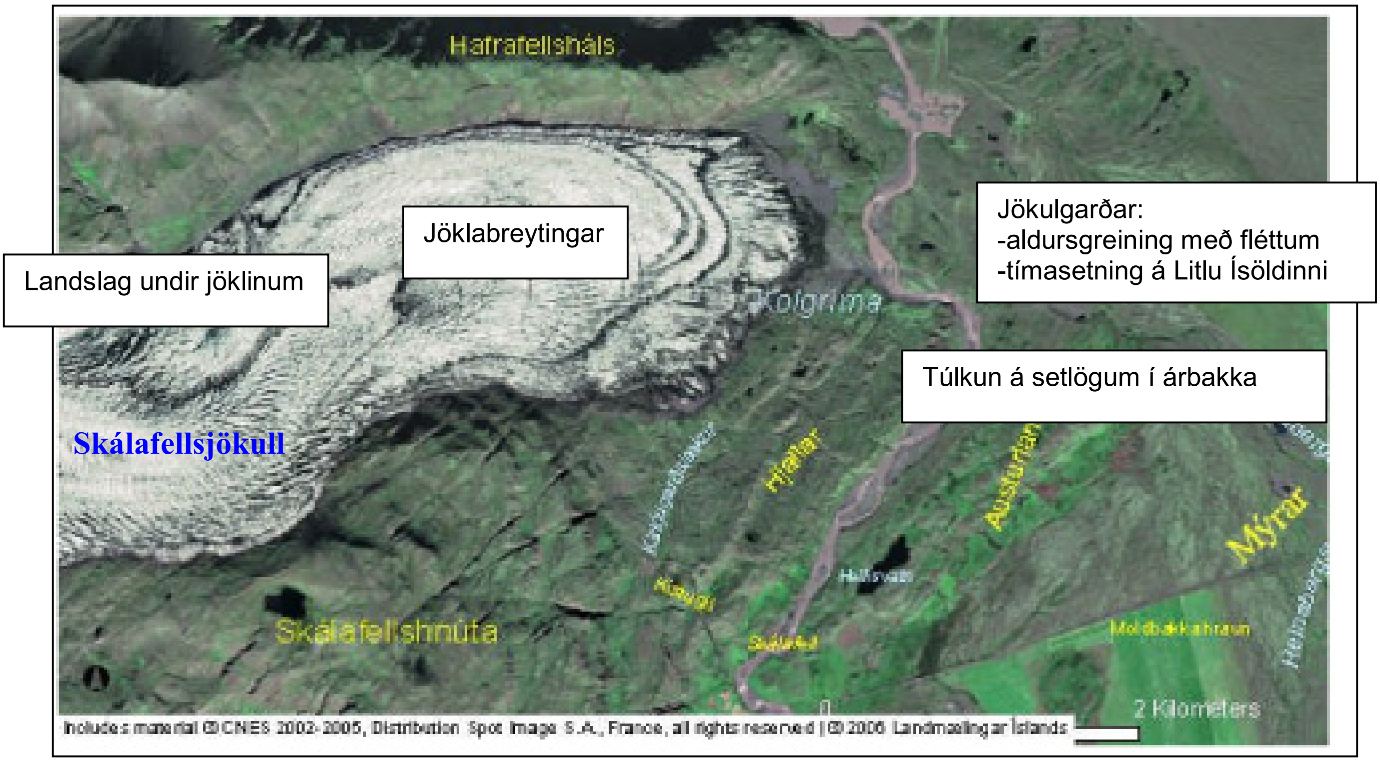
Grein um jökla milli Fells og Staðarfjalls eftir Flosa Björnsson birtist í Skaftfellingi (1993) og Jökli (1998).

Helgi Björnsson og aðrir hafa rannsakað rof af völdum jökla og kannað landslagið undir Vatnajökli og skriðjöklunum sem teygja sig niður frá honum.



Mynd 24: Algengar plöntur í Kálfafellsdal (Úr :Winser 1985)

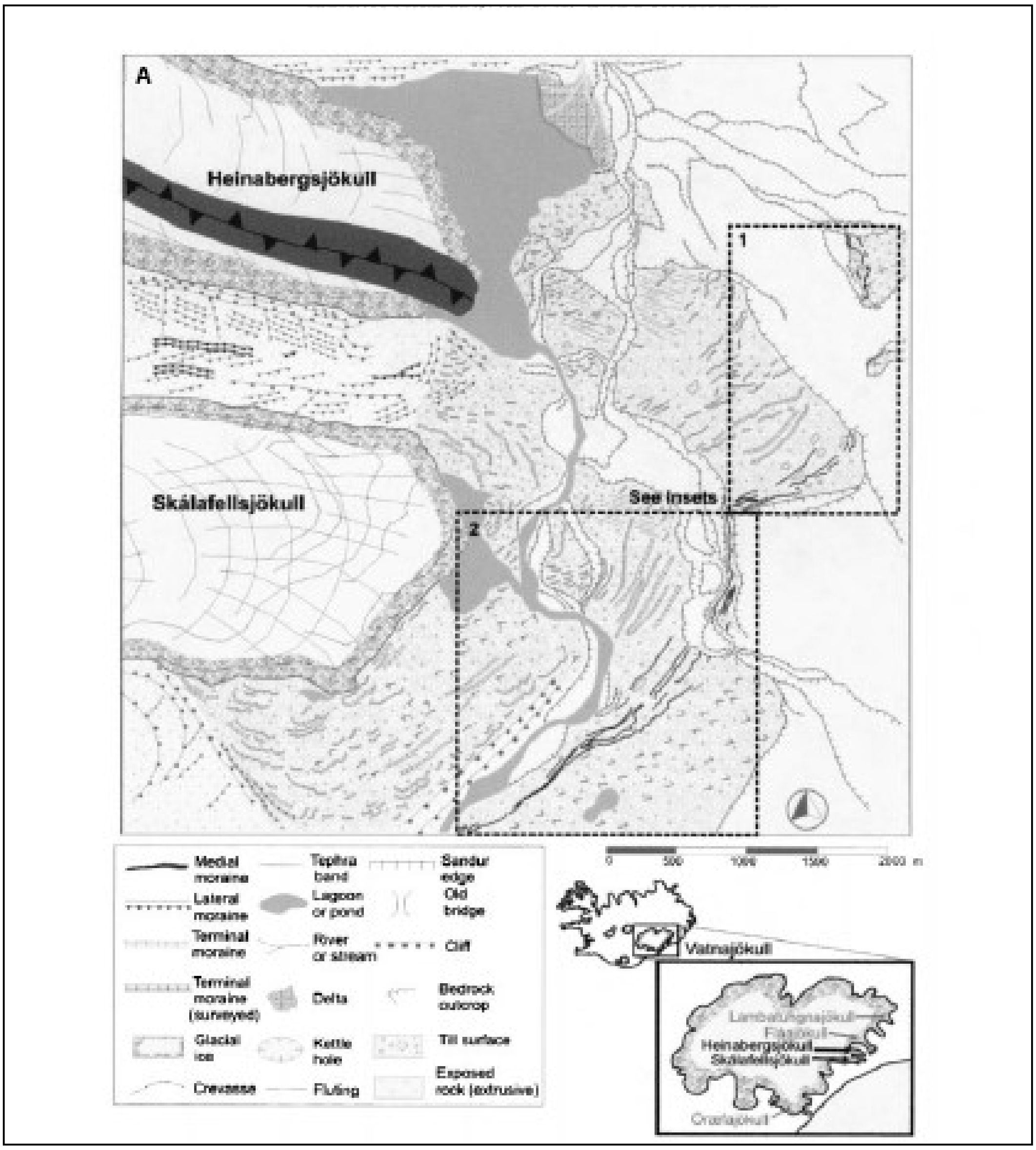
3.20 Skálafellsjökull



Árið 1930 voru nokkrir skriðjöklar í Austur-Skaftafellssýslu, skoðaðir og mældir, þ.a.m. Skálafellsjökull við Sultartungugil (Eiríksson 1932). Reglulega hafa verið birtar niðurstöður úr sporðmælingum á Skálafellsjökli í tímaritinu Jökli (Eyporsson 1963; Rist 1984; Sigurdsson 1998-2006).

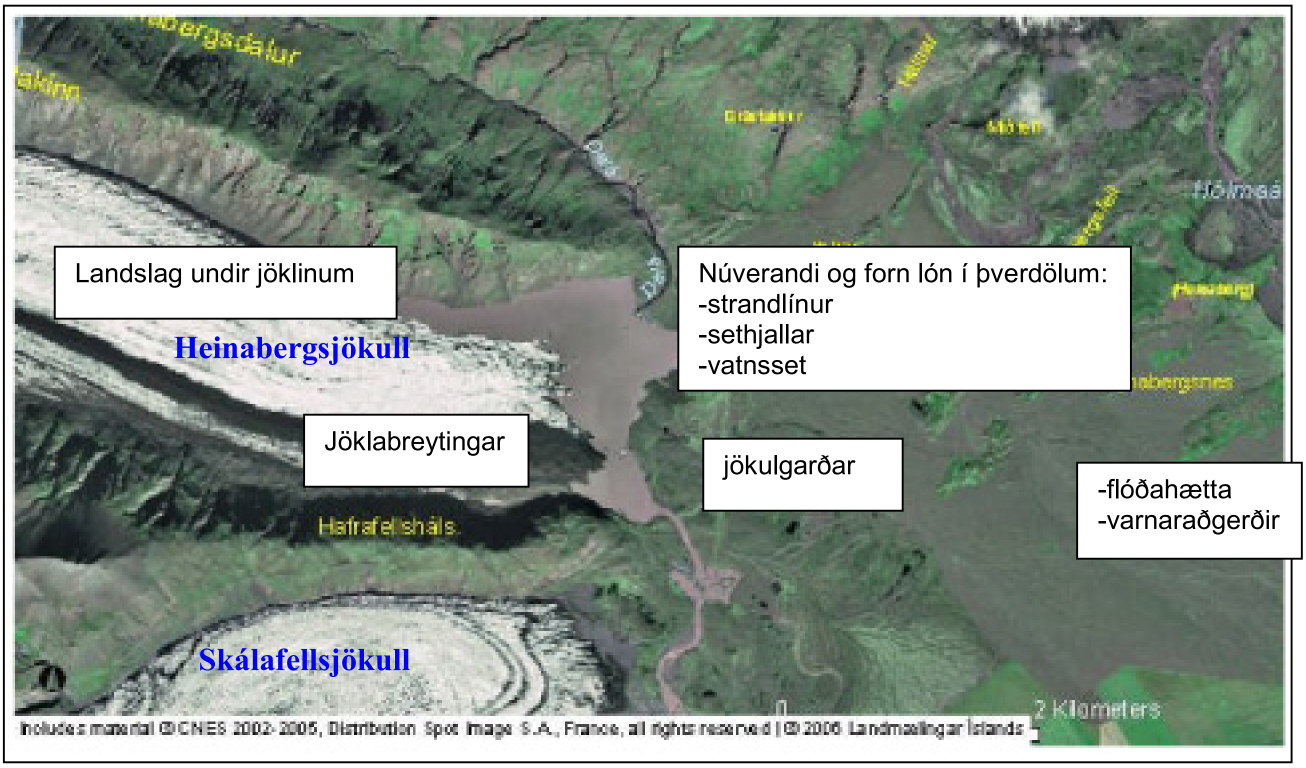
Helgi Björnsson og aðrir hafa rannsakað rof af völdum jökla og kannað landslagið undir Skálafellsjökli. Sigfinnur Snorrason skrifaði árið 1979 4. árs ritgerð í jarðfræði við Háskóla Íslands um "Mýrajökla og Vatnsdal. Hann kortlagði jökulgarða og aðrar jökulminjar framan við m.a. Skálafellsjökul og aldurgreindi þau. Árið 1984 skrifaði hann yfirgripsmikla doktorsritgerð um sama viðfangsefni.

Sérstaklega Bretar hafa verið duglegir að rannsaka Skálafellsjökul. M. Sharp rannsakaði jarðlög og jökulgarða framan við Skálafellsjökul til að fá upplýsingar um hop og framskrið jökla á austurlandi á Hólosen-tímabilinu (M.J. Sharp 1984; M.J. Sharp og A. Dugmore 1985). D. Evans skoðaði snið í gegnum setlög sem var sýnilegt í árbakka við jökuljaðarinn. Úr því mátti lesa þá rás atburða sem áttu sér stað frá myndun laganna: setmyndun við jökuljaðarinn, framskrið Skálafellsjökuls yfir þessi setlög á Litlu Ísöldinni, breytingar sem áttu sér stað í þessum lögum af völdum jökulfargs og botnurð sem hefur myndast undir jöklinum (Evans 2000). T. Bradwell hefur, ásamt K.M. McKinzey og J.F. Orwin, gert rannsóknir á fléttum sem vaxa á jökulgörðum og reynt að finna fylgni milli stærðar flétta og aldurs jökulgarðsins sem þær vaxa á. Bradwell, Orwin og McKinzey endur-aldursgreindu jökulgarðana framan við Heinabergsjökul og Skálafellsjökul til að gera samanburð á tveimur mismunandi aldursgreiningaraðferðum með fléttum og að finna út hvor aðferðin gæfi bestu niðurstöðurnar. Þeir bjuggu til tímatal um jöklabreytingar, tímasettu Litlu Ísöldina og ákváðu útbreiðslu hennar (K.M. McKinzey, J.F. Orwin, T. Bradwell 2004 og 2005). Mynd 25 sýnir landmótunarkort sem þeir teiknuðu fyrir svæðið framan við Skálafells- og Heinabergsjökla.



Mynd 25: Landmótunarkort af svæðinu framan við Skálafellsjökul og Heinabergsjökul. Kortið sýnir jökulrönd, jaðarurð, jökulgarða, jökulsprungur, öskulög, jökullón, ár, jökulvatnsset, jökulker, jökulkemba, sanda, botnurð og berggrunn (McKinzey, Orwin og Bradwell 2004, bls. 320).

3.21 Heinabergsjökull



Heinabergsjökull stíflar Vatnsdal og þar hefur myndast lón sem tæmist árlega. Áður fyrr hljóp úr Vatnsdal suður yfir Mýrar og þá ollu Vatnsdalshlaup miklum skemmdum. Í lok 19. aldur gekk Heinabergsjökull svo langt fram að hann lokaði fyrir Heinabergsdal og þá myndaðist lón framarlega í dalnum (Dalvatn). Þar má sjá strandlínu í 133 hæð sem vitnar um tilvist þessa horfna lóns. Hærra í hlíðum dalsins sjást eldri strandlínur (Hjörleifur Guttormsson, 1993; bls. 158).
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Tiltölulega margar rannsóknar hafa verið gerðar við Heinabergsjökul. Viðfangsefni flestra rannsókna hafa verið:

1- núverandi og forn jökulstífluð lón í þverdölum við Heinabergsjökul, sethjallar, strandlínur og aðrar setmyndanir í lóni
2- aldursgreining á jökulgörðum framan við Heinabergsjökul með kortum, fléttum, Schmidt-hammer aðferð og öskulögum til að fá upplýsingar um jöklabreytingar eftir að Litla Ísöldin náði hámarki sínu. Tímasetja Litlu Ísöldina.
3- flóðahætta á Mýrum og varnaraðgerðir heimamanna gegn ágengi jökulfljóta
4- jöklabreytingar
5- landslag undir jöklinum

1- **Núverandi og forn jökulstífluð lón í þverdölum**

Breskir vísindamenn rannsökuðu setmyndanir og landmótun sem tengjast núverandi og fornum lónum sem hafa myndast í þverdölum við Heinabergsjökul. Þeir könnuðu m.a. sethjalla og fornar strandlínur við núverandi jökullón og strandlínur og vatnsset við forna lónið (M.R. Bennett, D. Huddart, T. McCormick 2000). Á mynd 26 má sjá landmótunarkort af svæðinu við jaðar Skálafells- og Heinabergsjökla.

2- **Aldursgreining á jökulgörðum**

Sigfinnur Snorrason skrifaði árið 1979 4. árs ritgerð í jarðfræði við Háskóla Íslands um “Mýrajökla” (Skálafellsjökul, Heinabergsjökul og Fláajökul). Hann kortlagði jökulgarða og aðrar jökulminjar framan við Mýrajöklana og aldurgreindi þau. Árið 1984 skrifaði hann yfirgripsmikla doktorsritgerð um sama viðfangsefni. Tveir hópar breskra vísindamanna hafa unnið að því að aldursgreina jökulgarða framan við Heinabergsjökul. Fyrri hópurinn gerði samanburð á tveimur aðferðum sem eru notaðar til að aldursgreina jökulminjar: Schmidt-hammer aðferð og fléttuaðferð. Þeir notuðu þessar aðferðir til að fá upplýsingar um hop Heinabergs-, Kvíár- og Hólárjökuls eftir að Litla Ísöldin náði hámarki sínu (D.J.A. Evans, S. Archer, D.J.H. Wilson 1999). Markmið með rannsókninni var aðallega að ákveða hvaða aðferð hentaði best. Seinni hópurinn endur-aldursgreindi jökulgarðana framan við Heinabergsjökul (og Skálafellsjökul) til að gera samanburð á tveimur mismunandi aldursgreiningaraðferðum með fléttum og að finna út hvor aðferðin gæfi bestu niðurstöðurnar. Þeir bjuggu til tímatal um jöklabreytingar, tímasettu Litlu Ísöldina og ákváðu útbreiðslu hennar (K.M. McKinzey, J.F. Orwin, T. Bradwell 2004 og 2005).

3- Flóðahætta á Mýrum og varnaraðgerðir

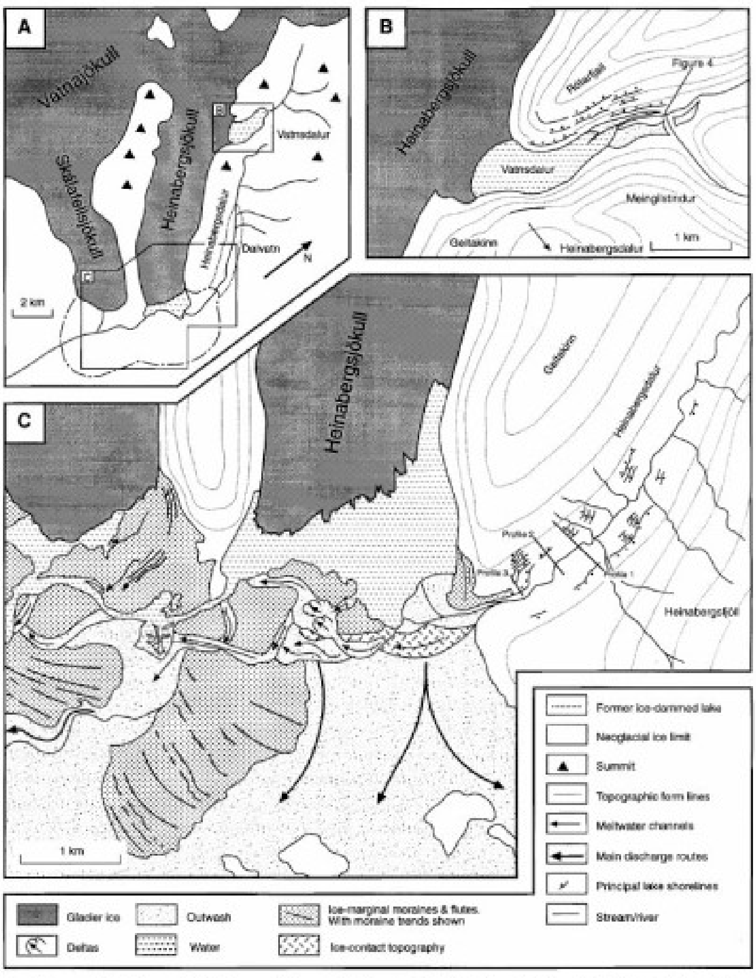
Jóhanna Katrín Þórhallsdóttir skrifaði BS-ritgerð í landafræði við H.Í. um flóðahættu á Mýrum og gerði samantekt á varnaraðgerðum sem Mýramenn hafa gripið til í gegnum tíðina til að verja byggð (J.K. Þórhallsdóttir 2004)

4- Jöklabreytingar

Árið 1930 voru nokkrir skriðjöklar í Austur-Skaftafellssýslu, þ.a.m. Heinabergsjökull og Vatnsdalur, skoðaðir og mældir (Eiríksson 1932). Reglulega hafa verið birtar niðurstöður úr sporðmælingum á Heinabergsjökli í tímaritinu Jökli (Eyporsson 1963; Rist 1984; Sigurdsson 1998-2006).

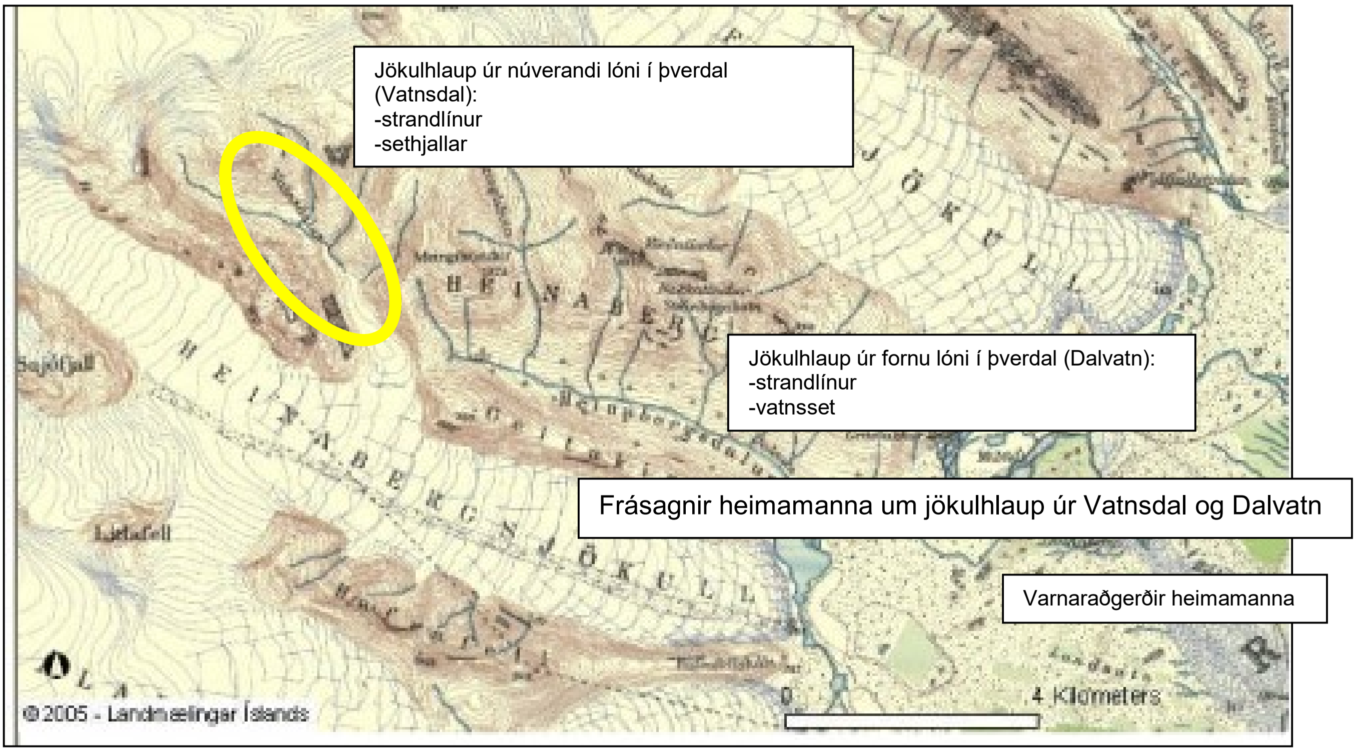
5- Landslag undir jöklinum

Helgi Björnsson og aðrir hafa rannsakað rof af völdum jökla og kannað landslagið undir Vatnajökli og skriðjöklunum sem teygja sig niður frá honum.



Mynd 26: Landmótunarkort af svæðinu við jaðar Skálafells- og Heinabergsjökla (Bennett og aðrir 2000)

3.22 Vatnsdalur og Dalvatn

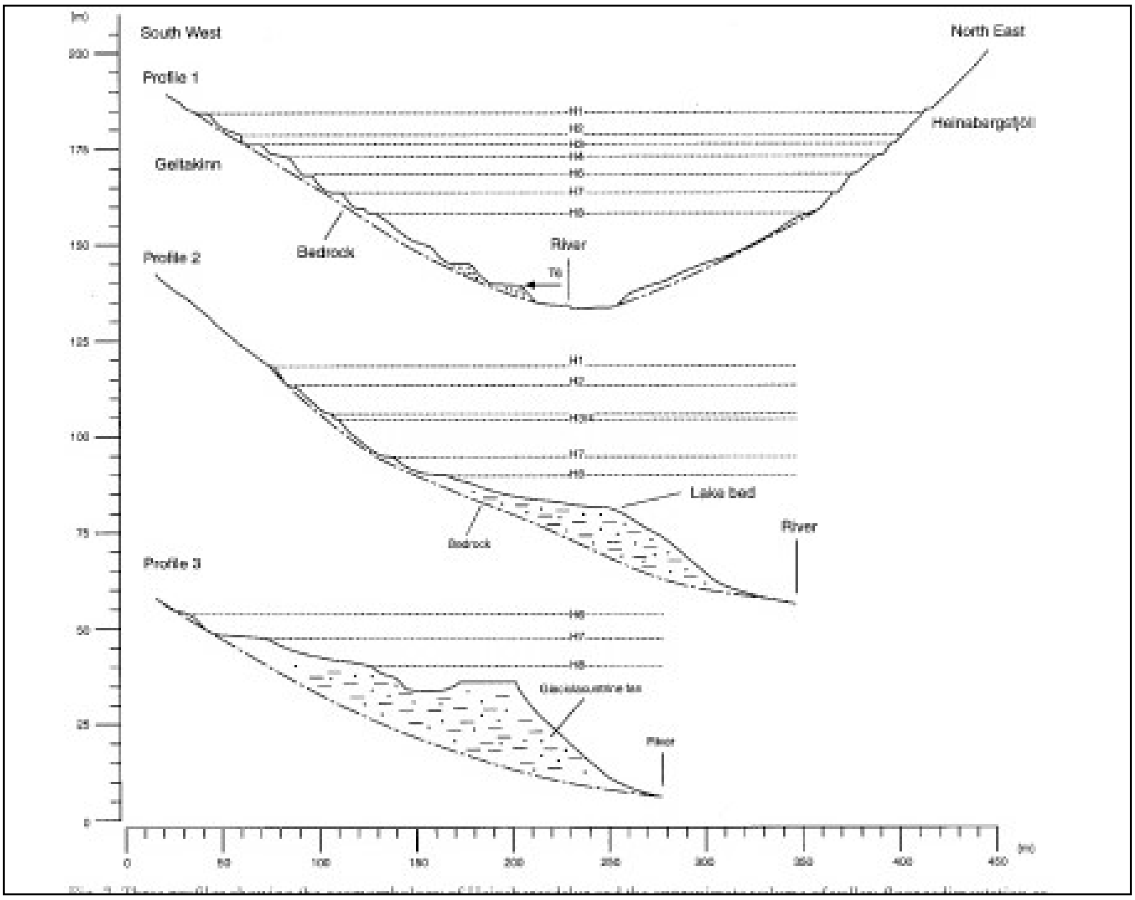


Heinabergsjökull stíflar Vatnsdal og þar myndast lón sem tæmist árlega. Snemma á árinu fljóta margir ísjakar á lóninu en eftir hlaup er lónið "tómt" og er dalbotninn þá þakinn bráðnandi ísjökum. Áður fyrr hljóp úr Vatnsdal suður yfir Mýrar og þá ollu Vatnsdalshlaup miklum skemmdum.Eftir 1948 færðu Heinabergsvötn sig vestur og fóru að renna í Kolgrímu. Síðan hafa hlaupin úr Vatnsdal fundið sér farveg í Kolgrímu og hafa hlaupin verið tiltölulega meinlaus. Í lok 19. aldur gekk Heinabergsjökull svo langt fram að hann lokaði fyrir Heinabergsdal og þá myndaðist lón (Dalvatn) framarlega í dalnum. Þar má sjá strandlínu í 133 hæð sem vitnar um tilvist þessa horfna lóns. Hærra í hlíðum dalsins sjást eldri strandlínur (Hjörleifur Guttormsson, 1993; bls.158).

Til eru bæði vísindalegar rannsóknir og frásagnir heimamanna um hlaup úr Vatnsdal og Dalvatni.

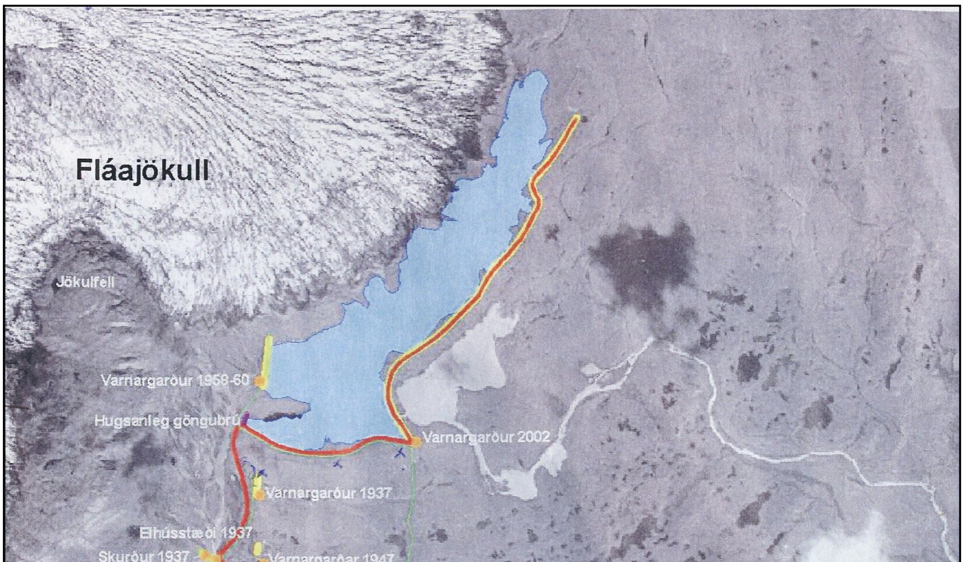
Frásagnir heimamanna um hlaup úr Vatnsdal og Dalvatn hafa birst í Skaftfellingi (Unnur Kristjánsdóttir 1993 og 2000), Jódýnum (Unnur Kristjánsdóttir 1988) og Jöklaveröld (Egill Jónsson 2004).

Nokkrir vísindamenn hafa samið greinar og ritgerðir um Vatnsdal. Sigurður Þórarinsson heimsótti Vatnsdal og lýsti dalnum í bók um jöklabreytingar og hafís (S. Þórarinsson 1969). Sigfinnur Snorrason skrifaði árið 1979 4. árs ritgerð í jarðfræði við Háskóla Íslands um "Mýrajökla og Vatnsdal". Hann kortlagði jökulgarða og aðrar jökulminjar framan við Mýrajöklana og aldurgreindi þau. Árið 1984 skrifaði hann yfirgripsmikla doktorsritgerð við Háskólann í Oslo um sama viðfangsefni. Þrír breskir jarðfræðingar rannsökuðu setmyndanir og landmótun sem tengjast núverandi og fornum lónum sem hafa myndast í þverdölum við Heinabergsjökul (Vatnsdalslón og Dalsvatn). Þeir könnuðu m.a. sethjalla og fornar strandlínur við núverandi lón í Vatnsdal og strandlínur og vatnsset við forna lónið í Heinabergsdal (M.R. Bennett, D. Huddart, T. McCormick 2000). Mynd 27 sýnir þversnið af Heinabergsdal, á myndinni sjást nokkrar fornar strandlínur í mismunandi hæð.



Mynd 27: þversnið af Heinabergsdal; á myndinni sjást fornarrandlínur í mismunandi hæð (úr Bennett 2000).

Jóhanna Katrín Þórhallsdóttir hefur gert sögulega samantekt á varnaraðgerðum sem heimamenn á Mýrum hafa gripið til í gegnum aldirnar til að vernda byggð fyrir ágengi jökulvatna (Þórhallsdóttir 2004). Á loftmyndinni hér að neðan sjást varnargarðar sem heimamenn hafa byggt í gegnum tíðina.



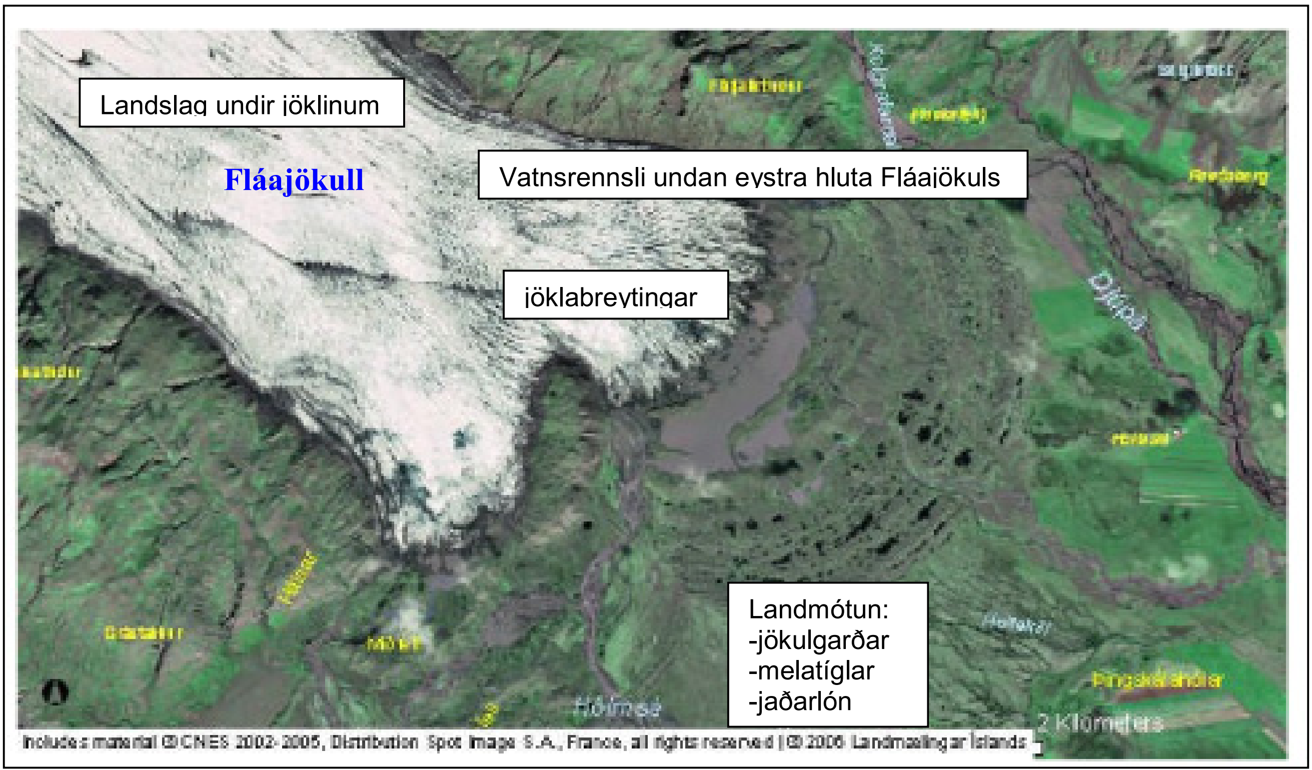
Mynd 28: Varnaraðgerðir Mýramanna við Hólmsá (Þórhallsdóttir 2004, bls. 24).

3.23 Mýrar

Hólmsá, sem rennur undan Fláajökli, hefur lengi ógnað byggð á Mýrum. Heinabergsjökull stíflar þverdal, Vatnsdal og þar myndast lón; áður fyrr hljóp reglulega úr lóninu í Vatnsdal í Hólmsá suður yfir Mýrar. Heimamenn hafa í gegnum tíðina með handverkfærum byggt margar “kynslóðir” varnargarða, sem áttu að vernda sveitina fyrir ágangi jökulfljóta. Flestar heimildir sem varða Mýrar tengjast þessum skaðlegu jökulhlaupum í Hólmsá. Gunnar Benediktsson lýsir þessari eilífu baráttu Mýramanna við illvíg jökulfljót í ritgerðum og í sjálfsævisögu sinni (Gunnar Benediktsson 1944,1954, 1977, 1978).

Jóhanna Katrín Þórhallsdóttir skrifaði BS-ritgerð í landafræði við H.Í. um flóðahættu á Mýrum og gerði samantekt á varnaraðgerðum sem Mýramenn hafa gripið til í gegnum tíðina til að verja byggð (J.K. Þórhallsdóttir 2004; R. Ólafsdóttir og J.K. Þórhallsdóttir 2004).

3.24 Fláajökull, Hólmsá



Við Fláajökul hefur aðallega þrennt verið rannsakað:

1-Jöklabreytingar
2-Jökulgarðar, melatíglar, landmótun almennt
3-Vatnsrennsli undan Fláajökli
4-Landslag undir jöklinum

1- Jöklabreytingar
Árið 1930 voru nokkrir skriðjöklar í Austur-Skaftafellssýslu, þ.a.m. Fláajökull, skoðaðir og mældir (Eiríksson 1932). Reglulega hafa verið birtar niðurstöður úr jökulsporðamælingum í tímaritinu Jökli (Eyporsson 1963; Rist 1984; Sigurdsson 1998-2006).

2-Jökulgarðar, melatíglar, landmótun almennt
Howarth og Price könnuðu árið 1969 jaðarlón við Fláajökul (Howarth og Price 1969). Sigfinnur Snorrason skrifaði árið 1979 4. árs ritgerð í jarðfræði við Háskóla Íslands um "Mýrajökla" (Skálafellsjökul, Heinabergsjökul og Fláajökul). Hann kortlagði jökulgarða og aðrar jökulminjar framan við Mýrajöklana og aldurgreindi þau. Árið 1984 skrifaði hann yfirgripsmikla doktorsritgerð um sama viðfangsefni. Pólskir vísindamenn hafa verið duglegir að rannsaka Fláajökul. M. Dabski hefur notað upplýsingar um landmótun, gömul kort og niðurstöður úr aldursgreiningu með fléttum til að ákveða hvað jökulgarðarnir framan við Fláajökul eru gamlir (Dabski, 2002). Einnig hefur hann skoðað melatígla í jökulbergi við Fláajökul (Dabski 2005). Aðrir pólskir vísindamenn, frá Háskólanum í Torun, rannsökuðu landmótun við Fláajökul og gerðu landmótunarkort fyrir jaðarsvæði jökulsins (P. Molewski 2005, sjá mynd 29).

3-Vatnsrennsli undan Fláajökli
Hólmsá, sem rennur undan Fláajökli, hefur oft ógnað byggð á Mýrum. Þegar Fláajökull fór að hopa færði útfallið sig austur og byrjaði vatn að renna austur í Hleypilæk, í staðinn fyrir vestur í Hólmsá og

ógnaði ræktuðu landi. Til að koma í veg fyrir það, byggði Vegagerðin varnargarð árið 2002 að ósk heimamanna en þá varð til nýtt uppistöðulón. Nokkrar rannsóknir tengjast byggingu þessa varnargarðs; gert var mat á umhverfisáhrifum (Sigurðardóttir, Smáradóttir 2001) og vatnsrennsli undan eystra hluta Fláajökuls var rannsakað ítarlega (Pálsson, Björnsson 2000). Í kjölfar byggingar varnargarðs 2002 var gert mat á flóðahættu (Þórhallsdóttir 2004) og úttekt á varnaraðgerðum heimamanna (Þórhallsdóttir & Vegagerðin 2004).

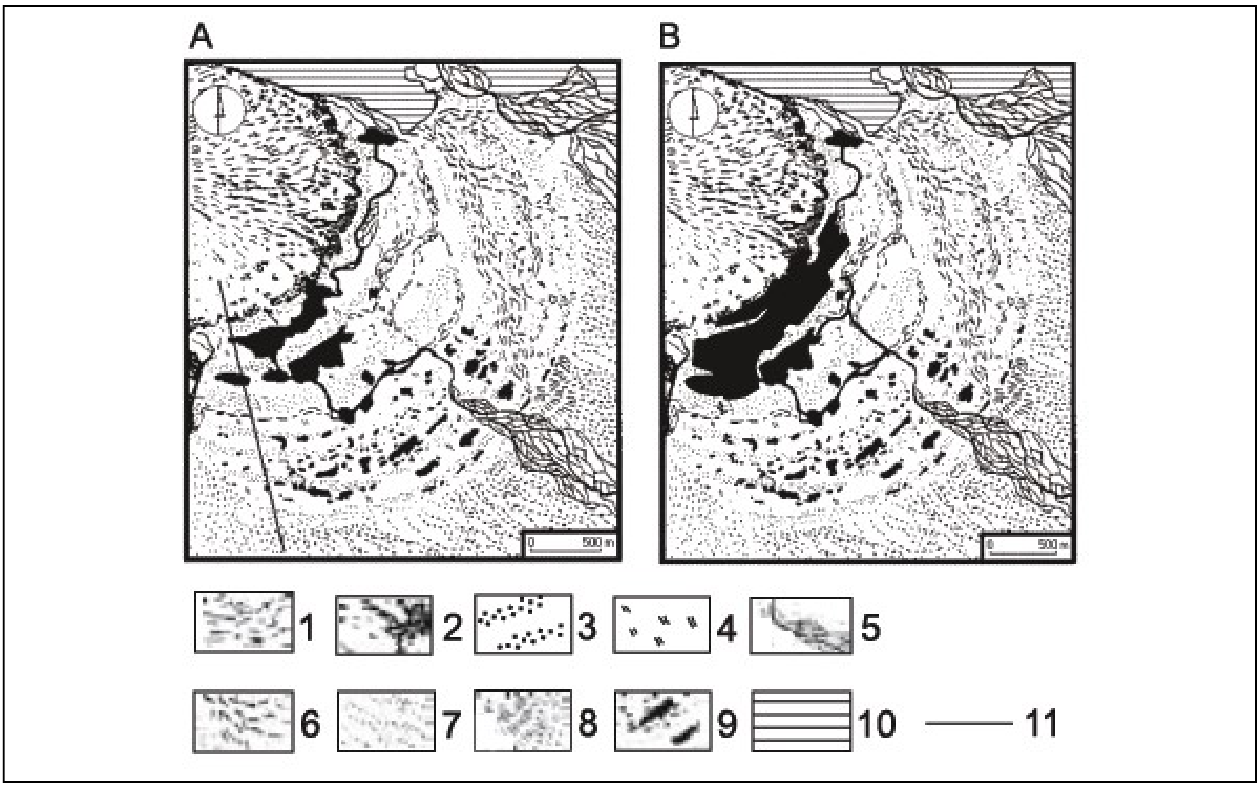


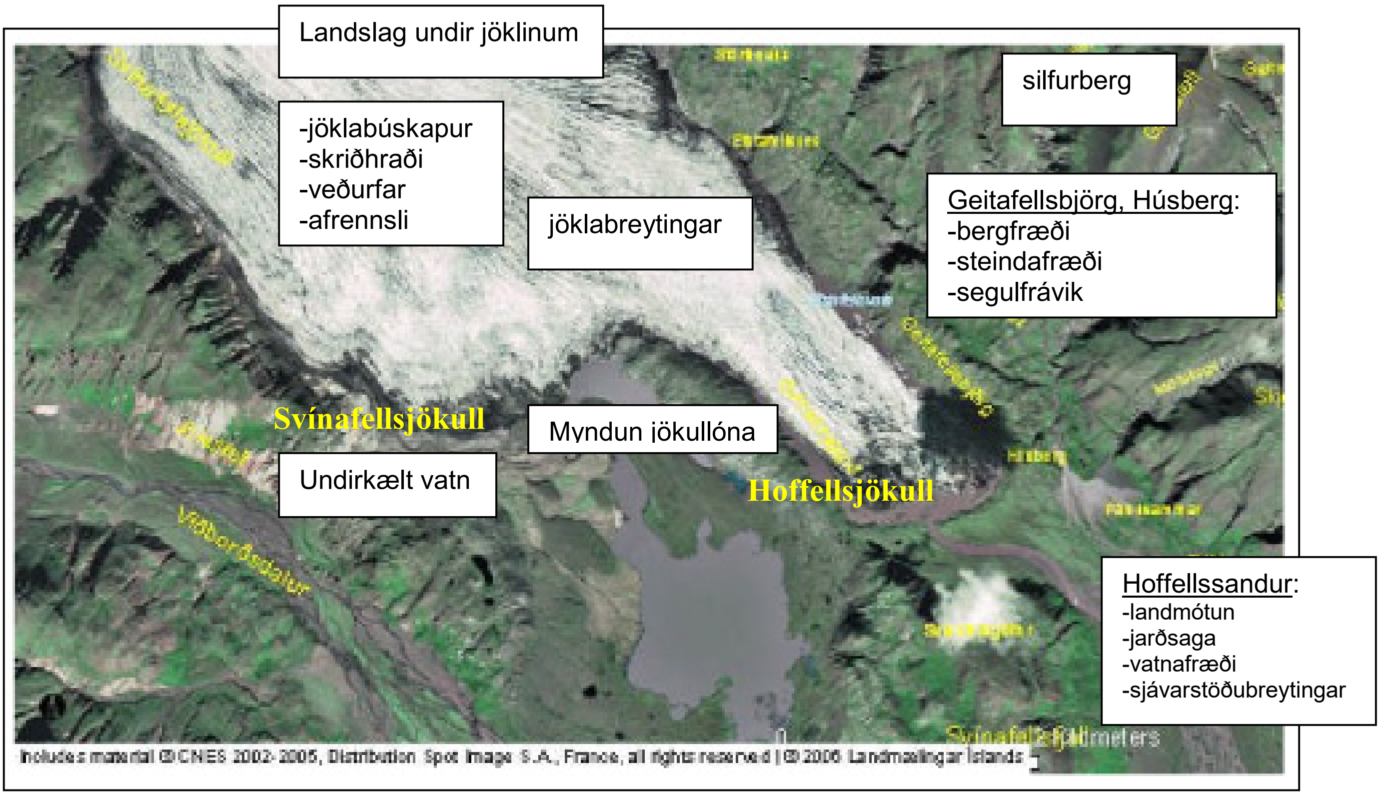
Fig. 1. Geomorphological sketch of Fláajökull marginal zone based on a stereoscopic pair of aerial photographs from 1989: A – situation from 1989, B – simplified situation after spring 2001; 1 – crevasses on glacier surface, 2 – glacier surface covered supraglacial debris, 3 – moraine ridges, 4 – ground moraine, 5 – channels of current rivers, 6 – abandoned beds of proglacial outflow, 7 – former traces of sandur outflow, 8 – alluvial cones, 9 – lakes, 10 – outcrops of bedrock, 11 – *Hólmsárgarð* profile along which the research was conducted.

Mynd 29: Landmótunarkort: jökulminjar við sporð Fláajökuls A = árið 1989; B = vorið 2001 (úr Molewski 2005).

4- Landslag undir jöklinum

Helgi Björnsson og aðrir hafa rannsakað rof af völdum jökla og kannað landslagið undir Vatnajökli og skriðjöklunum sem teygja sig niður frá honum, þ.a.m. Fláajökli.

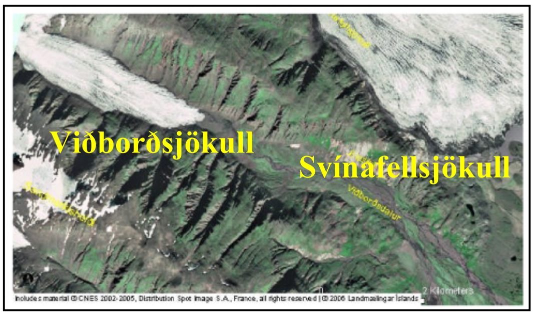
3.25 Viðborðsjökull, Svínafellsjökull í Nesjum, Hoffellsjökull, Hoffellssandur, Geitafell



Viðborðsjökull

Engar heimildir fundust um Viðborðsjökul. Engar sporðmælingar virðast hafa verið gerðar.

Svínafellsjökull í Nesjum



Svínafellsjökull og Hoffellsjökull eru kvíslar af sama jöklinum. Vestari kvíslin er kölluð Svínafellsjökull og austari kvísl heitir Hoffelsjökull. Lítið fell, Öldutangi skilur jökularmana að. Báðir jökularmarnir hafa verið mældir reglulega. Árið 1930 voru nokkrir skriðjöklar í Austur-Skaftafellssýslu, þ.a.m. Svínafellsjökull, skoðaðir og mældir (Eiríksson 1932). Helgi Björnsson og aðrir hafa rannsakað rof af völdum jökla og kannað landslagið undir Svínafells- og Hoffelsjökli. (sjá mynd 30). Um 1890 gekk Svínafelllsjökull lengra fram en Hoffellsjökull en Svínafellsjökull hefur hopað miklu meira en Hoffellsjökull og er nú miklu stytttri. Fáir jökulsporðar hafa hopað jafnmikið og Svínafellsjökull. Á árabilinu 1930-1992 nam það 2,6 km og við jökulsporðinn hefur myndast geisistórt lón.

Hoffellsjökull

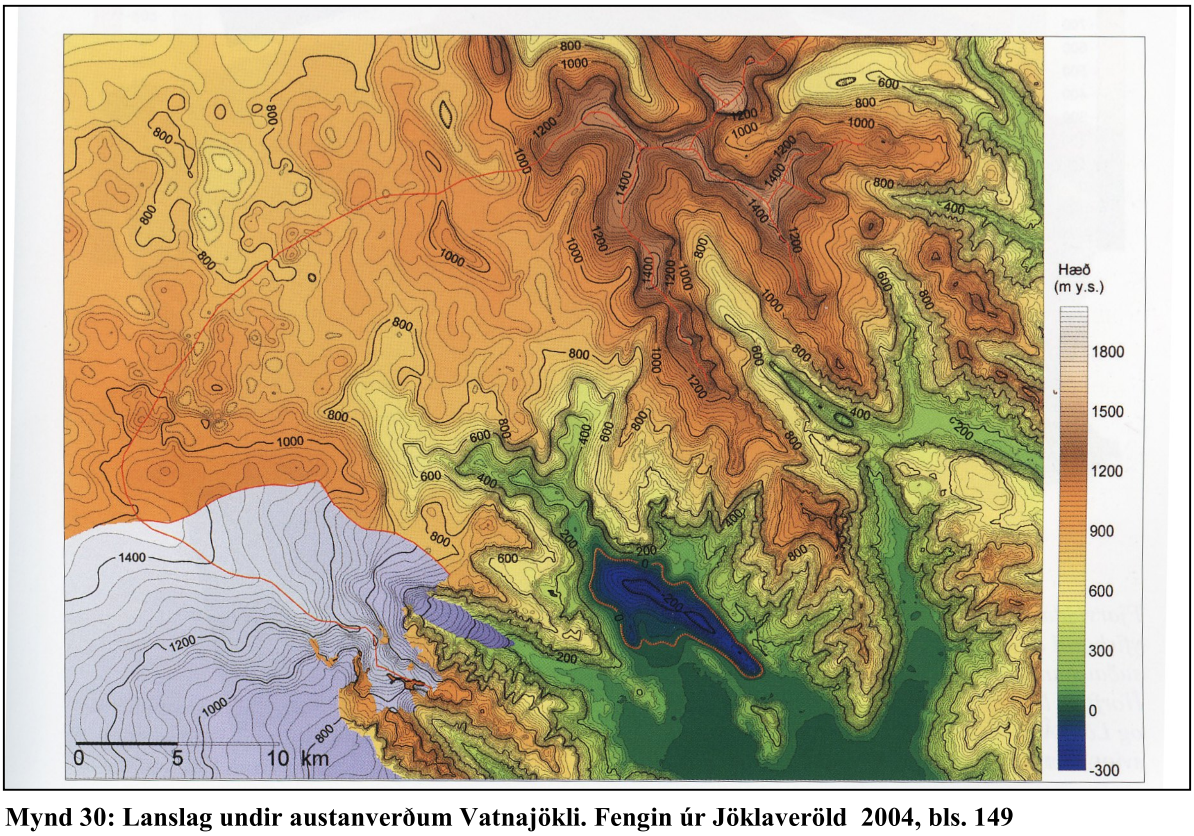
Sænskir vísindamenn hafa sýnt Hoffellsjökli mikinn áhuga. Hans W:sson Ahlmann skipulagði með aðstoð Sigurðar Þórarinssonar nokkra sænsk-íslenska rannsóknaleiðangra á Hoffellsjökul árin 1938, 1939 og 1940 og gerði athuganir á jöklabúskap (ákomu og leysingu), veðurfari, skriðhraða, áhrif sem úrkoma og hiti hafa á jöklabúskap og afrennsli. Árið 1952 skoðaði Svíinn Gunnar Hoppe nokkra skriðjökla á Suðausturlandi, þ.a.m. Hoffellsjökul, og árið 1955 rannsakaði Svíinn L. Arnborg jaðarlónin við Hoffellsjökul. T. Ebert rannsakaði undirkælt vatn við Hoffellsjökul og greindi frá niðurstöðum sínum í meistararitgerð (Ebert 2003).

Hoffellssandur
Í jökulgarðinum framan við Hoffellsjökul hafa leifar af sjávardýrum fundist og í Hoffellssandi voru 7000 ára gamlar rostungstennur uppgötvaðar. Bendir þetta til þess að sjórinn hafi um tímabil náð langt inn í land. Hoffellsandur hefur verið rannsakaður mjög vel. Svíarnir F. Hjulström og Å.Sundborg hafa ásamt Jóni Jónssyni skipulagt tvo rannsóknaleiðangra til að kanna sandinn. Þeir kortlögðu sandinn með tilliti til landmótunar og rannsökuðu m.a. jarðsögu Hoffellsands, jökulberg, veðurfar, vatnafræði Austurfljóta, sjávarstöðubreytingar og myndun jökullóna.

Geitafell
Hvergi á landinu má finna jafn mikið af stórum djúpbergsinnskotum á yfirborði eins og á Suðausturlandi. Þessi innskot hafa myndast á töluverðu dýpi og ástæða fyrir því að þau sjást núna er að (ísaldar)jöklar hafa rofið burt jarðlögin sem áður huldu þau. Djúpberg finnst helst í rótum (fornra) megineldstöðva, eins og Geitafellseldstöð. Gabbró-innskot sem tengjast Geitafellseldstöð má finna í klettahryggjum austan við Hoffellsjökul (Geitafellsbjörgum og Húsbergi) og í vestanverðum Viðborðsdal. Nokkrir vísindamenn hafa rannsakað bergfræði og steindafræði Geitafellseldstöðvar og segulfrávik við gabbró-innskot (m.a. Annels 1967, Schönhärting 1978, Friðleifsson 1983 og 2004).

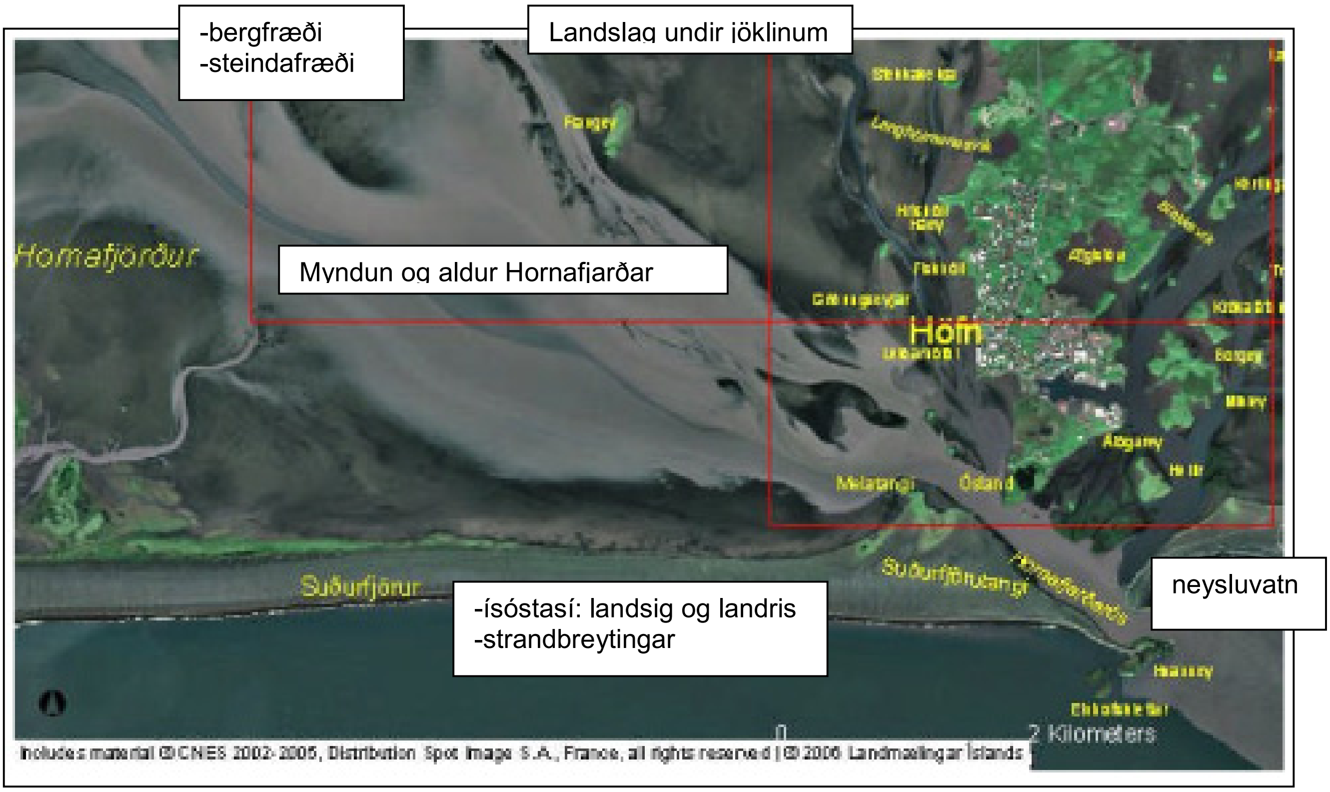
Silfurberg
Í Hoffelsfjöllum fannst silfurberg og þar var um tímabil stundað silfurbergsnám. Greinar um silfurbergið í Hoffelli hafa birst í Náttúrufræðingnum og Skaftafellingi (Þórðarson 1945; Gísladóttir 2004)

Jarðlagafræði, gróður og loftslag
Rússneskir vísindamenn undir handleiðslu M.A. Akhmetiev rannsökuðu jarðlagafræði, gróður og loftslag á Íslandi á Nýlífsöld (Akhmetiev 1978, 1991)

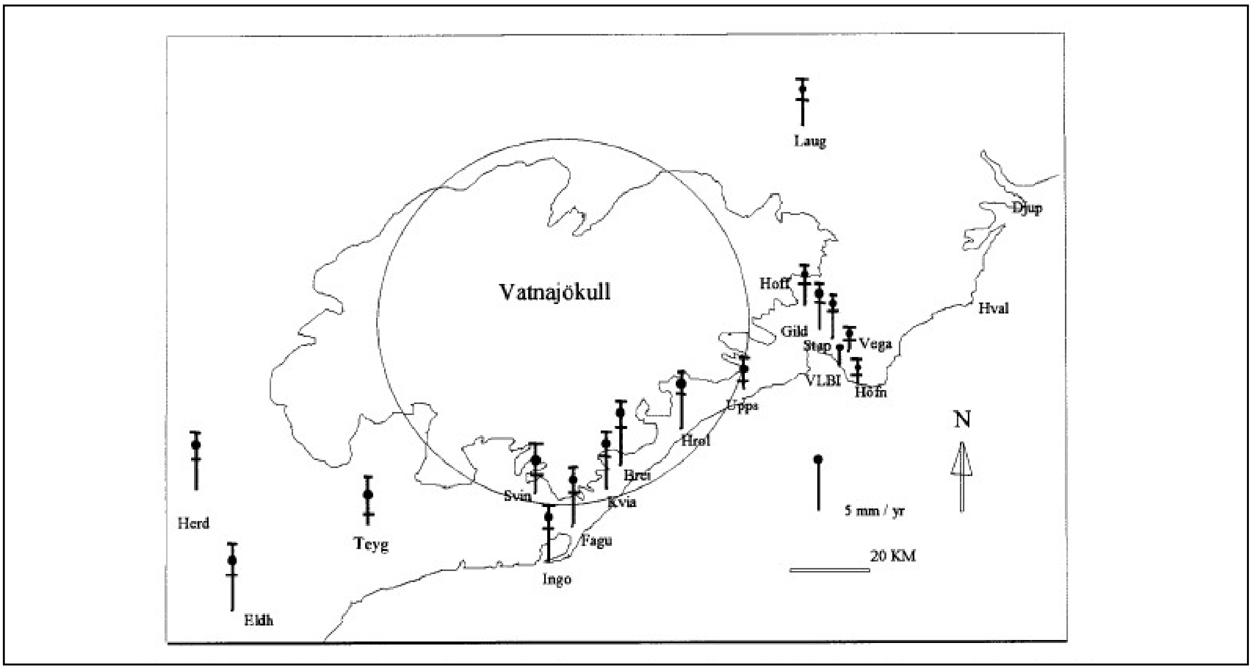


Mynd 30: Lanslag undir austanverðum Vatnajökli. Fengin úr Jöklaveröld 2004, bls. 149

3.26 Höfn, Hornafjörður



Jarðskorpan sígur niður undan þyngð jökulfargs. Þegar jöklar stækka sígur jarðskorpan (”landsig”) en um leið og jöklar fara að bráðna og farginu léttir af lyftist hún (”landris”). Bráðnun jökla veldur auk þess breytingum á sjávarborði. Á þessari og síðasti öld hefur Vatnajökull minnkað, jökulfarginu hefur létt af landinu og það hefur risið, allt að einum metra á jaðri jökulsins og 0,5 metra í Hornafirði. Landris lýsir sér í breytingum á fjörum, leirum og votlendissvæðum og innsiglingsleiðin um Hornafjarðarós hefur grynnkað. Þessar breytingar hafa valdið Hornfirðingum áhyggjur og hafa þeir skipulagt þrjár ráðstefnur (árin 1990, 1994 og 2005) um hafnarmannvirki og innsiglingar, strandbreytingar, landris o.fl. Árið 1997 var haldin spástefna um framtíð byggðar.



Mynd 31: Áætlað landris (innan skekkjumarka) í grennd við Vatnajökul milli 1992-1996. Fengið úr Sjöberg (2000)

Flestar rannsóknir sem hafa verið gerðar í Hornafirði tengjast því ”ísóstasí” (landrisi og landsigi í kjölfar jöklabreytinga), sjávarstöðubreytingum og breytingum á strandlínum (Páll Imsland 1986, 1990, 1992, 1994, 1997, 2004 og 2005; G. Viggóson et al. 1993; L.E. Sjöberg et al. 2000); C. Pagli, et al. 2005). Mynd 31 sýnir áætlað landris í grennd við Vatnajökul milli 1992-1996.

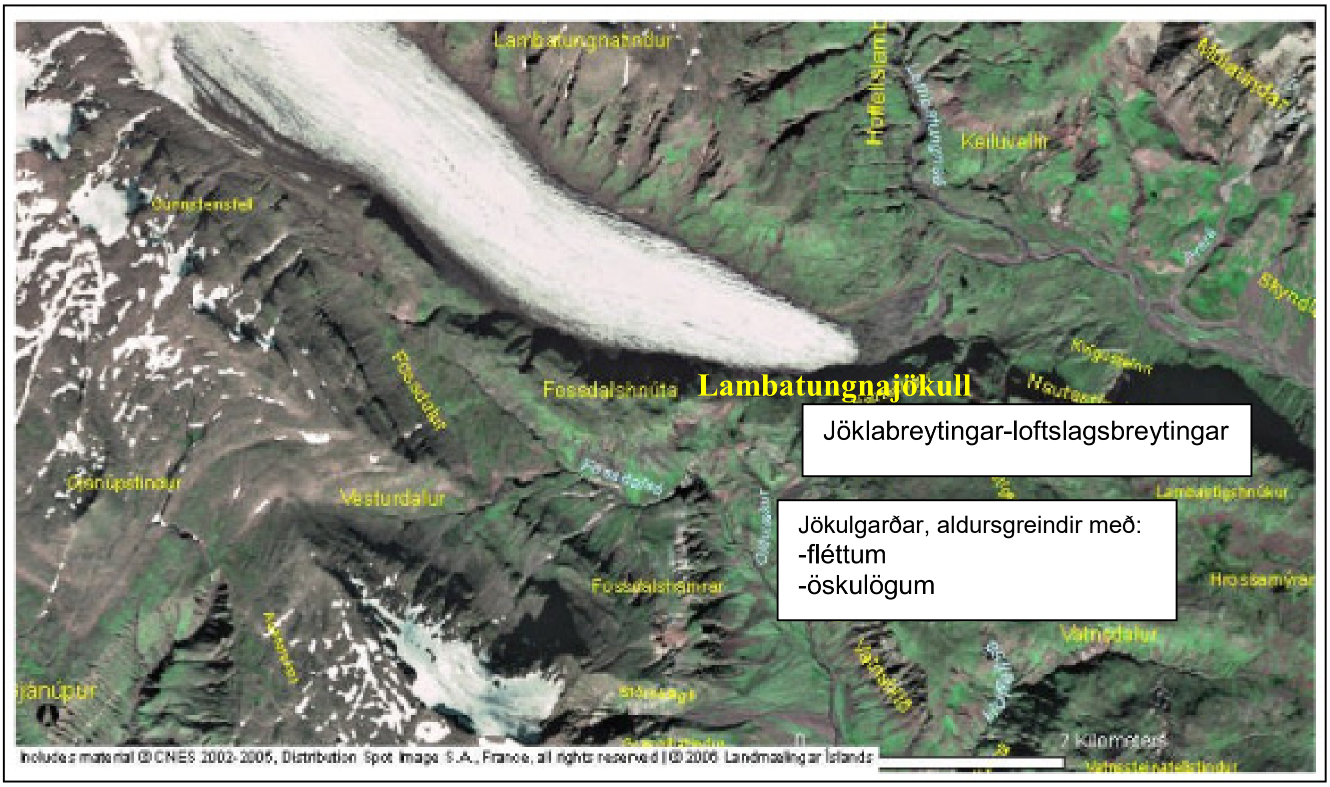
Aðrar rannsóknir hafa beinst að myndun og aldri Hornafjarðar (Sigbjarnarson 1997, Imsland 2005).

E.A. Annels frá Háskólanum í London skrifaði árið 1967 doktorsritgerð um ”jarðfræði Hornafjarðar”. Í ritgerð sinni lýsti hann aðallega gerð og uppruna bergs (bergfæði) og gerð steinda í því (steindafræði).

Helgi Björnsson og aðrir hafa rannsakað rof af völdum jökla og kannað landslagið undir Vatnajökli og skriðjöklunum sem teygja sig niður frá honum.

Árið 1974 gerði E. Gunnlaugsson könnun á neysluvatni í Hornafirði.

3.27 Lambatungnajökull



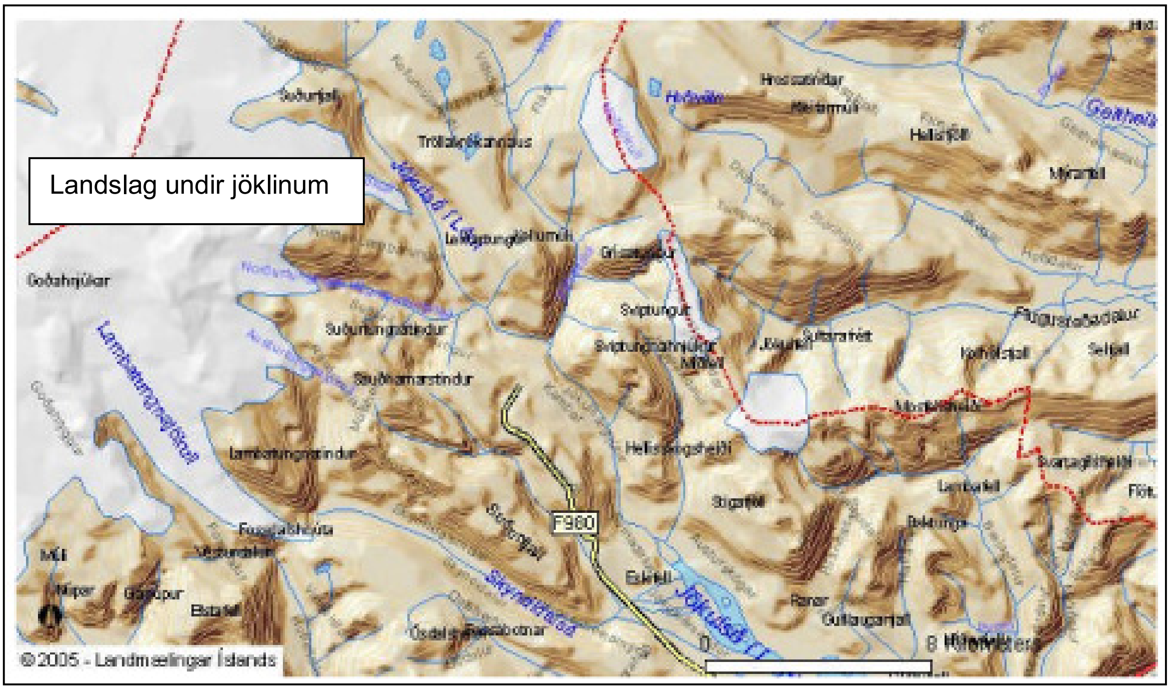
Lambatungnajökull er aðgengilegastur austurjöklanna og best rannsakaður. Þórður Þorkelsson Vídalín (1661-1742) sem bjó um skeið í Þórisdal skrifaði ritgerð um rannsóknir sínar á þessum skriðjökli. Telst hún vera eitt elsta vísindarit um jökla.

Hoffellsdalsjökull var hluti af Lambatungnajökli. Sporður hans hefur verið mældur á þremur stöðum á stuttu tímabili milli 1930-1940.

Árið 1952 rannsakaði Svíinn Gunnar Hoppe ásamt Jóni Jónssyni jökulminjar, sérstaklega jökulruðning, við jaðar Lambatungnajökuls.

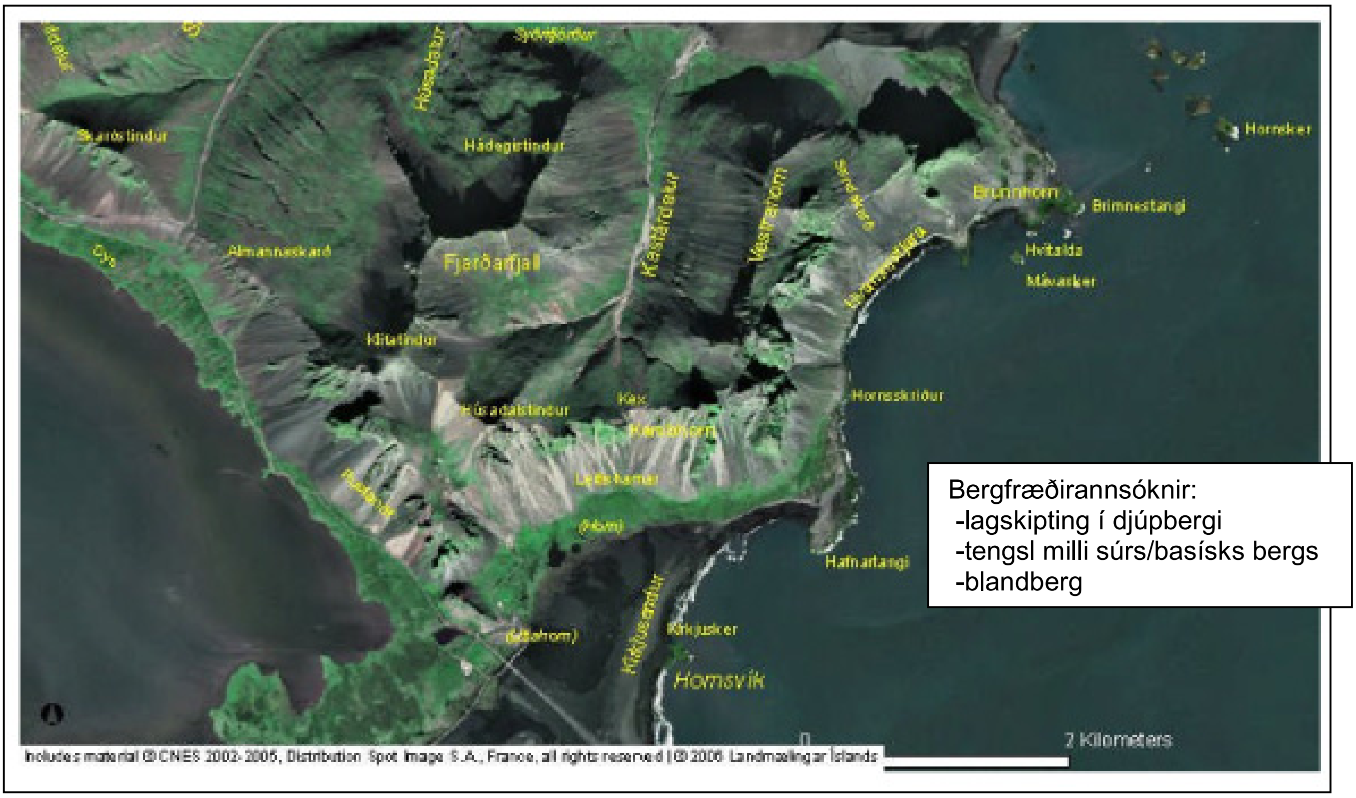
Á árunum 2004-2006 könnuðu Tom Bradwell, Andrew Dugmore and David Sugden jökulgarða við Lambatungnajökul. Þeir rannsökuðu hvort það væri hægt að finna samband milli jöklabreytinga Lambatungnajökuls í lok Hólósens og loftslagsbreytinga. Þeir notuðu upplýsingar um landmótun til þess að rekja jöklabreytingar og aldursgreindu jökulminjar, þ.a.m. jökulgarða með fléttum og öskulögum. Niðurstöður úr þessum rannsóknir voru notaðar til að ákveða hvenær Litla Ísöldin hafði náð hámarki sínu á Suðausturlandi (Bradwell 2004; Bradwell, Dugmore og Sugden 2006).

3.28 Austurtungnajökull, Norðurtungnajökull, Axarfellsjökull, Vesturdalsjökull



Skriðjöklarnir sem teygja sig niður frá austanverðum Vatnajökli hafa mjög lítið verið rannsakaðir, sökum erfiðs aðgengis. Ekki hafa verið gerðar jökulsporðamælingar á þessum jöklum en Helgi Björnsson og aðrir jöklafræðingar á vegum Raunvísindastofnun Háskóla Íslands eru að kanna landslagið undir jöklunum.

3.29 Vestrahorn

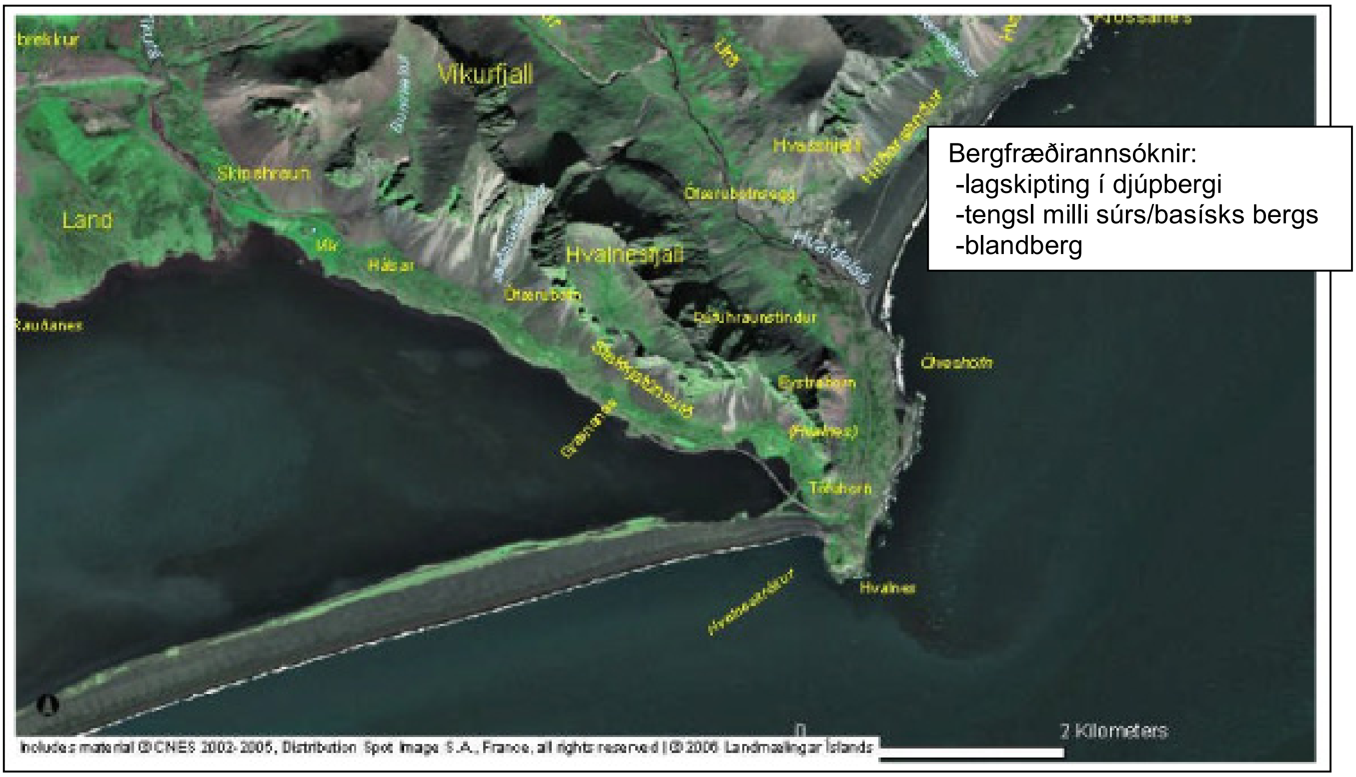


Hvergi á landinu má finna jafn mikið af stórum djúpbergsinnskotum á yfirborði eins og á Suðausturlandi. Djúpberg finnst helst í rótum (fornra) megineldstöðva og er Vestrahorn ein af þeim. Vestrahorn er að miklu leyti úr gabbró og granófýr. Fjallið telst vera “berghleifur”, þ.e.a.s. stærsta gerð af innskotum og er hluti af fornu kvikuhólfi (Jarðfræðilykill, bls. 29). Bergið er lagskipt, vegna þess að efnasamsetning kvikunnar hefur breyst töluvert á meðan storkunin átti sér stað.

Í Vestrahorni má finna súrt berg, basískt berg og blanda af þeim. Nokkrir vísindamenn hafa kannað tengslin milli súrs og basísks bergs í Vestrahorni og blandbergið sem hefur myndast.

Djúpbergsinnskotin á Suðausturlandi vöktu athygli breskra vísindamanna og komu nokkrar þeirra til að rannsaka lagskiptingu í gabbrói eða tengslin milli súrs og basísks bergs í Vestrahorni (m.a. Cargill 1928; Blake 1965; Roobol 1969,1974; Thomadsen, Tegner og aðrir 2004).

3.30 Eystrahorn

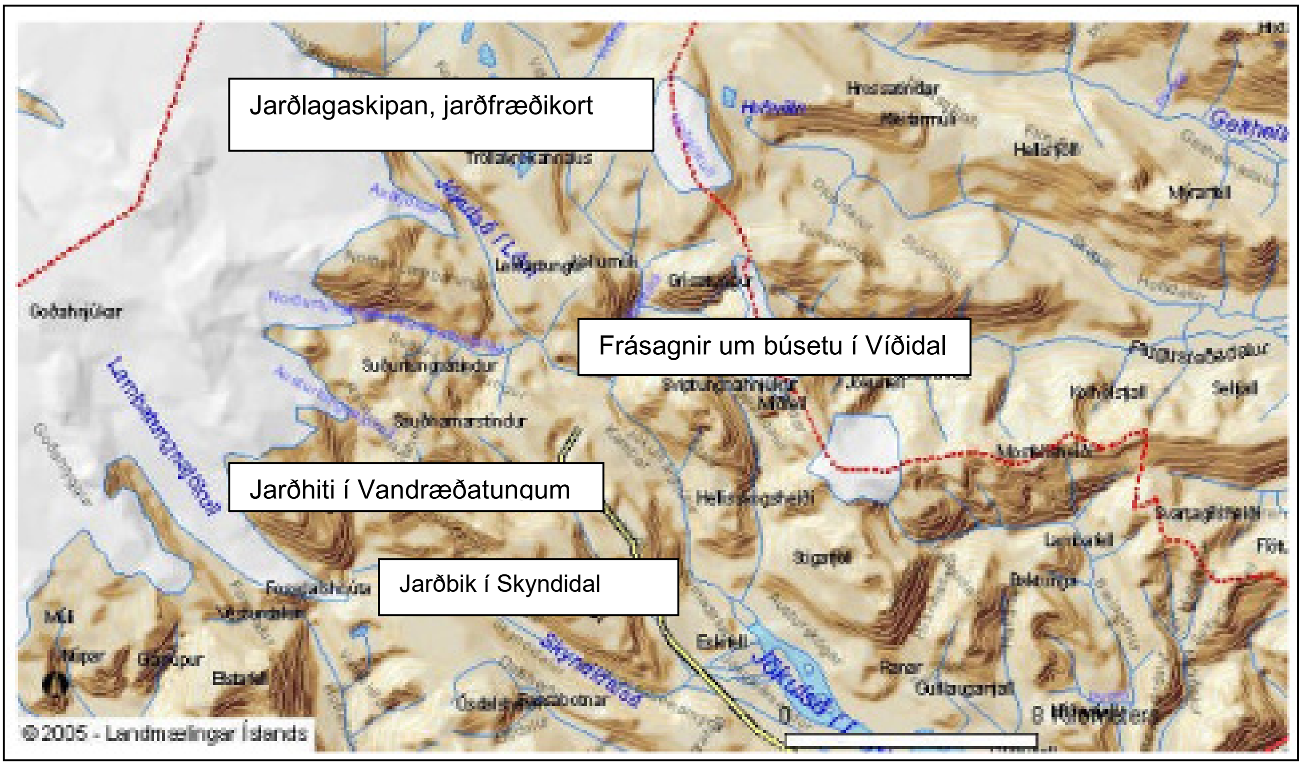


Eystrahorn er eins og Geitafell og Vestrahorn forn megineldstöð. Fjallið er svokallaður berghleifur, tiltölulega stórt djúpbergsinnskot sem samanstendur af lagskiptu gabbrói, granófýr og "blandbergi".

Breskir vísindamenn (Cargill 1928, Blake 1964/1966, Mattson 1986, Thomadsen, Tegner og aðrir 2004) hafa rannsakað bergfræði Eystrahorns ítarlega og hafa rannsóknir þeirra aðallega beinst að tvennu:

-lagskipting djúpbergs
-tengsl milli súrs og basísks bergs

3.31 Lónsöræfi



Jarðfræði Lónsöræfa hefur verið rannsökuð ítarlega af Helga Torfasyni, sem skrifaði árið 1979 doktorsritgerð við Háskóla í Liverpool um jarðlagaskipan og höggun á Suðausturlandi (Torfason 1979).

Árið 1985 fannst jarðbik í holufyllingum í Skyndidal. Talið er að jarðbikið hafi myndast þegar berggangur hafi skotist inn í surtarbrandsæð og snögghitað hana. Um þennan merkilega fund birtust nokkrar greinar, í Náttúrufræðingnum (Sveinn Jakobsson & Guðmundur Ó. Friðleifsson 1989) og í tímaritinu Týli (N.N. 1985).

Þó að lítið sé um jarðhita á Suðausturlandi, hefur jarðhiti fundist á illaðgengilegum stað í Hoffellslambatungum, Vandræðatungum (Jón Jónsson 1977)

Þórður Þorkelsson Víðalín í Þórisdal, samdi fyrsta vísindarit um íslenska jökla . Hann reyndi að finna út hvað olli myndun skriðjökla og studdist m.a. við athuganir sínar á Lambatungnajökli.

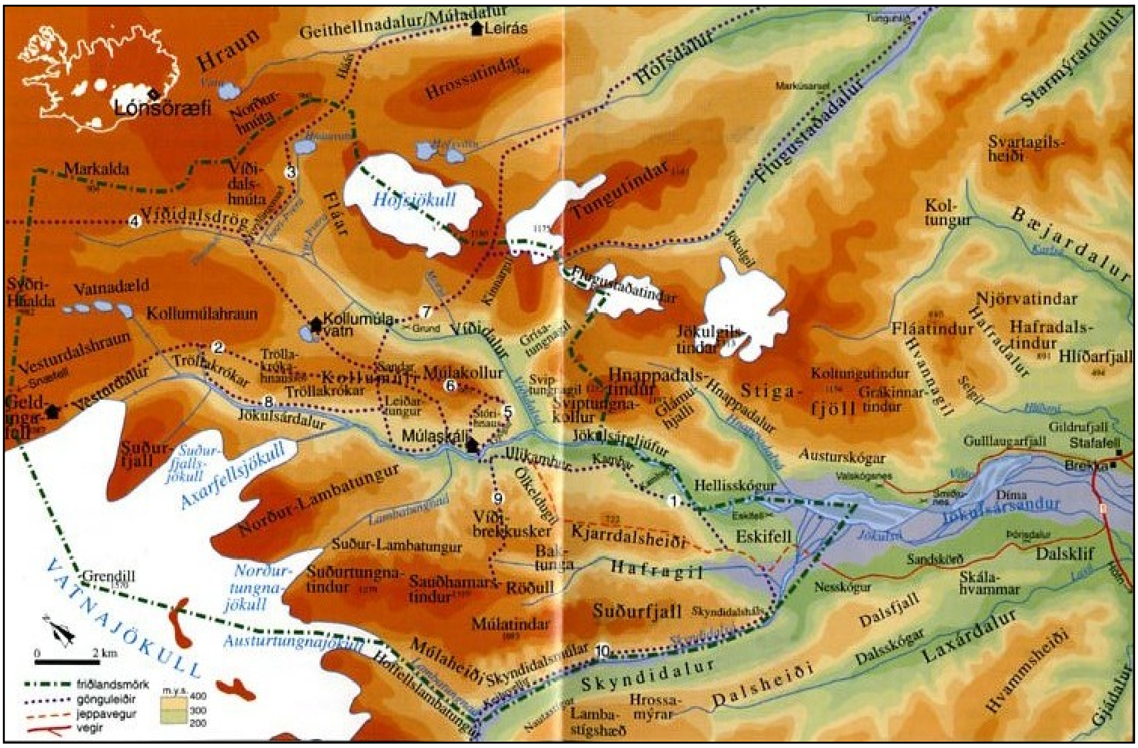
Náttúrufræðingurinn Þorvaldur Thoroddsen ferðaðist árin 1882 og 1894 um svæðið og lýsti gróðurfar og jarðfræði þess í ferðabók sinni.

Á tímabilinu 1835-1897 var búið í Grund í Víðidal. Mikil er til af frásögnum um búsetu í dalnum og í þeim má finna greinargóðar lýsingar á búskaparhættum og landslaginu íVíðidal og nágrenni.

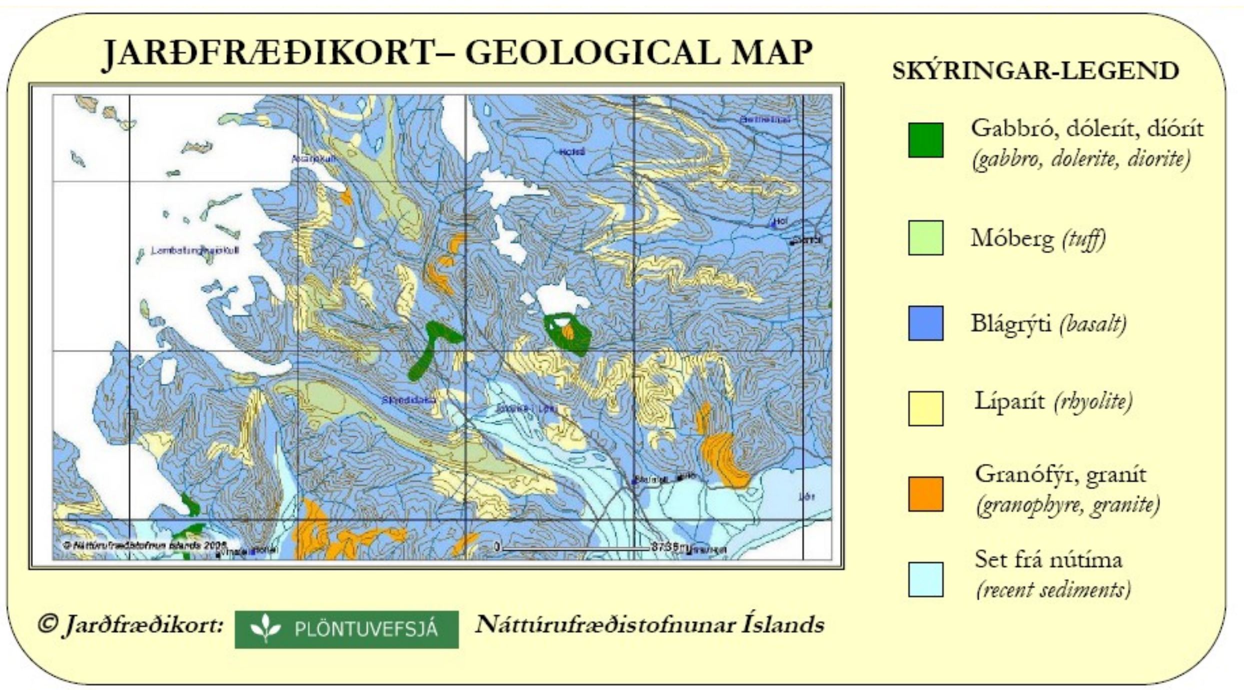
Árið 2003 var unnið rannsóknarverkefni “Þolmörk ferðamennsku í friðlandinu á Lónsöræfum” sem hafði það markmið að skoða hvaða áhrif fjölgun ferðamanna hefur á umhverfi og samfélag nokkurra ferðamannastaða (Anna Dóra Sæþórsdóttir 2003).

Árið 1996 gaf Umhverfisstofnun út bækling um friðlandið í Lónsöræfum með upplýsingum um sögu, jarðfræði, gróður, fuglalíf og gönguleiðir í friðlandinu (sjá mynd 32).

Mál og Menning hefur gefið út sérkort “Lónsöræfi. Stafafell-Berufjörður” 1:100.000 með upplýsingum um gönguleiðir í Lónsöræfum. Á bakhliðinni er gott jarðfræðikort eftir Helga Torfason, sem sýnir jarðfræði Kollumúlaeldstöðvarinnar. Svipað kort má finna á Plöntuvefsjá Náttúrufræðistofnun Íslands (http://www.ni.is; sjá mynd 33).

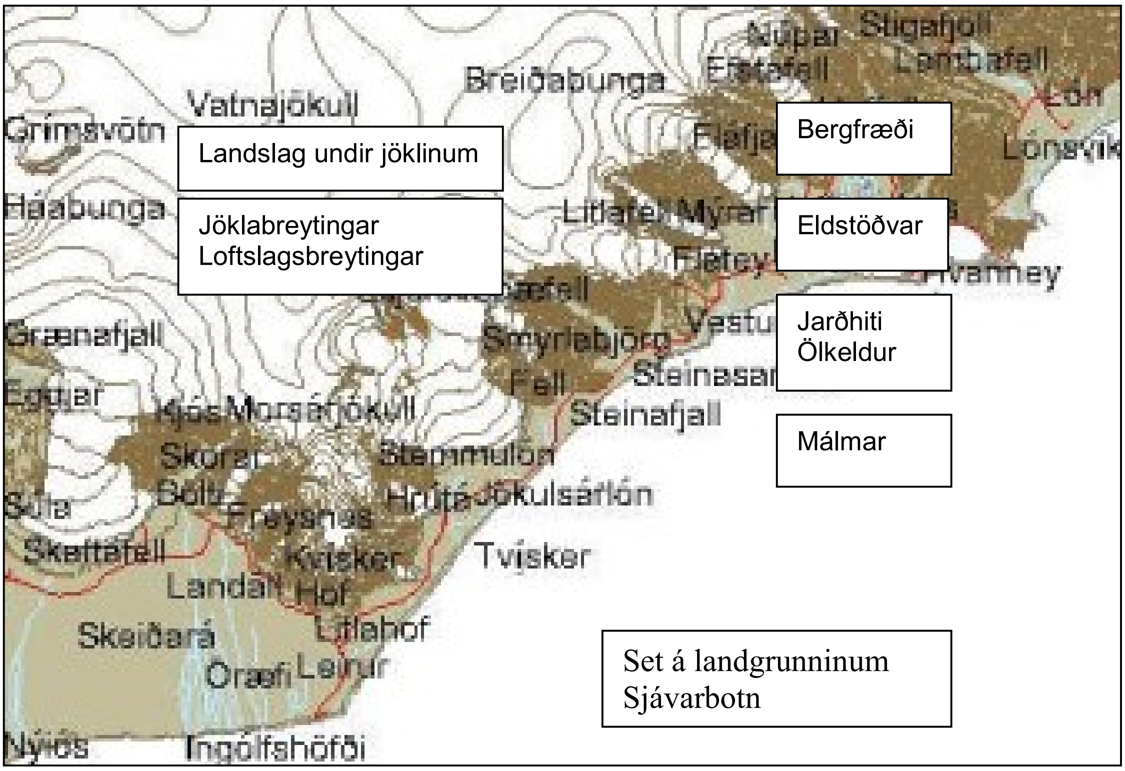


Mynd 32: Gönguleiðir í Lónsöræfum (úr bækling UST 2004).



Mynd 33: Jarðfræðikort af Kollumúlaeldstöð (Plöntuvefsjá Náttúrfræðistofnun Íslands).

3.32 Suðausturland



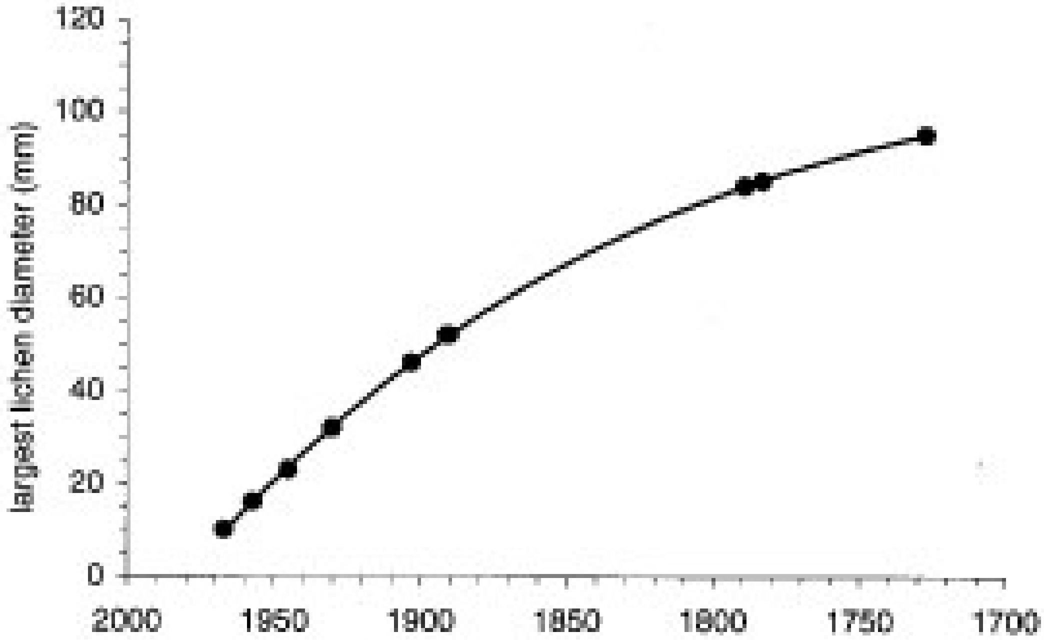
Nokkrar rannsóknir ná yfir allt Suðausturland. Má skipta þessum rannsóknum í eftirfarandi flokka:

1- landslag undir jöklinum
2- jöklabreytingar og loftslagsbreytingar í gegnum tíðina
3- bergfræði, með áherslu á djúpbergsinnskotum
4- lögun sjávarbotns og set á landgrunninu suðaustan Íslands
5- leit að hagnýtum málmum
6- yfirlit yfir jarðhita og ölkeldur
7- yfirlit yfir eldstöðvar

1- landslag undir jöklinum
Helgi Björnsson og aðrir hafa rannsakað rof af völdum jökla og kannað landslagið undir Vatnajökli og skriðjöklunum sem teygja sig niður frá honum. Árið 1994 hélt Helgi Björnsson erindi um rof af völdum jökla og landslagi undir sunnanverðum Vatnajökli á ráðstefnu um strandrof og strandvarnir sem var haldin á Höfn í Hornafirði (Björnsson 1994).

2- jöklabreytingar og loftslagsbreytingar í gegnum tíðina
Nokkrir vísindamen hafa rannsakað framskrið og hop skriðjökla á Suðausturlandi í gegnum tíðina. Sumarið 1930 voru nokkrir skriðjöklar í Austur-Skaftafellssýslu skoðaðir og mældir (Eiríksson 1932). Í nokkrum ítarlegum greinum hefur Jack Ives lýst loftslagsbreytingum og áhrifum þeirra á skriðjökla á Suðausturlandi undanfarin tvö árþúsund (Ives 1994-1996). Hópur breskra vísindamanna, T. Bradwell, J.F. Orwin og K.M.McKinzey, hafa aldursgreint jökulminjar (aðallega jökulgarða) við sporð skriðjökla með fléttum til að fá upplýsingar um hop og framskrið jöklanna. Þeir hafa búið til tímatal um jöklabreytingar, tímasett Litlu Ísöldina og ákveðið útbreiðslu hennar á Suðausturlandi (Bradwell 2001, 2004; Orwin og McKinzey óútgefin grein). Bradwell hefur teiknað línurit sem sýnir hvernig fléttustærð tengist aldri jökulminja á Suðausturlandi (sjá mynd 34). Guðmundur Ómar Friðleifsson

hefur tekið saman upplýsingar um útbreiðslu jökla á Suðausturlandi á Míósen (síðtertíer) og birt niðurstöðurnar í ítarlegri grein (Friðleifsson 1995).



Mynd 34: Línurit sem sýnir hvernig fléttustærð tengist aldri jökulminja á Suðausturlandi (Bradwell 2001, bls.

3- bergfræði, með áherslu á djúpbergsinnskotum
Á Sauðausturlandi má finna óvenju mörg djúpbergsinnskot (m.a. gabbró, granófýr) í rótum útkulnaðra megineldstöðva. Sérstaklega hafa breskir vísindamenn sýnt þessum djúpbergsinnskotunum mikinn áhuga. Aðallega tvennt hefur vakið athygli þeirra; lagskipting djúpbergs og náin tengsl milli súrs og basísks bergs í djúpbergsinnskotum. Á áttundi áratugnum hafa G.P.L. Walker og (doktors)nemendur hans gert ítarlegar rannsóknir á bergfræði (Suð)austurlands og kannað ummerki um landrek (Anderson 1949; Tyrell 1949; Blake 1965, 1968; Gale and Moorbath 1966; Johnson 1968; Roobol 1971, 1972; Ward 1978-1979). Helgi Torfason rannsakaði jarðfræði Suðausturlands ítarlega og skrifaði árið 1979 doktorsritgerð við Háskóla í Liverpool um bergfræði og jarðlagaskipan á Suðausturlandi. Hann teiknaði einnig jarðfræðikort af Suðausturlandi (Torfason 1979). Daninn M.B. Klausen kannaði aðallega halla og þykkt berggangna í gangaþyrpingum sem tengjast fornum eldstöðvum á Suðausturlandi (Klausen 2006).

4- lögun sjávarbotns og set á landgrunninu suðaustan Íslands
Landgrunn suðaustan Íslands einkennist af djúpum jökulgröfnum dölum. J.K. Hartsock og H. Hafliðason hafa rannsakað landgrunn við suðausturströnd Íslands og setlög á sjávarbotninum (Hartsock 1960; Hafliðason 1979).

5- leit að hagnýtum málmum
Árið 1970 skipulagði Rannsóknarráð Íslands leit að hagnýtum málmum á Suðausturlandi. Júgóslavinn Slobodan Janković var ráðinn í verkið og skrifaði nokkrar skýrslur um rannsóknir sínar (Janković 1970).

6- yfirlit yfir jarðhita og ölkeldur
Suðausturland telst vera eitt af svokölluðum “köldum svæðum” landsins. Ekki finnst mikill jarðhiti á yfirborðinu. Samt koma heitar uppsprettur og ölkeldur fyrir á nokkrum stöðum. Jón Jónsson gerði árið 1981 fyrir Orkustofnun samantekt á jarðhita og ölkeldum “í Skaftafellsþingi” (Jónsson 1981).

7- yfirlit yfir eldstöðvar

Jón Jónsson gerði árið 1979 samantekt á eldstöðvum "í Skaftafellsþingi" (Jónsson 1979).

II: heimildir flokkaðar eftir landssvæðum

4. Heimildir, flokkaðar eftir landssvæðum

4.1 Jökulröndin og jaðarsvæði

4.1.1 Skeiðará, Skeiðarársandur, Skeiðarárjökull

Alsdorf, D.E., and Smith, L.C. (1999) "Interferometric SAR observations of ice topography and velocity changes related to the 1996, Gjálp subglacial eruption, Iceland": International Journal of Remote Sensing, v. **20**(15-16): p. 3031-3050.

A major volcanic eruption beneath the Vatnajökull ice cap from 30 September to 13 October 1996 melted up to 500m of overlying ice and produced 3.5km(3) of water that was later released catastrophically onto the Skeiðarársandur outwash plain. Here, we present pre- and post-event topography and velocity field maps of the ice cap surface derived from ERS-1/2 synthetic aperture radar (SAR) interferometry. Within the errors of this method our results reveal local topographic and ice flow variations near the eruption site and incision of a 140m meltwater trench. A 24-hour, 50cm subsidence of the frozen surface of the Grimsvötn caldera lake was also detected. However, despite the large increases in geothermal heat flux and basal meltwater availability associated with this event, there appears to be no regional-scale ice subsidence and little to no alteration in flow dynamics of the Vatnajökull ice cap.

Áskelsson, J. (1959) "Skeiðarárhlaupið og umbrotin í Grímsvötnum": Jökull, v. **9**: p. 22-29.

Benediktsson, S., and Helgadóttir, S. (1997) Skeiðarárhlaup: Reykjavík, Náttúruverndarráð.

Bennett, M.R., Huddart, D., and Waller, R.I. (2000) "Glaciofluvial crevasse and conduit fills as indicators of supraglacial dewatering during a surge, Skeiðarárjökull, Iceland": Journal of Glaciology, v. **46**: p. 25-34.

Björnsson, F. (1959) "Skipsstrandið við Skeiðarársand árið 1667": Heima er best, v. **9. árg.**(4. tbl.): p. 121-123.

Björnsson, H. (1975) "Subglacial water reservoirs, jökulhlaups and volcanic eruptions": Jökull, v. **25**: p. 1-14.

Water may accumulate in a reservoir that forms beneath a depression in a glacier surface. The water reservoir will grow unstable. The accumulation will cause a jökulhlaup from the reservoir. Water may also accumulate beneath a slightly inclined or a convex glacier surface. The reservoir will remain stable. A jökulhlaup will not result under these conditions. A depression in the glacier surface may be created by melting above a permanent geothermal area. The depression at Grímsvötn in Vatnajökull is a well known example. Jökulhlaups at Skeiðarársandur originate at Grimsvötn. An ice cauldron which is situated 10 km north-west of Grímsvötn is an other example. Jökulhlaups in the river Skaftá drain from a reservoir, which is situated beneath the ice cauldron.

A depression may also be created by a subglacial volcanic eruption. The eruption will cause considerable subglacial melting. A depression is formed in the glacier surface if the meltwater drains towards the glacier rivers. The subglacial waterways around the depression may become sealed. Meltwater would then be trapped beneath the depression. A dome-shaped subglacial water reservoir will be formed at the bed of the glacier. Jökulhlaups will occur from the reservoir. Pillow lava and hyaloclastic materials are piled up within such a reservoir during subglacial volcanic eruptions.

— (1998) "Hydrological characteristics of the drainage system beneath a surging glacier": Nature, v. **395**: p. 771-774.

A unique combination of natural circumstances allows us to assess current theories about water flow beneath glaciers. Outburst floods from the subglacial lake, Grímsvötn, have taken place before, during and subsequent to surging of Skeiðarárjökull, the glacier beneath which they drain. The observable drainage patterns associated with these floods show the different nature of the basal water conduit system of the glacier during surge and non-surge phases. During surge, basal water is dispersed slowly across the bed in a distributed drainage system; but when the glacier is not surging, water is transported rapidly through a system of tunnels.

Björnsson, H., and Einarsson, P. (1990) "Volcanoes beneath Vatnajökull, Iceland: Evidence from radio echo-sounding earthquakes and jökulhlaups": Jökull, v. **40**: p. 147-168.

Integration of knowledge of subglacial topography, earthquake activity and jökulhlaups has contributed to more precise locations of the volcanic systems beneath Vatnajökull. Bárðarbunga is the centre of a volcanic system which includes the fissure swarms of Veiðivötn to the SW and Dyngjuháls to the NE. The Grímsvötn volcano is the centre of a system that comprises the Laki fissure swarm in the SW and extends for an unknown distance to the NE of the volcano. Þórðarhyrna is probably a separate central volcano within this system. The Kverkfjöll system can be traced 10 km to the SW of the Kverkfjöll volcano. It appears to be separated from the Grímsvötn volcano. The Askja fissure swarm extends beneath Dyngjujökull and can possibly be traced to the Grímsvötn volcano. Hamarinn and the ridge striking eastward from Hamarinn (Loki Ridge) are central volcanoes which together with the Fögrufjöll fissure swarm form a volcanic system. No support can be found in the topographic data for the existence of a central volcano near Breiðabunga. Volcanic activity in historical times has mainly been limited to the Grímsvötn and Bárðarbunga systems. Major rifting events have affected large sections of these volcanic systems but both have been remarkably quiet for the past decades. A few volcanic events are presumed to have occurred on the Hamarinn - Loki system and on the Askja fissure swarm beneath Dyngjujökull, but no event is known with certainty on the Kverkfjöll system. The rivers Skeiðará and Súla have the most frequent eruption-related jökulhlaups. They receive meltwater from the Grímsvötn caldera and the area to the SW of it, including Þórðarhyrna. Núpsvötn, Djúpá and Hverfisfljót drain the southwestern part of the Grímsvötn system, an area bounded by Þórðarhyrna, Geirvörtur, Hágöngur and Pálsfjall. Skaftá drains the Loki Ridge and the area west of Grímsvötn. Jökulhlaups in Kaldakvísl, and ultimately Þjórsá, must originate in the Bárðarbunga or the Hamarinn - Loki systems, and the only possible source for volcanic jökulhlaups in Skjálfandafljót is the northern part of the Bárðarbunga system. Jökulsá á Fjöllum may drain meltwater from activity in all the volcanic systems in northern Vatnajökull: Bárðarbunga, the Askja fissure swarm and Kverkfjöll. This includes the voluminous, ice-filled calderas of Bárðarbunga and

Kverkfjöll. Activity in the northern part of the Grímsvötn system may cause floods in Jökulsá á Fjöllum. Meltwater from volcanic activity on the SE flank of a ridge that strikes south from Kverkfjöll may drain to Jökulsá á Brú. Volcanic activity farther north on the E flanks of this ridge would cause floods in Kreppa.

Björnsson, H., and Hallgrímsson, M. (1976) "Mælingar í Grímsvötnum við Skeiðarárhlaup 1972 og 1976": Jökull, v. **26**: p. 91-92.

Björnsson, H., and Kristmannsdóttir, H. (1984) "The Grímsvötn geothermal area, Vatnajökull, Iceland (Jarðhitasvæðið í Grímsvötnum)": Jökull, v. **34**: p. 25-50.

Melting of ice at the Grímsvötn geothermal area has created a depression in the surface of the ice cap Vatnajökull and produced a subglacial lake from which jökulhlaups drain to Skeiðarársandur. The geothermal activity is also expressed by small cauldrons on the surface of the ice as well as by fumaroles on two nunataks that rise 300 m above the lake level. Vapour from the fumaroles yields little information about the deep reservoir fluid. The vapour seeps upwards from the water table and repeatedly condenses and evaporates on the way to the surface. The chemistry of the water in jökulhlaups, however, provides information about the fluid in the geothermal system. This information is not easy to interpret because of water-rock interaction in the lake. Silica solubility data and assumptions about the likely reservoir temperature, however, indicate that about 15% of the total mass in the lake is fluid discharged from the geothermal reservoir. This information about the geothermal mass fraction together with mass and energy balances for the lake enables one to calculate the masses of water and steam discharged from the geothermal reservoir as well as the mass of ice melted in the lake. The steam mass fraction os estimated to be 20-35% when the fluid enters the lake. From this, new estimates of the thermal power of the geothermal system are obtained. The total thermal power of the system is 4700-4900 MW, of which 2100-2300 MW are transported by steam and the rest by water.

Grímsvötn is one of few geothermal areas where active volcanism is observed and where there is a direct interaction between magma and geothermal water. Evidence of volcanic activity was found in the water chemistry of the jökulhlaup in December 1983. The high content of sulphate and the presence of iron indicated eruption of magma into the geothermal fluid.

the nineteen-fifties jökulhlaups have occurred regularly at 4-6 year intervals when the lake level has risen up to a critical level required for draining water from the bottom of the lake. However, jökulhlaups may occur at lower water levels. In 1983 a jökulhlaup was triggered at a water level 20-30 m lower than the critical level. This jökulhlaup may have been triggered by the opening of waterways into the lake along the slopes of Grímsfjall, where increased geothermal or volcanic activity has melted ice in places. An odour of hydrogen sulphide was detected for two months on Skeiðarársandur before the jökulhlaup commenced. Sulphurous odour for long periods may warrant a forecast of such premature jökulhlaups.

Björnsson, H., Pálsson, F., and Magnússon, E. (1999) Skeiðarárjökull: landslag og rennslisleiðir vatns undir sporði, RH-11-99: Reykjavík, Raunvísindastofnun Háskólans, p. 20.

Björnsson, P. (1984) "Skeiðarársandur hækkar enn": Náttúrufræðingurinn, v. **54**(2.h.): p. 58.

Björnsson, S. (1972) "Blinda í fé af völdum Skeiðarárhlaups": Jökull, v. **22**: p. 95.

— (1972) "Þankabrot um Skeiðará": Náttúrufræðingurinn, v. **42**(1-2): p. 36-43.

— (1989) "Ferðir yfir Skeiðarársand": Skaftfellingur, v. **6. árg.**: p. 75-80.

— (1998) "Skeiðará og Skeiðarársandur": Skaftfellingur, v. **12**: p. 69-83.

— (1999) "Eldgos 1861": Skaftfellingur, v. **13**: p. 55-58.

— (2002) "Jökulleir og Skeiðarárhlaup": Skaftfellingur v. **15**: p. 129-132.

— (2003) "Aldagamlar athuganir": Skaftfellingur, v. **16**: p. 71-76.

Blöndal, S.B. (1997) "Á að láta menn álpast út í fenið? " Dagur-Tíminn,**42. tbl. 80.-81. árg.**(laugard. 1. mars 1997).

Viðtal Sigurðar B. Blöndals við P.I. um hættumálin á Skeiðarársandi

Brandsdóttir, B. (1984) "Seismic activity in Vatnajökull in 1900-1982 with special reference to Skeiðarárhlaups, Skaftárhlaups and Vatnajökull eruptions (Jarðskjálftar í Vatnajökli 1900-1982, tengsl þeirra við Skeiðarárhlaup, Skaftárhlaup og eldgos í jöklinum)": Jökull, v. **34**: p. 141-150.

Cassidy, N.J., Russell, A.J., Marren, P.M., Fay, H., Ó., K., Rushmer, E.L., and van Dijk, T.A.G.P. (2003) GPR-derived architecture of November 1996 jökulhlaup deposits, Skeiðarársandur, Iceland. 2003, *in* Bristow, C.S., and Jol, H.M., eds., Ground Penetrating Radar in Sedimentation: Special Publication of the Geological Society no. 211, Geological Society of London, p. 153-166.

Einarsson, Eyþór., and others (1987) Skaftafell og Öræfi : þættir um náttúru og sögu, Hið íslenska náttúrufræðifélag, 20 s.: myndir, kort p.

Eiríksson, J., and others (1994) Roadlog : Nordic geological excursion in Iceland : quaternary geology - glaciology Reykjavík, myndir, kort, línurit

Everest, J., and Bradwell, T. (2003) "Buried glacier ice in southern Iceland and its wider significance": Geomorphology, v. **52**(3-4): p. 347-358.

Geo-electrical resistivity surveys have been carried out at recently deglaciated sites in front of three glaciers in southern Iceland: Skeiðarárjökull, Hrútarjökull, and Virkisjökull. The results show the presence of old glacier ice beneath debris mantles of various thickness. We conclude that buried glacier ice has survived for at least 50 years at Virkisjökull and Hrútarjökull, and probably for over 200 years at Skeiðarárjökull. Additional data from a further site have identified a discontinuous ice core within 18th-century jokulhlaup deposits. Photographic and lichenometric evidence show that the overlying debris has been relatively stable, and hence melting of the ice at all four sites is proceeding slowly due to the heat-shielding properties of the overburden. The geomorphic implications are pertinent when considering the potential longevity of buried ice. The possible implications for dating techniques, such as lichenometry, radiocarbon dating and cosmogenic surface-exposure dating are also important, as long-term readjustments of surface forms may lead to dating inaccuracy. Finally, it is recognised that landscape development in areas of stagnant ice topography may post-date initial deglaciation by a considerable degree. (C) 2002 Elsevier Science B.V. All rights reserved.

Eyþórsson, J. (1934) "Skeiðarársandur hækkar : athuganir Helga Arasonar á Fagurhólsmýri": Náttúrufræðingurinn, v. **4**: p. 178-180.

— (1960) "Fyrir 500 árum var mómýri þar sem nú er Skeiðarárjökull": Veðrið, v. **5**: p. 14-16.

— (1960) Vatnajökull: Reykjavík, Almenna bókafélagið, 44 s., [62] mbls. : teikn., ritsýni, uppdr. p.

Fairchild, I.J., Tooth, A.F., and Russell, A.J. (1999) Chemical weathering of volcanogenic sediments, Skeiðarársandur, SE Iceland, *in* Ármannsson, H., ed., Geochemistry of the Earth's Surface. : Proceedings of the 5th International Symposium on Geochemistry of the Earth's Surface: Reykjavík, Iceland, Balkema Publishers, p. 91-94.

Fay, H. (2002) Formation of ice block obstacle marks during the November 1996 glacier-outburst flood (jökulhlaup), Skeiðarársandur, southern Iceland, *in* Martini, P.I., Baker, V.R., and Garzon, G., eds., Flood and Megaflood processes and deposits.Special Publication of the International Association of Sedimentologists Volume **32**, p. 85-97.

Glacier outburst floodes or "jökulhlaups" commonly involve the transport of ice blocks released from glacier margins. Very few published studies have focussed on the effects of ice blocks on outwash plains during and following jökulhlaups. A volcanic eruption benaeth the Vatnajökull ice-cap in southern Iceland generated a jökulhlaup on 5 November 1996 that transported numerous ice blocks as large as 45 m in diameter on to Skeiðarársandur. The morphology and sedimentology of a series of large, coarse grained bedforms formed around large stranded ice blocks during the November 1996 jökulhlaup are examined in relation to flow conditions. Ice-block obstacle marks were formed both by scour during the flow and by in situ melting after the flood receded. Flow separation around ice blocks resulted in the lee of the blocks

becoming a locus of rapid deposition and led to the formation of entirely aggradational obstacle shadows. Flow around ice blocks also resulted in the deposition of upstream-dipping strata in sets up to 4 m thick that are interpreted as antidune stoss sides. Evidence of deposition from traction carpets during both rising and waning stages of the flood was preserved around iced blocks. It is suggested that the 1996 jökulhlaup flow was predominently subcritical, but thet locally flow became supercritical around ice blocks

— (2002) Formation of kettle holes following a glacial outburst flood (jökulhlaup), Skeiðarársandur, southern Iceland, *in* Snorrason, Á., ed., The Extremes of the Extremes : Extraordinary Floods. Proceedings of a Symposium held at Reykjavik: International Association of Hydrological Sciences Publication 271, p. 205-210.

The 1996 jökulhlaup on Skeiðarársandur, southern Iceland, involved the transport of ice blocks released fronm the glacier margin. the morphology, sedimentology and spatial distribution of kettle holes and other ice-block-related features, which developed post-flood in this proglacial fluvial system, were examined. Four types of phenomena are described and explained: kettle chains orientated both parallel and transverse to the principal paleoflow direction, hummocky topography, steep-walled and inverse-conical kettle holes and conical sediment mounds

Fowler, A.C. (1999) "Breaking the seal at Grimsvotn, Iceland": Journal of Glaciology, v. **45**(151): p. 506-516.

Of several problems associated with theoretical explanations of the jökulhlaups which emerge from the outlet glacier Skeiðarárjökull of the ice cap Vatnajökull in southeast Iceland, the mechanism of flood initiation is one that has hitherto defied explanation. We provide, such an explanation based on a careful analysis of the classical Nye-Rothlisberger model; near the subglacial lake Grimsvötn, the hydraulic potential gradient is towards the lake, and there is therefore a catchment boundary under the ice, whose location depends on the subglacial meltwater drainage characteristics. As the conditions for a flood approach, we show that the water divide migrates towards the lake, while at the same time the lake pressure increases. When the hydraulic potential gradient towards the lake is low and the refilling rate is slow, the seal will "break" when the catchment boundary reaches the lake, while the lake level is still below flotation pressure, whereas if refilling is rapid, flotation can be achieved before a flood is initiated. This theory can thus explain why the seal is normally broken when the lake level at Grimsvotn is still some 60 m below flotation level. In addition, we are able to explain why the jokulhlaup following the 1996 eruption did not occur until flotation level was achieved, and we show how the cyclicity and magnitude of jökulhlaups can be explained within this theory.

Galon, R. (1970) "Mechanism and Stages of Retreating of Skeiðarárjokull (Vatnajökull, Iceland)": Bulletin De L´Academie Polonaise Des Sciences-Serie Des Sciences Geologiques Et Geographiques, v. **18**(4): p. 245-?

Gao, J., and Liu, Y. (2001) "Applications of remote sensing, GIS and GPS in glaciology: a review ": Progress in Physical Geography, v. **25** (No. 4): p. 520-540.

Remote sensing has served as an efficient method of gathering data about glaciers since its emergence. The recent advent of Geographic Information Systems (GIS) and Global

Positioning Systems (GPS) has created an effective means by which the acquired data are analysed for the effective monitoring and mapping of temporal dynamics of glaciers. A large number of researchers have taken advantage of remote sensing, GIS and GPS in their studies of glaciers. These applications are comprehensively reviewed in this paper. This review shows that glacial features identifiable from aerial photographs and satellite imagery include spatial extent, transient snowline, equilibrium line elevation, accumulation and ablation zones, and differentiation of ice/snow. Digital image processing (e.g., image enhancement, spectral ratioing and automatic classification) improves the ease and accuracy of mapping these parameters. The traditional visible light/infrared remote sensing of two-dimensional glacier distribution has been extended to three-dimensional volume estimation and dynamic monitoring using radar imagery and GPS. Longitudinal variations in glacial extent have been detected from multi-temporal images in GIS. However, the detected variations have neither been explored nor modelled from environmental and topographic variables. GPS has been utilized independent of remote sensing and GIS to determine glacier ice velocity and to obtain information about glacier surfaces. Therefore, the potential afforded by the integration of nonconventional remote sensing (e.g., SAR interferometry) with GIS and GPS still remains to be realized in glaciology. The emergence of new satellite images will make remote sensing of glaciology more predictive, more global and towards longer terms.

Gavin, J.B., and Williams Jr., R.S. (1993) "Geodetic airborne laser altimetry of Breiðamerkurjökull and Skeiðarárjökull, Iceland and Jakobshavns Isbræ, West Greenland": Annals of Glaciology v. **17**: p. p. 379-385.

Gíslason, S.R., Snorrason, A., Kristmannsdóttir, H.K., Sveinbjörnsdóttir, A.E., Torsander, P., Ólafsson, J., Castet, S., and Dupre, B. (2002) "Effects of volcanic eruptions on the CO_2 content of the atmosphere and the oceans: the 1996 eruption and flood within the Vatnajökull Glacier, Iceland": Chemical Geology, v. **190**(1-4): p. 181-205.

The October 1996 eruption within the Vatnajökull Glacier, Iceland, provides a unique opportunity to study the net effect of volcanic eruptions on atmospheric and oceanic CO_2. Volatile elements dissolved in the meltwater that enclosed the eruption site were eventually discharged into the ocean in a dramatic flood 35 days after the beginning of the eruption, enabling measurement of 50 dissolved element fluxes. The minimum concentration of exsolved CO_2 in the 1x1012 kg of erupted magma was 516 mg/kg, S was 98 mg/kg, Cl was 14 mg/kg, and F was 2 mg/kg. The pH of the meltwater at the eruption site ranged from about 3 to 8. Volatile and dissolved element release to the meltwater in less than 35 days amounted to more than one million tonnes, equal to 0.1% of the mass of erupted magma. The total dissolved solid concentration in the floodwater was close to 500 mg/kg, pH ranged from 6.88 to 7.95, and suspended solid concentration ranged from 1% to 10%. According to H, O, C and S isotopes, most of the water was meteoric whereas the C and S were of magmatic origin. Both C and S went through isotopic fractionation due to precipitation at the eruption site, creating "short cuts" in their global cycles. The dissolved fluxes of C, Ca, Na, Si, S and Mg were greatest ranging from 1.4x1010 to 1.4x109 mol. The dissolved C flux equaled 0.6 million tonnes of CO_2. The heavy metals Ni, Mn, Cu, Pb and Zn were relatively mobile during condensation and water-rock interactions at the eruption site. About half of the measured total carbon flood flux from the 1996 Vatnajokull eruption will be added to the long-term CO_2 budget of the oceans and the atmosphere. The other half will eventually precipitate with the Ca and Mg released. Thus, for eruptions on the ocean

floor, one can expect a net long-term C release to the ocean of less than half that of the exsolved gas. This is a considerably higher net C release than suggested for the oceanic crust by Staudigel et al. [Geochim. Cosmochim. Acta, 53 (1989) 3091]. In fact, they suggested a net loss of C. Therefore, magma degassed at the ocean floor contributes more C to the oceans and the atmosphere than magma degassed deep in the oceanic crust. The results of this study show that subglacial eruptions affecting the surface layer of the ocean where either Mn, Fe, Si or Cu are rate-determining for the growth of oceanic biomass have a potential for a transient net CO2 removal from the ocean and the atmosphere. For eruptions at high latitudes, timing is crucial for the effect of oceanic biota. Eruptions occurring in the wintertime when light is rate-determining for the growth of biota have much less potential for bringing about a transient net negative CO2 flux from the ocean atmosphere reservoir.

Gomez, B. (2001) Patterns of erosion and deposition in the proglacial zone associated with the 1996 jökulhlaup on Skeiðarársandur, *in* Jónsson, S.S., ed., Vorráðstefna 2001: ágrip erinda og veggspjalda: Hótel Loftleiðum, Reykjavík, Jarðfræðifélag Íslands, p. 81, línurit, teikn., töflur.

Gomez, B., Russell, A.J., Smith, L., and Knudsen, Ó. (2002) Erosion and deposition in the proglacial zone: the 1996 jökulhlaup on Skeiðarársandur, *in* Snorasson, A., Finsdottir, H.P., and Moss, M., eds., The Extremes of the Extremes: Extraordinary Floods: Proceedings of a symposium held at Reykjavík, Iceland. IAHS Publication Number 271 p. 217-221.

The 1996 jökulhlaup from Skeiðarárjökull Glacier, Iceland, had little impact on the proximal surface of Skeiðarársandur, though most channel change occurred in the proximal zone. Patterns of erosion and deposition were revealed by aerial photography, repeat-pass interferomerty and field survey. The jökulhlaup bypassed the proximal zone becuase meltwater ponded in an ice-marginal depression, which regulated the flow of water and calibre of sediment supplied to Skeiðarársandur, and most drainage was through a single primary outlet (the Gígjukvísl River). The geomorphic impact of jökulhlaups may vary between periods of glacier advance when a glacier and sandur are coupled and active aggradation occurs in the proximal zone, and periods of glacier retreat when the glacier is decoupled from the sandur. The style of sedimentation in rivers which route water and sediment directly on to the sandur will also differ from that in rivers buffered by ponding in the proglacial zone.

Gomez, B., Smith, L.C., Magilligan, F.J., Mertes, L.A.K., and Smith, N.D. (2000) "Glacier outburst floods and outwash plain development:Skeiðarársandur, Iceland": Terra Nova, v. **12**: p. 126-131.

Guðmundsson, M.T., Bonnel, A., and Gunnarsson, K. (2002) "Seismic soundings of sediment thickness on Skeiðarársandur, SE Iceland": Jökull, v. **51**: p. 53-64.

Halldórsson, S.M. (1996) "Eldgos í Vatnajökli": Eystrahorn,**34. tbl. 14. árg.**(fimmtud. 3. okt. 1996): p. Forsíða.

Frásögn Sigurðar M. Halldórssonar með tilvitnunum í Pál Imsland

— (1996) "Samgöngur ekki sjálfsagður hlutur ": Eystarhorn,**39. tbl. 14. árg.**(fimmtud. 7. nóv. 1996): p. 4.

Frásögn Sigurðar M. Halldórssonar með tilvitnun í Pál Imsland

— (1996) "Verður hlaupið verra en 1938? " Eystrahorn,**36. tbl. 14. árg.**(fimmtud. 17. okt. 1996): p. 3.

Frásögn Sigurðar M. Halldórssonar með fléttuðu viðtali við Pál Imsland

Hannesson, P. (1958) Skeiðarárhlaupið 1945, Frá óbyggðum: Reykjavík, Bókaútgáfa Menningarsjóðs, p. 293-320.

Hannesson, S.Ö. (2005) "Minnisvarði um náttúruhamfarir": Glettingur, v. **15 (39-40. tölubl.)**(2-3): p. 18.

Haraldsson, H. (1997) Vatnajökull : gos og hlaup 1996 : skýrsla unnin fyrir Vegagerðina af Raunvísindastofnun Háskólans og Orkustofnun: Reykjavík, Vegagerðin, p. 184 s. : kort, línurit, töflur, uppdr.

Harðardóttir, J., Víkingsson, S., and Pálsson, S. (2006) Niðurstöður kornastærðargreininga og bergflokkunar sýna af Skeiðarár- og Breiðamerkursandi; Greinargerð, unnið fyrir Vegagerðina JHa-SV-SvP-2006/001: Reykjavík, Orkustofnun, p. 19 s. gröf, töflur.

Þrjú sýni af Skeiðarár- og Breiðamerkursandi voru kornastærðargreind og bergflokkuð á Vatnamælingum Orkustofnunar og niðurstöðurnar bornar saman við niðurstöður samskonar greiningar eldri sýna frá svæðinu. Meginmarkmið ransóknanna var að meta hvort hægt væri að útskýra minna strandrof við Jökulsá á Breiðamerkursandi síðastliðin ár með auknum efnisflutningum austur fyrir Ingólfshöfða í kjölfar hamfarahlaupsins á Skeiðarársandi árið 1996. Niðurstöður benda til að sandur austan við Jökulsá sé að öllum líkindum að hluta til kominn frá Skeiðarársandi, en þar gefa kornastærðargreiningar afdráttarlausari niðurstöður en bergflokkunin. Samanburður við eldri sýni er þó erfiður vegna mismunandi kornastæðrar nýrri og eldri bergflokkunarsýna og þar sem engin sýni voru tekin úr hlaupinu 1996 sem hægt er að bera saman við

Imsland, P. (1997) "Váin á Skeiðarársandi - Ástæður og fjölbreytileiki hættunnar": Morgunblaðið,**41. tbl. 85. árg.** (19. febr. 1997): p. 24.

— (1997) "Váin á Skeiðarársandi - Varminn í sandinum og viðbrögð við hættunni": Morgunblaðið,**44. tbl. 85. árg.**(22. febr. 1997): p. 42.

Ísleifsson, K. (2000) Setlaga- og bergfræðirannsóknir við Gígjukvísl á Skeiðarársandi [**Námsritgerð thesis**]: Reykjavík, Háskóli Íslands.

Jóhannesson, H. (1985) "Þættir úr sögu Skeiðarárjökuls", v. **54. árg**(1 hefti): p. 31-45.

Jónsson, H. (1965) "Ýmislegt um Skeiðarárjökul": Jökull, v. **15**: p. 140-142.

Jónsson, J. (1960) "Mórinn á Skeiðarársandi": Náttúrufræðingurinn, v. **30. árg.**(1.hefti): p. 36-38.

— (1983) "Sandur á sjávarströnd": Náttúrufræðingurinn, v. **53**(1.-2.h.): p. 69-72.

— (1995) Sandur-Sandar : nokkrar athuganir Skýrsla, 52: Hveragerði, Rannsóknarstofnunin Neðri Ás, p. 105 s. : myndir, súlurit, töflur

Kaldal, I., and Vilmundardóttir, E.G. (1997) Hlaup á Skeiðarársandi haustið 1996. Könnun á farvegi Gígjukvíslar 13 nóvember 1996; greinargerð. , IK/EGV-9701 Orkustofnun.

— (1997) Könnun á farvegi Gígjukvíslar, Ráðstefna um eldgos í Vatnajökli 1996. Ágrip erinda og veggspjalda, Jarðfræðafélag Íslands, p. 36.

Kjaran, B. (1964) Bærinn í skjóli Lómagnúps, Auðnustundir: Reykjavík, Bókfellsútgáfan, p. 351 s., [8] mbl., [16] mbls. : teikn.

Inniheldur:
Gos í Öskju
Náttúran talar
Þeir, sem landið erfa
Skáld litanna
*Í afturelding*u
Tveir Reykvíkingar
Gróður á gömlum akri
Litli víxlarinn af Skaga
Eyðibyggðir
Konungur fuglanna og þegnar hans
Vörn og sókn

Knudsen, O., Jóhannesson, H., Russell, A.J., and Haraldsson, H. (2001) "Changes in the Gígjukvísl river channel during the November 1996 jökulhlaup, Skeiðarársandur, Iceland." Jökull, v. **50**: p. 19-32.

Aerial photos taken in 1992 and 1997 enabled the production of maps of Skeiðarársandur before and after the November 1996 jökulhlaup. This paper presents pre- and post-jökulhlaup maps of the Gígjukvísl river channel, providing an excellent opportunity to examine geomorphological change resulting from the jökulhlaup. The Gígjukvísl channel system underwent spectacular transformation from a complex system of low capacity channels and proglacila lakes to a large high capacity channel, scaled to the November 1996 jökulhlaup flows. The overall size of the Gígjukvísl channel increased, reducing flood flow resistance and decreasing future potential for the formation of *backwater lakes. specific change within the Gígjukvísl channel, upstream of the Little Ice Age moraines, consists of bank erosion of up to 300 m at the main Gígjukvísl outlet and within channel deposition of between 6 and 12 m. Downstream of the Little Ice Age moraines channel change consists of bank erosion of 600 m and localised within-channel aggradation of 4 m. Comparison of 1992 and 1997 aerial photographs also provides a clear picture of the glacier snout retreat of 300 m and thinning of 50-60 m during this period. drastic change within the Gígjukvísl channel was brought about by the recent (post-1954) creation of a proglacial trench within the river system. Prior to the November 1996 jökulhlaup, the proximal Gígjukvísl river channel had never experience a high-magnitude jökulhlaup. Extensive bank erosion during the jökulhlaup drastically changed teh channel, so it is now well-adjusted to high-magnitude flood flows reducing the geomorphological impact of future jökulhlaups.*

Knudsen, Ó. (2001) Undirkælt vatn og ísmyndun undir sporðum skriðjökla í sunnanverðum Vatnajökli, Vorráðstefna 2001: ágrið erinda og veggspjalda: Hótel Loftleiðum, Reykjavík, Jarðfræðifélag Íslands.

Kristinsson, B. (1986) "Tvíhlaup á Skeiðarársandi 1986": Jökull, v. **36**: p. 56.

Kristinsson, B., Zophóníasson, S., Pálsson, S., and Kristmannsdóttir, H. (1986) Hlaup á Skeiðarársandi 1986, OS-86080/VOD-23 B: Reykjavík, National Energy Authority, p. 42.

Magilligan, F.J., Gomez, B., Mertes, L.A.K., Smith, L.C., Smith, N.D., Finnegan, D., and Garvin, J.B. (2002) "Geomorphic effectiveness, sandur development, and the pattern of landscape response during jökulhlaups: Skeiðarársandur, southeastern Iceland": Geomorphology, v. **44**(1-2): p. 95-113.

By contrast with other historical outburst floods on Skeiðarársandur, the 1996 jökulhlaup was unprecedented in its magnitude and duration, attaining a peak discharge of ~53,000 m3/s in 7 m3 of sediment, and along channel systems that remained connected to subglacial sediment supplies. This shift to a laterally dissimilar, channelized routing system creates a more varied depositional pattern that is not explicitly controlled by the concave longitudinal profile down-sandur. Laterally contiguous units, therefore, may vary greatly in age and sediment character, suggesting that current facies models inadequately characterize sediment transfers when the ice front is decoupled from its sandur. Water was routed onto the sandur in a highly organized fashion; and this jokulhlaup generated major geomorphic changes, including sandur incision in normally aggradational distal settings and eradication of proximal glacial landforms dating to ~A.D. 1892.

Maria, A., Carey, S., Sigurðsson, H., Kincaid, C., and Helgadóttir, G. (2000) "Source and dispersal of jökulhlaup sediments discharged to the sea following the 1996 Vatnajökull eruption": Geological Society of America Bulletin, v. **112**(10): p. 1507-1521.

The October 1996 Gjálp eruption beneath Vatnajökull glacier led to one of the largest jökulhlaups (glacial floods) in Iceland in the twentieth century. A catastrophic discharge of meltwater and sediment swept across the Skeidararsandur flood plain to the sea. Tephra from the eruption consists of vesicular sideromelane shards with a

basaltic andesite composition (53% SiO2, 3% MgO, 0.8% K2O). After the flood, sediment samples were collected from the hood plain and off the southeast coast of Iceland, where a major sediment plume had been created by the discharge. Compositions of glass shards from hood-plain and seafloor deposits do not match those of the Gjálp magma. Flood-plain samples consist primarily of blocky to poorly vesicular sideromelane clasts with compositions that are characteristic of Grimsvötn volcanic products (similar to 50% SiO2, 5.5% MgO, 0.4% K2O). Marine samples collected near the jökulhlaup outflow into the sea also consist primarily of blocky to poorly vesicular sideromelane clasts with compositions that are, for the most part, similar to products of the Grimsvötn volcanic center. Distal marine samples have more vesicular sideromelane clasts with compositions that are similar to products of the Katla volcanic center (e.g., 48% SiO2, 4.5% MgO, 0.8% K2O). Significant deposition to the seafloor was apparently limited to an area just offshore of the Skeiðarársandur. There is no indication that juvenile volcanic material from the Gjálp eruption was carried by the 1996 jökulhlaup onto the flood plain or into the ocean, Instead, the jökulhlaup carried primarily older volcaniclastic material eroded by the flood.

Marren, P.M. (2002) "Fluvial-lacustrine interaction on Skeiðarársandur, Iceland: implications for sandur evolution": Sedimentary Geology, v. **149**(1-3): p. 43-58.

A complex assemblage of fluvial and lacustrine sediments is identified in a major section through proglacial sediments on Skeiðarársandur, south Iceland. High magnitude-low frequency events are identified in both the fluvial and lacustrine sediments. However, much of the sedimentary succession is composed of `normal' low magnitude-high frequency sediments. Retreat of Skeiðarárjökull following a surge event created a topographic basin occupied at various times by both fluvial and lacustrine depositional systems and also subjected to a high magnitude jökulhlaup. Previous studies have examined the processes and events occurring on Skeiðarárjákull in isolation. This paper improves the understanding of the way in which processes with varying magnitude and frequency regimes interact and contribute to the sedimentary record of proglacial environments.

— (2004) "Present-day sandurs are not representative of the geological record - Sedimentary Geology 152, 1-5 (2002)": Sedimentary Geology, v. **164**(3-4): p. 335-340.

— (2005) "Magnitude and frequency in proglacial rivers: a geomorphological and sedimentological perspective": Earth-Science Reviews, v. **Vol. 70**(3-4): p. 203-251.

Proglacial fluvial sedimentary systems receive water from a variety of sources and have variable discharges with a range of magnitudes and frequencies. Little attention has been paid to how these various magnitude and frequency regimes interact to produce a distinctive sedimentary record in modern and ancient proglacial environments. This paper reviews the concept of magnitude and frequency in relation to proglacial fluvial systems from a geomorphic and sedimentary perspective rather than a hydrological or statistical perspective. The nature of the meltwater inputs can be characterised as low-magnitude–high-frequency, primarily controlled by ablation inputs from the source glacier, or highmagnitude–low-frequency, primarily controlled by dexceptionalT inputs. The most important high magnitude–low-frequency inputs are catastrophic outburst floods, often referred to by the term jökulhlaup (Icelandic for glacier-burst). Glacier surges are an additional form of cyclical variation impacting the proglacial environment, which briefly alter the volumes and patterns of meltwater input. The

sedimentary consequences of low-magnitude–high-frequency discharges are related to frequent variations in stage, the greater directional variability that sediment will record, and the increased significance of channel confluence sedimentation. In contrast, the most significant characteristics of high-magnitude–low-frequency flooding include the presence of large flood bars and mid-channel jökulhlaup T bars, hyperconcentrated flows, large gravel dunes, and the formation of ice-block kettle hole structures and rip-up clasts. Glacier surges result in a redistribution of low-magnitude–high-frequency processes and products across the glacier margin, and small floods may occur at the surge termination. Criteria for distinguishing magnitude and frequency regimes in the proglacial environment are identified based on these major characteristics. Studies of Quaternary proglacial fluvial sediments are used to determine how the interaction of the various magnitude and frequency regimes might produce a distinctive sedimentary record. Consideration of sandur architecture and stratigraphy shows that the main controls on the sedimentary record of proglacial regions are the discharge magnitude and frequency regime, sediment supply, the pattern of glacier advance or retreat, and proglacial topography. A model of sandur development is suggested, which shows how discharge magnitude and frequency, in combination with sandur incision and aggradation (controlled by glacier advance and retreat) can control sandur stratigraphy.

Molewski, P. (2005) REKONSTRUKCJA PROCESÓW GLACJALNYCH W WYBRANYCH STREFACH MARGINALNYCH LODOWCÓW ISLANDII - FORMY I OSADY. Reconstruction of glacial processes in the chosen marginal zones of the Icelandic glaciers - forms and deposits: Torun, Instytut Geografii UMK; Stowarzyszenie Geomorfologów Polskich, p. 148.

Nummedal, D., and Hayes, M.O. (1974) Recent migrations of the Skeiðarársandur shoreline, Southeast Iceland : final report Columbia, South Carolina, University of South Carolina, p. 2 b. (xiii, 183 s.) : myndir, kort, línurit, töflur

Óla, Á. (1944) Öræfaferð Ferðafélagsins, *in* Óla, Á., ed., Landið er fagurt og frítt: Reykjavík, Bókfellsútgáfan, p. 138-172.

Pálsson, S., Ingólfsson, P., and Tómasson, H. (1980) "Comparison of sediment load transport in the Skeiðarár jökulhlaups in 1972 and 1976 (Samanburður á aurburði í Skeiðarárhlaupum 1972 og 1976)": Jökull, v. **30**: p. 21-33.

Pálsson, S., and others (1999) Grímsvatnahlaupið fyrra 1996; greinargerð, unnið fyrir Vegagerðina, OS-99115: Reykjavík, Orkustofnun, Vatnamælingar, p. 26 s. : línurit, töflur.

Rist, S. (1955) "Skeiðarárhlaup 1954": Jökull, v. **5**: p. 30-36.

Roberts, M., Magnússon, E., Geirsson, H., and Sturkell, E. (2006) Meltwater dynamics beneath Skeiðarárjökull from continuous GPS measurements, Haustfundur Jarðfræðafélags Íslands 2006: Reykjavík, p. 23.

Roberts, M.J., Pálsson, F., Guðmundsson, M.T., Björnsson, H., and Tweed, F.S. (2005) "Ice-water interactions during floods from Grænalón glacier-dammed lake, Iceland": Annals of Glaciology, v. **40**(1): p. 133-138.

This paper explores changing ice–water interactions during jökulhlaups from Grænalón, a 5 × 108 m3 subaerial lake dammed by Skeiðarárjökull, Iceland. Unstable drainage of Graenalón since the early 20th century has resulted in 45 jökulhlaups whose hydrologic character has varied enormously. Geomorphic observations and geophysical measurements from the inlet and outlet zones of the subglacial floodwater tract constrained the hydromechanical factors governing ice–water interactions at Grænalón. To date, three distinct drainage regimes have occurred in response to the changing surface elevation of Grænalón. Shifts from one drainage regime to another involved pronounced changes in jökulhlaup magnitude, timing and cyclicity. Present hydraulic conditions for lake drainage differ from the classical view of a pressure-coupled lake draining directly beneath an ice dam. Instead, lowamplitude drawdown occurs at regular, frequent intervals when hydrostatic pressure in a shallow, rock–ice trench enables water to flow beneath a sagging ice barrier. Floodwater exits Skeiðarárjökull in a supercooled state due to rapid hydraulic displacement from an overdeepened subglacial basin.

Roberts, M.J., Russell, A.J., Tweed, F.S., and Knudsen, Ó. (2000) "Ice fracturing during jökulhlaups: implications for englacial floodwater routing and outlet development": Earth Surface Processes and Landforms, v. **25**: p. 1429-1446.

Theoretical studies of glacial outburst floods (jökulhlaups) assume that: (i) intraglacial floodwater is transported efficiently in isolated conduits; (ii) intraglacial conduit enlargement operates proportionally to increasing discharge; (iii) floodwater exits glaciers through pre-existing ice-marginal outlets; and (iv) the morphology and positioning of outlets remains fixed during flooding. Direct field observations, together with historical jökulhlaup accounts, confirm that these theoretical assumptions are not always correct. This paper presents new evidence for spatial and temporal changes in intraglacial floodwater routing during jökulhlaups; secondly, it identifies and explains the mechanisms controlling the position and morphology of supraglacial jökulhlaup outlets; and finally, it presents a conceptual model of the controls on supraglacial outbursts. Field observations are presented from two Icelandic glaciers, Skeiðarárjökull and Sólheimajökull. Video footage and aerial photographs, taken before, during and after the Skeiðarárjökull jökulhlaup and immediately after the Sólheimajökull jökulhlaup, reveal changes in floodwater routing and the positioning and morphology of outlets. Field observations confirm that glaciers cannot transmit floodwater as efficiently as previously assumed. Rapid increases in jökulhlaup discharge generate basal hydraulic pressures in excess of ice overburden. Under these circumstances, floodwater can be forced through the surface of glaciers, leading to the development of a range of supraglacial outlets. The rate of increase in hydraulic pressure strongly influences the type of supraglacial outlet that can develop. Steady increases in basal hydraulic pressure can retro-feed pre-existing englacial drainage, whereas transient increases in pressure can generate hydraulic fracturing. The position and morphology of supraglacial outlets provide important controls on the *spatial and temporal impact of flooding. The development of supraglacial jökulhlaup outlets provides a new mechanism for rapid englacial debris entrainment.*

— (2001) "Controls on englacial sediment deposition during the november 1996 jökulhlaup, Skeiðarárjökull, Iceland": Earth Surface Processes and Landforms, v. **26**: p. 935-952.

This paper presents sedimentary evidence for rapid englacial debris entrainment durin jökulhlaups. Previous studies of jökulhlaup sedimentology have focused predominantly on proglacial impact, rather than depositional processes within glaciers. However, observations of supraglacial floodwater outbursts suggest that englacial sediment emplacement is possible during jökulhlaups. The November 1996 jökulhlaup from Skeidarárjökull, Iceland presented one of the first opportunities to examine englacial flood deposits in relation to former supraglacial outlets. Using observations from Skeidarárjökull, this paper identifies and explains controls on the deposition of englacial flood sediments and presents a qualitative model for englacial jökulhlaup deposition. Englacial jökulhlaup deposits were contained within complex networks of upglacier-dipping fractures. Simultaneous englacial deposition of fines and boulder-sized sediment demonstrates that englacial fracture discharge had a high transport capacity. Fracture geometry was an important control on the architecture of englacial jökulhlaup deposits. The occurrence of pervasively frozen flood deposits within Skeidarárjökull is attributed to freeze-on by glaciohydraulic supercooling. Floodwater, flowing subglacially or through upglacier-dipping fractures, would have supercooled as it was raised to the surface faster than its pressure-melting point could increase as glaciostatic pressure decreased. Evidence for floodwater contact with the glacier bed is supported by the ubiquitous occurrence of sheared diamict rip-ups and intra-clasts of basal ice within jökulhlaup fractures, deposited englacially some 200–350 m above the bed of Skeidarárjökull. Evidence for fluidal supercooled sediment accretion is apparent within stratified sands, deposited englacially at exceptionally high angles of rest in the absence of post-depositional disturbance. Such primary sediment structures cannot be explained unless sediment is progressively accreted to opposing fracture walls. Ice retreat from areas of former supraglacial outbursts revealed distinct ridges characterized by localized upwellings of sediment-rich floodwater. These deposits are an important addition to current models of englacial sedimentation and demonstrate the potential for post-jökulhlaup landform development.

Roberts, M.J., Tweed, F.S., Russell, A.J., Knudsen, Ó., Lawson, D.E., Larson, G.J., Evenson, E.B., and Björnsson, H. (2002) "Glaciohydraulic supercooling in Iceland": Geology, v. **30**(no. 5): p. 439-442; 6 figures.

We present evidence of glaciohydraulic supercooling under jökulhlaup and ablationdominated conditions from two temperate Icelandic glaciers. Observations show that freezing of sediment-laden meltwater leads to intraglacial debris entrainment during normal and extreme hydrologic regimes. Intraglacial frazil ice propagation under normal ablation-dominated conditions can trap copious volumes of sediment, which forms anomalously thick sections of debris-rich ice. Glaciohydraulic supercooling plays an importantrole in intraglacial debris entrainment and should be given more attention in models of basal ice development. Extreme jökulhlaup conditions can result in significant intraglacial sediment accretion by supercooling, which may explain the concentration of englacial sediments deposited in Heinrich layers in the North Atlantic during the last glaciation.

Robinson, Z.P. (2001) Groundwater geochemistry and behaviour in an Icelandic sandur [**Unpublished Ph.D. thesis**], Keele University, U.K.

Rushmer, E.L. (2004) The role of hydrograph shape and sediment sorting in controlling jökulhlaup sedimentary successions [**Unpublished Ph.D. thesis**], Keele University, U.K.

Glacial outburst floods (jökulhlaups) play an important part in proglacial geomorphology and sedimentology. Research on the impact of floods has made assumptions by associating jökulhlaup sedimentary successions with distinctive hydrograph shapes and flow rheology. However, jökulhlaup hydrograph shape alone is thougt to have a significant impact on proglacial sedimentology. To date, little information exists on the role of hydrograph shape as a control an the sedimentological and geomorphological impact on jökulhlaups. This paper illustrates how field interpretation of flood deposits can be related to specific hydrograph shapes, and outlines how flume experiments can be used to assess the extent to which hydrograph shape exerts a control on jökulhlaup sedeimentology.

Russell, A.J., Knudsen, Ó., Maizels, J.K., and Marren, P.M. (1999) "Channel cross-section area changes and peak discharge calculations in the Gígjukvísl river during the November 1996 jökulhlaup, Skeiðarársandur, Iceland": Jökull, v. **47**: p. 45-58.

Russell, A.J. (2005) The geomorphological and sedimentary impact of jökulhlaups Skeiðarársandur, Rekonstrukcja Procesow Glacjalnych W Wybranych Strefach Marginalnych Lodowcow Islandii - Formy I Osady Islandia (Reconstruction of galcial processes in the chosen marginal zones of the Icelandic Glaciers - forms and deposits), 14-28 sierpnia 2005 Torun, Poland, Instytut Geografii UMK, p. 73-96.

Russell, A.J., Gregory, A.G., Large, A.R.G., Fleisher, P.J., and Harris, T. (2007) "Tunnel channel formation during the November 1996 jökulhlaup, Skeiðarárjökull, Iceland": Annals of Glaciology, v. **45**.

Despite the ubiquity of tunnel channels and valleys within formerly glaciated areas, their origin remains enigmatic. Few modern analogues exist for event-related subglacial erosion. This paper presents evidence of subglacial meltwater erosion and tunnel channel formation during the November 1996 jökulhlaup, Skeiðarárjökull, Iceland. The jökulhlaup reached a peak discharge of 45,000 – 50,000 m 3 s -1 , with flood outbursts emanating from multiple outlets across the entire 23 km wide glacier snout. Subsequent retreat of the south-eastern margin of Skeiðarárjökull has revealed a tunnel channel excavated into the surrounding moraine sediment and ascending 11.5 m over a distance of 160 m from a larger trough to join the apex of an ice-contact fan formed in November 1996. The tunnel channel formed via hydro- mechanical erosion of 14,000 m 3 - 24,000 m 3 of unconsolidated glacier substrate, evidenced by copious rip-up clasts within the ice-contact fan. Flow reconstruction provides peak discharge estimates of 683 m 3 s -1. The tunnel channel orientation, oblique to local ice flow direction nd within a col, suggests that local jökulhlaup routing was controlled by (a) subglacial topography and (b)the presence of a nearby proglacial lake. We describe the first modern example of tunnel channel formation and illustrate the importance of pressurised subglacial jökulhlaup flow for tunnel channel formation.

Russell, A.J., Knight, P.G., and van Dijk, T.A.G.P. (2001) "Glacier surging as a control on the development of proglacial fluvial landforms and deposits, Skeiðarársandur, Iceland": Global and Planetary Change, v. **28**(1-4): p. 163-174.

Glacier-hydrological processes are one of the main factors controlling proglacial fluvial systems. It has been proposed that where jökulhlaups occur they play a dominant role in the evolution of proglacial outwash plains. However, extraordinary meltwater and sediment discharge associated with glacier surging can also play a crucial role in the proglacial system. The interplay of surge-related and jökulhlaup floods has been investigated at Skeiðarárjökull, a jökulhlaup type-site where surging is also known to occur, allowing the geomorphological and sedimentological effects of these events to be differentiated.

Skeiðarársandur contains a spectacular assemblage of landforms and deposits associated with the 1991 surge of Skeiðarárjökull. The impact of the 1991 surge was felt mainly on the western half of the glacier where the ice advanced up to 1 km between September and November. The surge limit is marked by a push-moraine complex up to 5 m in height and 10 m in breadth. Proglacial fluvial sediments were deposited as a series of outwash fans adjacent to the glacier, up to 400 m in diameter, as the glacier advanced during the surge. Glaciotectonic structures associated with ice pushing inter-finger with undisturbed proglacial fluvial fan sediments, constraining timing of deposition of proglacial fans to the period during and immediately following the glacier surge.

The study of landforms and sedimentary successions associated with the 1991 surge provides an excellent modern analogue for larger-scale push moraines and proglacial fans on Skeiðarársandur, which are related to similar processes. Surge-related outflows operating over timescales of months–years, together with jökulhlaup flows play a major role in the creation of distinctive proglacial fluvial landforms and deposits. Examination of the sedimentary and landform records of areas presently subject to surging will allow the development of models which can be used to differentiate glacier surging from rapid glacier response to abrupt climate change.

Russell, A.J., Knudsen, O., Fay, H., Marren, P.M., Heinz, J., and Tronicke, J. (2001) "Morphology and sedimentology of a giant supraglacial, ice-walled, jökulhlaup channel, Skeiðarárjokull, Iceland: implications for esker genesis": Global and Planetary Change, v. **28**(1-4): p. 193-216.

This paper examines the sedimentary infill of a spectacular, 500-m-long, 100-m-wide ice-walled supraglacial channel, excavated into the snout of Skeiðarárjokull, Iceland during the November 1996 jokulhlaup. The ice-walled channel developed in an area of the glacier, which was extensively fractured during the jokulhlaup. Sculpting of the ice-walled channel into the active snout of Skeiðarárjokull suggests that the presence of stagnating glacier ice is not a prerequisite for the development of ice-walled channels. The ice-walled channel occupied an inter-lobate location, which acted as a focus for meltwater during the November 1996 jokulhlaup. The geometry of the supraglacial ice-walled channel system acted as a major control on the morphology and sedimentology of jokulhlaup deposits, through the tremendous spatial variability of resultant flow conditions. Maximum calculated jokulhlaup powers and shear stresses for the supraglacial ice-walled channel reached 40,000 W m-2 and 5000 N m-2, respectively, with associated mean flow velocities between 7 and 11 m s-1.Within the main ice-walled channel, Ground Penetrating Radar and outcrop exposure provide evidence of

an ~8-m-thick progradational and aggradational gravel macroform succession. The supraglacial ice-walled channel system is therefore analogous to a bedrock-confined fluvial system. This study provides a new analogue for the interpretation of ice-contact glaciofluvial deposits associated with former ice margins in Iceland and other areas subject to high magnitude discharges. Former supraglacial ice-walled channels resulting from tunnel collapse and ice margin break-up during high magnitude jokulhlaups will be associated with extensive coarse-grained, heavily kettled proglacial outwash surfaces. It is clear that the relationship between the characteristics of former ice-walled channels labeled as eskers and the prevailing glaciological and hydrological conditions needs to be modified in light of our knowledge of a modern flood-related large-scale supraglacial channel and its sedimentary infill. Such re-evaluation may provide a valuable new insight into former ice margin positions, modes of glacier retreat, and the role of high magnitude floods within the sedimentary record of former proglacial areas. This study therefore improves our understanding of the meltwater magnitude and frequency regime of former glaciers.

Russell, A.J., and Knudsen, Ó. (1999) Controls on the sedimentology of November 1996 jökulhlaup deposits, Skeiðarársandur, Iceland, *in* Smith, N.D., and Rogers, J., eds., Fluvial Sedimentology VI: International Association of Sedimentologists Special Publication 28, p. 315-329.

— (1999) "An ice-contact rhythmite (turbidite) succession deposited during the November 1996 catastrophic outburst flood (jökulhlaup), Skeiðarárjökull, Iceland": Sedimentary Geology, v. **127**(1-2): p. 1-10.

— (2002) The effects of glacier outburst flood flow dynamics on ice-contact deposits: November 1996 jökulhlaup, Skeiðarársandur, Iceland, *in* Martini, I.P., Baker, V.R., and Garzon, G., eds., Flood and Megaflood Deposits:Recent and Ancient: Special Publication of the International Association of Sedimentologists 32, p. 67-83.

This study examines the extent to which observed large-scale stage variations are reflected in the proglacial landform and sedimentary record of the November 1996 jökulhlaup, Skeiðarárjökull, Iceland. Discrimination of rising from falling flood stage landforms and deposits is usually based upon the interpretation of the geomorphic and sedimentary record. Sedimentary successions in proglacial environments have been interpreted on the basis of vertical sedimentary characteristics which are then linked to the flood hydrograph. Most research has considered efflux within channels active on both rising and falling flow stage where the resultant morphology and sedimentology are the product of the temporal variability of both water and sediment flux. Spatial segregation of rising and falling stage proglacial outwash during the November 1996 jökulhlaup provided a superb opportunity to examine the role of flow stage in the creation and preservation of distinctive proglacial jökulhlaup landforms and deposits. Rising stage deposits contained finer, more poorly sorted sediment than found on falling stage successions and erosional surfaces. Rising stage deposits showed upward-coarsening successions, characteristic of progressive supply of coarser-grained sediment with stage increase, compatible with previous models of rising stage sedimentation. Some rising stage successions however, showed few signs of large-scale grading, and instead contained repeated cycles of sedimentation, recording individual sedimentation pulses. Distinctive upward-coarsening successions on a waning stage outwash fan were generated by sediment reworking and winnowing. The presence of an upward-coarsening succession alone is clearly not diagnostic of rising stage deposition. Conduits occupied by flows on both rising and falling flow stages *were characterised by initial rising stage fan deposition followed by falling stage dissection and exhumation of ice blocks and rip-up clasts deposited on the rising flow stage. Rising stage deposits contained both single upward coarsening successions as well as successions consisting of stacked upward-coarsening and normally-graded units. Where waning stage flows were routed through a single conduit, high sediment efflux and aggradation rates were maintained late into the waning stage. Winnowing and sediment starvation resulted in progressive bed coarsening from matrix-supported gravels to clast-rich armour. This study illustrates the geomorphic and sedimentary significance of major within-jökulhlaup sediment reworking and ice-margin erosion over distances of 10^2-10^3 m. Ill-defined erosional, streamlined terraces reflect exhumation on the flood waning stage. This landform and sedimentary succession could easily be confused with the product of fluvial depositional and erosional cycles operating over longer timescales associated with more sedate rates of glacier retreat within former proglacial areas.*

— (2002) The influence of channel flood history on the impact of the November 1996 jökulhlaup, Skeiðarársandur, Iceland., *in* Snorasson, A., Finsdottir, H.P., and Moss, M., eds., The Extremes of the Extremes: Extraordinary Floods. Proceedings of a symposium held at Reykjavik, Iceland, July 2000: IAHS Publication Number 271, p. 243-247.

Multiple channel occupation during the November 1996 jökulhlaup Skeiðarársandur, Iceland, provided an opportunity to assess the role of flood history in controlling the varied impact of a single large jökulhlaup. This paper considers the immediate geomorphological impact of the 1996 jökulhlaup in relation to the flood history of each major ice-proximal channel system draining Skeiðarárjökull. The jökulhlaup had greatest impact on the Gígjukvísl river channel, whilst the Skeiðará and Sæluhúsavatn channels were impacted to a lesser degree. The jökulhlaup had very little impact on the Háöldukvísl and Súla. Large jökulhlaup impact within the central portion of the glacier occurred because non-jökulhlaup flows had dominated the central portion of the glacier for many years. The impact of the 1996 jökulhlaup on individual channels is strongly influenced by each channels' flood history, which in turn is driven by differential rates of glacier margin retreat.

Russell, A.J., and Marren, P.M. (1999) Proglacial fluvial sedimentary sequences in Greenland and Iceland: a case study from active proglacial environments subject to jökulhlaups, *in* A.P.Jones, Tucker, M.E., and Hart, J.K., eds., The description and analysis of Quaternary stratigraphic field sections, Technical Guide 7: London, Quaternary Research Association, p. 171-208.

Sigbjarnarson, G. (1990) Vatnið og landið : ávörp , erindi og ágrip : vatnafræðiráðstefna haldin 22.-23. október 1987 í tilefni 40 ára afmælis Vatnamælinga og 20 ára afmælis Orkustofnunar : tileinkuð Sigurjóni Rist vatnamælingamanni sjötugum, Vatnafræðiráðstefna: Reykjavík : Orkustofnun, p. 307 s. : myndir, kort, línurit, töflur

Sigurðsson, O. (1992) "Framhlaup Skeiðarárjökuls 1991": Glettingur, v. **2** (2): p. 25.

Sigurðsson, O., Jónsson, P., Snorrason, Á., Víkingsson, S., Kaldal, I., and Pálsson, S. (2000) "The jökulhlaup on Skeiðarársandur in November 1996: event, discharge and sediment": Mars Polar Science.

Sigurðsson, S. (2004),,Lífið er enn dásamlegt", *in* Björnsson, H., ed., Jöklaveröld, náttúra og mannlíf: Reykjavík, Skrudda, p. 319-390.

Smith, L.C., Alsdorf, D.E., Magilligan, F.J., Gomez, B., Mertes, L.A.K., Smith, N.D., and Garvin, J.B. (2000) "Estimation of erosion, deposition, and net volumetric change caused by the 1996 Skeiðarársandur jökulhlaup, Iceland, from synthetic aperture radar interferometry": Water Resources Research, v. **36**(6): p. 1583-1594.

Using repeat-pass satellite synthetic aperture radar interferometry, we develop a methodology to measure flood-induced erosion and deposition and apply it to a record 1996 glacier outburst flood (jökulhlaup) on Skeiðarársandur, Iceland. The procedures include (1) coregistration of backscatter intensity images to observe morphological differences; (2) mapping of interferometric phase correlation to identify preserved and modified surfaces; and (3) construction, correction, and differencing of pre-jökulhlaup and post-jökulhlaup topography. Procedures 1 and 2 are robust and should be widely applicable to other fluvial environments, while procedure 3 is complicated by uncertainties in phase measurement, baseline estimate, and atmospheric effects. After a correction procedure involving interpolation of digital elevation model elevation differences across low-correlation areas, we find similar to 4 m of elevation change are required to calculate volumes of erosion or deposition. This condition was satisfied for the 40 km(2) proglacial zone of Skeiðarársandur, where we estimate +38 x 10(6) m(3) of net sediment deposition along the ice margin, -25 x 10(6) m(3) of net erosion in channels downstream, and a total net balance of +13 x 10(6). These estimates are supported by field observations and survey data collected in 1997.

Smith, L.C., Sheng, Y., Magilligan, F.J., Smith, N.D., Gomez, B., Mertes, L.A.K., Krabill, W.B., and Garvin, J.B. (2006) "Geomorphic impact and rapid subsequent recovery from the 1996 Skeiðarársandur jökulhlaup, Iceland, measured with multi-year airborne lidar": Geomorphology, v. **75**(1-2): p. 65-75.

The November 1996 jökulhlaup that burst from the Vatnajökull ice cap onto Skeiðarársandur was the highest-magnitude flood ever measured on the largest active glacial outwash plain (sandur). Centimeter-scale elevation transects, measured from repeat-pass airborne laser altimetry missions flown in 1996 (pre-flood), 1997, and 2001, show that sediment deposition exceeded erosion across the central Skeiðarársandur and established an average net elevation gain of + 22 cm for the event. Net elevation gains of + 29 and + 24 cm occurred in braided channels of the Gigjukvísl and Skeiðará rivers, respectively. Nearly half of these gains, however, were removed within 4 years, and the two rivers contrast strongly in style of erosional/depositional impact and subsequent recovery. In the Gígjukvísl, the 1996 jökulhlaup caused massive sediment deposition (up to ~12 m) near the ice margin and intense "mega-forming" of braided channels and bars downstream. Post-jökulhlaup recovery (1997-2001) was characterized by rapid erosion (- 0.5 m) of ice-proximal sediments and their transport to downstream reaches, and eradication of the mega-forms. In contrast, the Skeiðará displays minimal post-jökulhlaup sediment erosion in its upstream reaches and little change in braided channel relief. This contrast between river systems is attributed to the presence of a previously studied ~2-km wide ice-marginal trench, caused by glacier retreat and lowering, which contained flows of the Gigjukvísl but not the Skeiðará prior to dispersal onto the outwash plain. Rapid removal of jökulhlaup *deposits from this trench suggests that in terms of long-term evolution of the sandur, such features only delay downstream migration of jökulhlaup-derived sediment. These results, therefore, suggest that the net geomorphic impact of jokulhlaups on surface relief of Skeiðarársandur, while profound in the short term, may be eradicated within years to decades.*

Snorrason, Á., Jónsson, P., Pálsson, S., Árnason, S., Sigurðsson, O., Víkingsson, S., Sigurðsson, Á., and Zóphóníasson, S. (1997) Hlaupið á Skeiðarársandi haustið 1996: Útbreiðsla, rennsli og aurburður, *in* Haraldsson, H., ed., Vatnajökull: Gos og Hlaup: Reykjavík: Reykjavík, Vegagerin, p. 79-137.

Snorrason, Á., Jónsson, P., Sigurðsson, O., Pálsson, S., Árnason, S., Víkingsson, S., and Kaldal, I. (2002) "November 1996 jökulhlaup on Skeiðarársandur outwash plain, Iceland": Special Publications of the International Association of Sedimentologists, v. **32**: p. 55-65.

Stefánsdóttir, M.B., and Gíslason, S.R. (2005) "The erosion and suspended matter/seawater interaction during and after the 1996 outburst flood from the Vatnajökull Glacier, Iceland": Earth and Planetary Science Letters, v. **237**(3-4): p. 433-452.

The Gjálp subglacial eruption 1996 within the Vatnajökull Glacier, Iceland triggered a catastrophic outburst flood, bringing at least 180 million tonnes of suspended solids to the sea in only 42 h. This amounts to 1% of the total annual global river suspended flux to the oceans. The specific BET-surface area of the suspended solids was measured to be 11.8-18.9 m2/g, translating to the average total BET-surface area of 2.8 x 10 9 km2, providing enormous potential for adsorption/desorption and precipitation/dissolution fluxes at the suspended solids-ocean water interface. Altered basalt glass was the major constituent of the suspended matter (80%), secondary minerals such as zeolites and calcite amounted to 11%, but only 5% was fresh volcanic glass. The suspended grains were generally rounded. The glass carried by the flood is different in chemical composition from the glass produced by the Gjálp eruption. The Gjalp material has higher FeOtotal / TiO2 and TiO2 / P2O5 ratios than the suspended glass in the flood waters. The majority of the flood samples match the composition of the volcanic system, down stream from the eruption site. The large amount of altered material in the flood and its chemical composition suggests erosion conforming to a 2 m deep, 1000 m wide and 50 000 m long channel in less than 42 h. The behaviour of 28 elements on the surface of the suspended solids exposed to seawater was quantified by experiments in the laboratory. The altered basaltic glass dissolved in seawater, as recorded by the Si release from the glass. The dissolved concentrations of Na, Ca, Si, Ba, Cd, Co, Cu, Hg, Mn, Ni, and total dissolved inorganic N increased considerably when the suspended solids come into contact with the seawater, but the concentrations of Mg, K, S, Sr, Fe, Pb and Zn decreased. The experimental seawater solutions were supersaturated with respect to calcite, Mg-montmorillonite and amorphous iron-hydroxide. The rate of release (mol/m2/s) of Si, Mn, Ba, Co, Ni and Cd decreased continuously during the one week exposure to sweater. After one week, the logarithm of the dissolution rate of the altered basaltic glass was - 11.9 to - 11.6 (Si mole/m2/sec). Significantly lower than the steady-state rates for fresh basaltic glass at similar conditions. Calculated one day desorbed/dissolution suspended material fluxes are greater than the integrated

dissolved flood fluxes for Mn, Ba, Ni, Co and Cd, but the Si dissolved food flux was greater than the one day desorbed/dissolved suspended material flux.

— (2006) "Suspended basaltic glass-seawater interactions": Journal of Geochemical Exploration, v. **88**(1-3): p. 332-335.

The objective of this study was to quantify by experiments the initial seawater-suspended basaltic glass interactions following the 1996 outburst flood from the Vatnajökull glacier, Iceland. The altered basaltic glass dissolved in seawater as recorded by the Si release from the glass. The dissolved concentrations of Na, Ca, Si, Ba, Cd, Co, Cu, Hg, Mn, Ni and total dissolved inorganic N increased with time but the concentrations of Mg, K, S, Sr, Fe, Pb and Zn decreased. Calculated 1 to 10 day fluxes for Si range from 38,000 tons/day to 70,000 tons/10 days. The fluxes for other major elements are more uncertain, but the positive flux (release from suspended matter to seawater) of Ca and Na, and negative flux of Mg, K and S are greater than the Si flux.

Stefánsdóttir, M.B., Gíslason, S.R., and Arnórsson, S. (1999) Flood from Grímsvötn subglacial caldera 1996 : composition of suspended matter, *in* Ármannsson, H., ed., 5th International Symposium on Geochemistry of the earth's surface: Reykjavík, Iceland, A.A. Balkema, Rotterdam, p. 539-542.

Stefánsson, R. (1957) Á Skeiðarársandi, *in* Hannesson, P., and Eyþórsson, J., eds., Hrakningar og heiðarvegir. Norðri 1950-1953, Volume **4.b.**: Akureyri, Norðri, p. 207-213.

— (1983) "Skeiðarárhlaupið 1939 (The jökulhlaup in Skeiðará in 1939)": Jökull, v. **33**: p. 148.

— (1997) Freysnes í Öræfum : saga og náttúrulýsing: Skaftafell, Hótel Skaftafell, 30, [1] s. : myndir, kort p.

Stefánsson Skaftafelli, R. (1982) "Skeiðarárhlaupin : margvíslegar afleiðingar þeirra": Skaftfellingur, v. **3**: p. 99-118.

— (1989) "Eftirlit og viðgerðir á landssímalínum á Skeiðarársandi 1929-1973": Skaftfellingur v. **6**: p. 41-62.

Steinþórsson, S., and Óskarsson, N. (1983) "Chemical monitoring of jökulhlaup water in Skeiðará and the geothermal system in Grímsvötn, Iceland. (Uppleyst efni í hlaupvatni Skeiðarár og jarðhitasvæðið í Grímsvötnum)": Jökull v. **33**: p. 73-86.

Theódórsson, P. (1977) Tilraun til að mæla rennsli í Skeiðará með geislavirku jóði, RH-77-4: Reykjavík, Raunvísindastofnun Háskólans, p. 8; línurit, teikn., töflur.

Tómasson, H., and others (1974) Efnisflutningar í Skeiðarárhlaupi 1972, OS-ROD-7407: Reykjavík, Orkustofnun. Raforkudeild, p. Óreglul. bls.tal : myndir, línurit, töflur.

Tómasson, H., Pálsson, S., and Ingólfsson, P. (1980) "Comparison of sediment load in the Skeiðarár jökulhlaups in 1972 and 1976": Jökull, v. **30**: p. 21-33.

Tweed, F.S., Roberts, M.J., and Russell, A.J. (2005) "Hydrologic monitoring of supercooled discharge from Icelandic glaciers: hydrodynamic and sedimentary significance": Quaternary Science Reviews, v. **24**(22): p. 2308-2318.

Knowledge of how glaciers entrain sediment is central to understanding processes of glacier movement and products of glacial sediment deposition. Previous work has shown that if the total hydraulic potential of subglacial meltwater increases more rapidly than the resulting mechanical energy can be transformed into sensible heat, then supercooling and ice growth will result. This process causes frazil ice to grow onto adjacent glacier ice, which acts to trap sediment in flowing meltwater eventually producing sedimentary inclusions within glacier ice. Supercooling has been recognised as a sediment entrainment mechanism at glaciers in Alaska, and more recently at several temperate Icelandic glaciers. Here we present short-period temperature measurements and field evidence of glaciohydraulic supercooling from three Icelandic glaciers. Temperature measurements demonstrate that supercooling occurs over a range of hydrological conditions and that the process does not operate continuously at all instrumented sites. Measurements of supercooling during a small jökulhlaup are also presented. Progressive accretion of supercooled meltwater creates sediment-laden ice exposures adjacent to active artesian vents. Understanding controls on the efficacy and pervasiveness of hydraulic supercooling is important for decoding the sedimentary record of modern and ancient glaciers and ice sheets.

van Dijk, T.A.G.P., and Sigurðsson, O. (2002) Surge-related floods at Skeiðarárjökull Glacier, Iceland: implications for ice-marginal outwash deposits, *in* Snorrason, A., Finnsdóttir, H.P., and Moss, M.E., eds., The Extremes of the Extremes: Extraordinary Floods. IAHS Special Publications Vol. 271, International Association of Hydrological Sciences, Wallingford, p. 193-198.

Wake, G.M. (1997) "After the flood ": Iceland review v. **35**(1): p. 32-35.

Waller, R.I., Russell, A.J., van Dijk, T.A.G.P., and Knudsen, O. (2001) "Jökulhlaup-related Ice Fracture and Supraglacial Water Release During the November 1996 Jökulhlaup, Skeiðarárjökull, Iceland": Geografiska Annaler, v. **83A**(1-2): p. 29-38.

During the initial stages of the November 1996 jökulhlaup at Skeiðarárjökull, Iceland, floodwaters burst onto the glacier surface via a series of fractures. This supraglacial drainage led to the formation of a number of distinct ice surface depressions, one of which is investigated in detail. The morphology and structural characteristics of this feature are described, as well as the sedimentology of an associated assemblage of debris-filled fractures. This work suggests that debris-charged subglacial floodwaters travelled up to the glacier surface, where supraglacial flow occurred initially via an extensive network of fractures, orientated parallel to the glacier margin. Supraglacial discharge became progressively more focused into a series of discrete outlets, leading to the mechanical erosion of a number of depressions on the glacier surface. The associated transfer of subglacially derived floodwaters to high levels within the glacier resulted in the rapid entrainment of large volumes of sediment which may influence the patterns, processes and products of ice-marginal sedimentation in the future.

Wisniewski, E., Andrzejewski, L., and Molewski, P. (1997) "Fluctuations of the snout of Skeiðarárjökull in Iceland in the last 100 years and some of their consequences in the central part of its forefield": Landform Analysis, v. **1**: p. 73-78.

Worsley, P. (1997) "The 1996 volcanically induced glacial mega-flood in Iceland-cause and consequence": Geology Today, v. **13**(6): p. 222-227.

— (1998) "Iceland: contrasting Skeidará mega-flood hydrographs": Geology Today v. **14**(3): p. 97-98.

Þorsteinsson, P. (1985) Samgöngur í Skaftafellssýslum: Hornafirði, 240 s., [3] mbl., [14] mbls. : kort p.

Ferðalög á liðnum öldum ; Landslag ; Þjóðbrautin sunnan jökla ; Núpsvötn ; Skeiðará ; Jökulsá á Breiðamerkursandi ; Verzlunarferðir ; Póstferðir ; Ýmsar langferðir á hestum ; Skipaferðir ; Bílferðir ; Hringvegurinn ; Landmælingar 1904 ; Vatnajökulsferðir að fornu ; Vatnajökulsferðir sumarið 1912

Þórarinsson, S. (1954) "Athuganir á Skeiðarárhlaupi og Grímsvötnum 1954 (The jökulhlaup (glacier burst) from Grímsvötn in July 1954). Bráðabirgða-greinargerð": Jökull, v. **4**: p. 34-37.

— (1967) "Forvitnilegir jökulgarðar við jaðar Skeiðarárjökuls (Washboard moraines in front of Skeiðarárjökull)": Jökull, v. **17**: p. 311-312.

— (1974) Vötnin stríð, saga Skeiðarárhlaupa og Grímsvatnagosa: Reykjavík, Bókaútgáfa Menningarsjóðs, 254 p.

— (1980) "Enn um Skeiðarárhlaup (An old letter on Skeiðarárhlaup)": Jökull, v. **30**: p. 74.

Þórðarson, T. (1943) "Vatnadagurinn mikli": Tímarit Máls og menningar v. **4**(2.h.): p. s. 69-84.

— (1972) Vatnadagurinn mikli, Frásagnir / Þórbergur Þórðarson: Reykjavík, Mál og menning.

4.1.2 Gígjukvísl

Gomez, B., Russell, A.J., Smith, L., and Knudsen, Ó. (2002) Erosion and deposition in the proglacial zone: the 1996 jökulhlaup on Skeiðarársandur, *in* Snorasson, A., Finsdottir, H.P., and Moss, M., eds., The Extremes of the Extremes: Extraordinary Floods: Proceedings of a symposium held at Reykjavík, Iceland. IAHS Publication Number 271 p. 217-221.

The 1996 jökulhlaup from Skeiðarárjökull Glacier, Iceland, had little impact on the proximal surface of Skeiðarársandur, though most channel change occurred in the proximal zone. Patterns of erosion and deposition were revealed by aerial photography, repeat-pass interferomerty and field survey. The jökulhlaup bypassed the proximal zone becuase meltwater ponded in an ice-marginal depression, which regulated the flow of *water and calibre of sediment supplied to Skeiðarársandur, and most drainage was through a single primary outlet (the Gígjukvísl River). The geomorphic impact of jökulhlaups may vary between periods of glacier advance when a glacier and sandur are coupled and active aggradation occurs in the proximal zone, and periods of glacier retreat when the glacier is decoupled from the sandur. The style of sedimentation in rivers which route water and sediment directly on to the sandur will also differ from that in rivers buffered by ponding in the proglacial zone.*

Harðardóttir, J., Víkingsson, S., and Pálsson, S. (2006) Niðurstöður kornastærðargreininga og bergflokkunar sýna af Skeiðarár- og Breiðamerkursandi; Greinargerð, unnið fyrir Vegagerðina JHa-SV-SvP-2006/001: Reykjavík, Orkustofnun, p. 19 s. gröf, töflur.

Þrjú sýni af Skeiðarár- og Breiðamerkursandi voru kornastærðargreind og bergflokkuð á Vatnamælingum Orkustofnunar og niðurstöðurnar bornar saman við niðurstöður samskonar greiningar eldri sýna frá svæðinu. Meginmarkmið ransóknanna var að meta hvort hægt væri að útskýra minna strandrof við Jökulsá á Breiðamerkursandi síðastliðin ár með auknum efnisflutningum austur fyrir Ingólfshöfða í kjölfar hamfarahlaupsins á Skeiðarársandi árið 1996. Niðurstöður benda til að sandur austan við Jökulsá sé að öllum líkindum að hluta til kominn frá Skeiðarársandi, en þar gefa kornastærðargreiningar afdráttarlausari niðurstöður en bergflokkunin. Samanburður við eldri sýni er þó erfiður vegna mismunandi kornastæðrar nýrri og eldri bergflokkunarsýna og þar sem engin sýni voru tekin úr hlaupinu 1996 sem hægt er að bera saman við

Ísleifsson, K. (2000) Setlaga- og bergfræðirannsóknir við Gígjukvísl á Skeiðarársandi [**Námsritgerð**]: Reykjavík, Háskóli Íslands.

Kaldal, I. (1997) Breytingar á farvegi Gígjukvíslar, greinargerð, IK-9702 Orkustofnun.

Kaldal, I., and Vilmundardóttir, E.G. (1997) Hlaup á Skeiðarársandi haustið 1996. Könnun á farvegi Gígjukvíslar 13 nóvember 1996; greinargerð. , IK/EGV-9701 Orkustofnun.

— (1997) Könnun á farvegi Gígjukvíslar, Ráðstefna um eldgos í Vatnajökli 1996. Ágrip erinda og veggspjalda, Jarðfræðafélag Íslands, p. 36.

Knudsen, O., Jóhannesson, H., Russell, A.J., and Haraldsson, H. (2001) "Changes in the Gígjukvísl river channel during the November 1996 jökulhlaup, Skeiðarársandur, Iceland." Jökull, v. **50**: p. 19-32.

Aerial photos taken in 1992 and 1997 enabled the production of maps of Skeiðarársandur before and after the November 1996 jökulhlaup. This paper presents pre- and post-jökulhlaup maps of the Gígjukvísl river channel, providing an excellent opportunity to examine geomorphological change resulting from the jökulhlaup. The Gígjukvísl channel system underwent spectacular transformation from a complex system of low capacity channels and proglacila lakes to a large high capacity channel, scaled to the November 1996 jökulhlaup flows. The overall size of the Gígjukvísl channel increased, reducing flood flow resistance and decreasing future potential for the formation of backwater lakes. specific change within the Gígjukvísl channel, upstream of the Little

Ice Age moraines, consists of bank erosion of up to 300 m at the main Gígjukvísl outlet and within channel deposition of between 6 and 12 m. Downstream of the Little Ice Age moraines channel change consists of bank erosion of 600 m and localised within-channel aggradation of 4 m. Comparison of 1992 and 1997 aerial photographs also provides a clear picture of the glacier snout retreat of 300 m and thinning of 50-60 m during this period. drastic change within the Gígjukvísl channel was brought about by the recent (post-1954) creation of a proglacial trench within the river system. Prior to the November 1996 jökulhlaup, the proximal Gígjukvísl river channel had never experience a high-magnitude jökulhlaup. Extensive bank erosion during the jökulhlaup drastically changed teh channel, so it is now well-adjusted to high-magnitude flood flows reducing the geomorphological impact of future jökulhlaups.

Molewski, P. (2005) REKONSTRUKCJA PROCESÓW GLACJALNYCH W WYBRANYCH STREFACH MARGINALNYCH LODOWCÓW ISLANDII - FORMY I OSADY. Reconstruction of glacial processes in the chosen marginal zones of the Icelandic glaciers - forms and deposits: Torun, Instytut Geografii UMK; Stowarzyszenie Geomorfologów Polskich, p. 148.

Russel, A.J., Knudsen, Ó., Maizels, J.K., and Marren, P.M. (1999) "Channel cross-section area changes and peak discharge calculations in the Gígjukvísl river during the November 1996 jökulhlaup, Skeiðarársandur, Iceland": Jökull, v. **47**: p. 45-58.

Russell, A.J., and Knudsen, Ó. (2002) The influence of channel flood history on the impact of the November 1996 jökulhlaup, Skeiðarársandur, Iceland., *in* Snorasson, A., Finsdottir, H.P., and Moss, M., eds., The Extremes of the Extremes: Extraordinary Floods. Proceedings of a symposium held at Reykjavik, Iceland, July 2000: IAHS Publication Number 271, p. 243-247.

Multiple channel occupation during the November 1996 jökulhlaup Skeiðarársandur, Iceland, provided an opportunity to assess the role of flood history in controlling the varied impact of a single large jökulhlaup. This paper considers the immediate geomorphological impact of the 1996 jökulhlaup in relation to the flood history of each major ice-proximal channel system draining Skeiðarárjökull. The jökulhlaup had greatest impact on the Gígjukvísl river channel, whilst the Skeiðará and Sæluhúsavatn channels were impacted to a lesser degree. The jökulhlaup had very little impact on the Háöldukvísl and Súla. Large jökulhlaup impact within the central portion of the glacier occurred because non-jökulhlaup flows had dominated the central portion of the glacier for many years. The impact of the 1996 jökulhlaup on individual channels is strongly influenced by each channels' flood history, which in turn is driven by differential rates of glacier margin retreat.

Smith, L.C., Sheng, Y., Magilligan, F.J., Smith, N.D., Gomez, B., Mertes, L.A.K., Krabill, W.B., and Garvin, J.B. (2006) "Geomorphic impact and rapid subsequent recovery from the 1996 Skeiðarársandur jökulhlaup, Iceland, measured with multi-year airborne lidar": Geomorphology, v. **75**(1-2): p. 65-75.

The November 1996 jökulhlaup that burst from the Vatnajökull ice cap onto Skeiðarársandur was the highest-magnitude flood ever measured on the largest active glacial outwash plain (sandur). Centimeter-scale elevation transects, measured from repeat-pass airborne laser altimetry missions flown in 1996 (pre-flood), 1997, and 2001, show that sediment deposition exceeded erosion across the central Skeiðarársandur and *established an average net elevation gain of + 22 cm for the event. Net elevation gains of + 29 and + 24 cm occurred in braided channels of the Gigjukvísl and Skeiðará rivers, respectively. Nearly half of these gains, however, were removed within 4 years, and the two rivers contrast strongly in style of erosional/depositional impact and subsequent recovery. In the Gígjukvísl, the 1996 jökulhlaup caused massive sediment deposition (up to ~12 m) near the ice margin and intense "mega-forming" of braided channels and bars downstream. Post-jökulhlaup recovery (1997-2001) was characterized by rapid erosion (- 0.5 m) of ice-proximal sediments and their transport to downstream reaches, and eradication of the mega-forms. In contrast, the Skeiðará displays minimal post-jökulhlaup sediment erosion in its upstream reaches and little change in braided channel relief. This contrast between river systems is attributed to the presence of a previously studied ~2-km wide ice-marginal trench, caused by glacier retreat and lowering, which contained flows of the Gigjukvísl but not the Skeiðará prior to dispersal onto the outwash plain. Rapid removal of jökulhlaup deposits from this trench suggests that in terms of long-term evolution of the sandur, such features only delay downstream migration of jökulhlaup-derived sediment. These results, therefore, suggest that the net geomorphic impact of jokulhlaups on surface relief of Skeiðarársandur, while profound in the short term, may be eradicated within years to decades.*

4.1.3 Öræfi, Öræfasveit; ekki skilgreint nánar

Ágústsdóttir, A. M. (1990). Efnafræði jökulárvatns í Öræfum. Jarðfræði Reykjavík, Háskóli Íslands.

Bingham, R.G. (1998) An assessment of rare, large magnitude (catastrophic) events in landscape evolution: a study of jökulhlaups in Öræfi, south-east Iceland. , University of Edinburgh.

Björnsson, F. (1969) A Short Survey of Changes in the Öræfa-Country, Brathay Exploration Group, Annual Report: Great Britain.

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4.1.4 Morsárdalur, Morsárjökull, Skaftafellsfjöll

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4.1.5 Skaftafellsjökull, Skaftafell

Guðmundsson, H.J. (1998) Holocene glacier fluctuations and tephrochronology of the Öræfi district, Iceland [**PhD thesis**], University of Edinburgh, Scotland.

Helgason, J. (2001) Þjóðgarðurinn í Skaftafelli: kortlagning berggrunns, *in* Jónsson, S.S., ed., Vorráðstefna: ágrip erinda og veggspjalda: Hótel Loftleiðum, Reykjavík, Jarðfræðifélag Íslands, p. 43.

Helgason, J., and Duncan, R.A. (2001) "Glacial-interglacial history of the Skaftafell region, southeast Iceland, 0-5 Ma": Geology, v. **29**(2): p. 179–182

Volcanic strata in the Skaftafell region, southeast Iceland, record a sequence of at least 16 glacial and interglacial intervals since 5 Ma. Two composite sections of 2 to 2.8 km thickness have been constructed from multiple, overlapping, cliff profiles. The timing of alternating sequences of subaerial lava flows, pillow basalts, and hyaloclastite deposits is provided by magnetostratigraphic mapping and K-Ar radiometric dating. We find that the frequency and intensity of glaciations increased significantly at ca. 2.6 Ma, and particularly since 0.8 Ma, amplifying topographic relief in this area from <100 m to 2 km. These changes correlate with increases in global ice volume, ice-rafted debris, and development from local to regional glacial conditions in the North Atlantic.

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Marren, P.M. (2002) "Glacier margin fluctuations, Skaftafellsjökull, Iceland: implications for sandur evolution." Boreas, v. **Vol. 31**: p. 75-81.

— (2005) "Magnitude and frequency in proglacial rivers: a geomorphological and sedimentological perspective": Earth-Science Reviews, v. **Vol. 70**(3-4): p. 203-251.

Proglacial fluvial sedimentary systems receive water from a variety of sources and have variable discharges with a range of magnitudes and frequencies. Little attention has been paid to how these various magnitude and frequency regimes interact to produce a distinctive sedimentary record in modern and ancient proglacial environments. This paper reviews the concept of magnitude and frequency in relation to proglacial fluvial systems from a geomorphic and sedimentary perspective rather than a hydrological or statistical perspective. The nature of the meltwater inputs can be characterised as low-magnitude–high-frequency, primarily controlled by ablation inputs from the source glacier, or highmagnitude–low-frequency, primarily controlled by dexceptionalT inputs. The most important high magnitude–low-frequency inputs are catastrophic outburst floods, often referred to by the term jökulhlaup (Icelandic for glacier-burst). Glacier surges are an additional form of cyclical variation impacting the proglacial environment, which briefly alter the volumes and patterns of meltwater input. The sedimentary consequences of low-magnitude–high-frequency discharges are related to frequent variations in stage, the greater directional variability that sediment will record, and the increased significance of channel confluence sedimentation. In contrast, the most significant characteristics of high-magnitude–low-frequency flooding include the presence of large flood bars and mid-channel djo¨kulhlaupT bars, hyperconcentrated flows, large gravel dunes, and the formation of ice-block kettle hole structures and rip-up clasts. Glacier surges result in a redistribution of low-magnitude–high-frequency processes and products across the glacier margin, and small floods may occur at the surge termination. Criteria for distinguishing magnitude and frequency regimes in the proglacial environment are identified based on these major characteristics. Studies of Quaternary proglacial fluvial sediments are used to determine how the interaction of the various magnitude and frequency regimes might produce a distinctive sedimentary record. Consideration of sandur architecture and stratigraphy shows that the main controls on the sedimentary record of proglacial regions are the discharge magnitude and frequency regime, sediment supply, the pattern of glacier advance or retreat, and proglacial topography. A model of sandur development is suggested, which shows how discharge magnitude and frequency, in *combination with sandur incision and aggradation (controlled by glacier advance and retreat) can control sandur stratigraphy.*

Morse, A., and Hunt, C. (1989) University of Liverpool and Liverpool Polytechnic Iceland Research Expedition, 1989. Final Report.: Liverpool, University of Liverpool and Liverpool Polytechnic.

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Persson, Å. (1964) "The vegetation at the margin of the receding glacier Skaftafellsjökull, southeastern Iceland": Botaniska Notiser(117): p. 323-354.

Roberts, M.J., Tweed, F.S., Russell, A.J., Knudsen, Ó., Lawson, D.E., Larson, G.J., Evenson, E.B., and Björnsson, H. (2002) "Glaciohydraulic supercooling in Iceland": Geology, v. **30**(no. 5): p. 439-442; 6 figures.

We present evidence of glaciohydraulic supercooling under jökulhlaup and ablationdominated conditions from two temperate Icelandic glaciers. Observations show that freezing of sediment-laden meltwater leads to intraglacial debris entrainment during normal and extreme hydrologic regimes. Intraglacial frazil ice propagation under normal ablation-dominated conditions can trap copious volumes of sediment, which forms anomalously thick sections of debris-rich ice. Glaciohydraulic supercooling plays an importantrole in intraglacial debris entrainment and should be given more attention in models of basal ice development. Extreme jökulhlaup conditions can result in significant intraglacial sediment accretion by supercooling, which may explain the concentration of englacial sediments deposited in Heinrich layers in the North Atlantic during the last glaciation.

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Þorsteinsdóttir, H. (2005) Breytingar á gróðri fyrir framan Skaftafellsjökul, á tímabilinu 1986-2044 [**BSc thesis**]: Reykjavík, Háskóli Íslands.

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4.1.6 Svínafellsjökull, Svínafell, Hafrafell

EinarBragi (1982) "Fréttir úr Öræfum 1900-1905 / Einar Bragi tíndi saman. Úr sendibréfum til Gísla Þorvarðssonar, Papey, frá Ara Hálfdanarsyni á Fagurhólsmýri, Sveini Bjarnasyni í Neðribænum á Fagurhólsmýri, Jóni Sigurðssyni í Svínafelli og Þorláki Jónssyni á Hofi." Skaftfellingur v. **3**( ): p. s. 153-168.

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Observations and measurements of ogives on Morsárjökull, Svínafellsjökull and Skaftafellsjökull are discussed. Problems associated with smaller ogives of Svínafellsjökull and ridges below ice falls are considered

Klok, E.J., and Oerlemans, J. (2003) "Deriving historical equilibrium-line altitudes from a glacier length record by linear inverse modelling": The Holocene, v. **13**(4): p. 343 - 351.

Glaciers have fluctuated in historic times and the length fluctuations of many glaciers are known. From these glacier length records, a climate reconstruction described in terms *of a reconstruction of the equilibrium-line altitude (ELA) or the mass-balance can be extracted. In order to derive a climate signal from numerous glacier length records, a model is needed that takes into account the main characteristics of a glacier, but uses little information about the glacier itself. Therefore, a simple analytical model was developed based on the assumption that the change in glacier length can be described by a linear response equation. Historical length observations, the climate sensitivity and the response time of a glacier were needed to calculate historical equilibrium-line altitudes. Both climate sensitivity and length response time were calculated from a perturbation analysis on the continuity equation. The model was tested on 17 European glacier length records. The results revealed that the ELA of most glaciers increased on average 54 m between AD 1920 and 1950. The results of the analytical model were compared to mass-balance reconstructions calculated with a numerical flowline model and derived from historical temperature and precipitation records. The findings lead us to believe that the analytical model could be very useful to gain information about the historical mass-balance rates and ELAs.*

Morse, A., and Hunt, C. (1989) University of Liverpool and Liverpool Polytechnic Iceland Research Expedition, 1989. Final Report.: Liverpool, University of Liverpool and Liverpool Polytechnic.

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Pálsson, F., Björnsson, H., and Magnússon, E. (1998) Könnun rennslisleiða vatns úr Skrámulóni, undir sporð Svínafellsjökuls, RH-08-98: Reykjavík, Raunvísindastofnun Háskólans.

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4.1.7 Svínafellslög

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Þórarinsson, S. (1963) "The Svínafell layers: plant bearing interglacial sediments in Öræfi, Southeast Iceland": Sérpr. úr North Atlantic biota and their history 1963.

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Stefánsson, R. (1997) Freysnes í Öræfum : saga og náttúrulýsing: Skaftafell, Hótel Skaftafell, 30, [1] s. : myndir, kort p.

4.1.9 Öræfajökull

Arason, H. (1959) "Gengið á Öræfajökul": Jökull, v. **9**: p. 51.

Baldursson, J. (1978) "Páskahret (A climbing tour to Öræfajökull during Easter 1978)": Jökull, v. **28**: p. 85-88.

Björnsson, F. (1957) "Gengið á Öræfajökul í slóð Sveins Pálssonar (On the track of Sveinn Pálsson to Öræfajökull)": Jökull, v. **7**: p. 37-39.

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Elliston, G.R. (1957) "A study of the ogive on some of the outlet glaciers of Öræfajökull": Jökull, v. **7**: p. 26-32.

Eyþórsson, J. (1960) Vatnajökull: Reykjavík, Almenna bókafélagið, 44 s., [62] mbls. : teikn., ritsýni, uppdr. p.

Guðmundsson, A.T. (1986) Íslandseldar : eldvirkni á Íslandi í 10.000 ár Reykjavík, Vaka-Helgafell, 168 s. : myndir, teikn., kort, línurit, töflur p.

— (2001) Íslenskar eldstöðvar: Reykjavík, Vaka-Helgafell, 320 s. : myndir, kort, línurit, töflur p.

— (2005) "Fjallarisinn Öræfajökull": Glettingur, v. **15 (39-40. tölubl.)**(2-3): p. 69-70.

Guðmundsson, A.T., and Sigurðsson, R.T. (1995) Jökulheimar : íslenskir jöklar: Seltjarnarnesi, Ormstunga, 82 s. : myndir, kort p.

Guðmundsson, A.T., Sigurðsson, R.T., and (1995) Light on ice : glaciers in Iceland: Seltjarnarnesi, Ormstunga, ISBN 9979904879 (ib.) p.

Guðmundsson, M. (1978) "Páskaferð 1978 (A climbing tour to Öræfajökull)": Jökull, v. **28**: p. 82-85.

Guðmundsson, M.T. (2000) "Mass balance and precipitation on the summit plateau of Öræfajökull, SE-Iceland": Jökull, v. **48**: p. 49-54.

Hards, V.L., Kempton, P.D., Thompson, R.N., and Greenwood, P.B. (2000) "The magmatic evolution of the Snaefell volcanic centre; an example of volcanism during incipient rifting in Iceland": Journal of Volcanology and Geothermal Research, v. **99**(1-4): p. 97-121.

The Snaefell volcanic centre is situated in central-east Iceland, at the northern end of a short flank volcanic zone. Its products represent a typical suite of Icelandic volcanics and comprise a bimodal suite of alkalic lavas: a series from basaltic to mugearitic compositions and a small cluster of peralkaline rhyolites. Compositional variations across the whole series can be broadly explained by fractional crystallisation of a family of related parental/primary magmas in a magma chamber at mid-crustal (~13 km) levels, that has been subject to periodic replenishment and periodic tapping, with sufficient repose times for extreme differentiation. Interaction with the crust appears minimal, although some crustal input into the rhyolites is indicated by their isotopic characteristics. The Snaefell volcanics therefore represent largely new additions to the Icelandic crust.The apparent depth of the magma chamber appears significant and sets Snaefell apart from the axial rift zones at centres such as Krafla, where seismic studies (e.g. Brandsdottir, B., Menke, W., Einarsson, P., White, R.S., Staples, R.K., 1997. Faeroe-Iceland ridge experiment. 2. Crustal structure of Krafla central volcano. J. Geophys. Res. 102 (B4), 7867-7886) have detected the presence of magma bodies at depths of around 3 km beneath centres in the northern volcanic zone. Comparing Snaefell with volcanic centres in the propagating eastern volcanic zone suggests that, in terms of its stage of evolution, Snaefell is approximately equivalent to Torfajokull. Thus, the Oraefajokull-Snaefell volcanic zone may have represented a site of incipient rifting.

Harris, T., Tweed, F.S., and Knudsen, O. (2004) "A Polygenetic Landform At Stígá;Öræfajökull, Southern Iceland": Geografiska Annaler, v. **86A**(2): p. 143-154.

Abstract Recent research has identified problems inherent in the identification and description of landforms. Morphologically similar small-scale glacial and periglacial landforms can be misinterpreted, thus hindering environmental reconstruction. This study reveals that a landform resembling a moraine at Stigarjokull, southern Iceland, is the product of both glacial deposition and mass movement. The landform has two distinct morphological and sedimentological components: a basal, lithologically diverse component, and an upper, lithologically homogenous component. Clast lithological analysis, particle shape and particle size measurements demonstrate that the basal component of the landform consists of sediment whose characteristics match nearby moraines. In contrast, the source of the upper component is a narrow outcrop of rock above the valley floor. Evidence suggests that frost-shattered material was transported across a perennial snow patch to a small moraine, leading to growth of the 'moraine'. This combination of processes is unlikely to be unique, but the geological peculiarities of the field site permitted their identification. It is possible that many similar 'moraines' could be enlarged by subaerial feeding, leading to false reconstruction of glacier form and/or associated rates of erosion and sedimentation. Such polygenetic landform genesis therefore has implications for environmental reconstruction.

Hálfdánarson, E. (1918-1920) Frásögn síra Einars Hálfdánarsonar um hlaupið í Öræfajökli 1727, Blanda: fróðleikur gamall og nýr Volume **1.b.**: Reykjavík, Sögufélag, p. 54-59.

Helgason, J., and Duncan, R.A. (1996) Jarðlagaskipan Svínafells í Öræfum: bergsegulstefna, aldursgreiningar og jöklunarsaga, Vorráðstefna 1996: ágrip erinda og veggspjalda: Odda, Reykjavík, Jarðfræðifélag Íslands.

Helgason, J., and Roberts, B. (1992) Skaftafell: Jarðlagaskipan, bergsegulstefna og K-Ar aldursgreiningar, Vorráðstefna 1992: ágrip erinda: Reykjavík.

Imsland, P. (1987) Öræfajökull - brot úr jarðfræði og sögu eldfjallsins, Ferð í Öræfi 9. - 12. júlí 1987: Reykjavík, Hið íslenska náttúrufræðifélag, p. 14-15.

— (1988) Öræfajökull - brot úr jarðfræði og sögu eldfjallsins, Skaftafell og Öræfi, þættir um náttúru og sögu: Reykjavík, Hið íslenska Náttúrufræðifélag, p. 13-14.

— (1989) The Volcano Öræfajökull and its Activity, Skaftafell and Öræfi, Hið íslenska náttúrufræðifélag og Náttúruverndarráð, p. 13-15.

— (2005) "Öræfajökull : brot úr jarðfræði og sögu eldfjallsins": Glettingur, v. **15 (39-40. tölubl.)**(2-3): p. 59-60.

Isólfsson, I. (1989) "Útsýni af Öræfajökli": Jökull, v. **39**: p. 99-103.

Kjartansson, Á. (1953) "Leit að brezkum stúdentum á Öræfajökli": Jökull, v. **3**(41-42).

N.N. (1990) "Vatnajökull: eitt mesta jökulhvel jarðarinnar": Áfangar: tímarit um Ísland, v. **11**(1): p. 12-17.

Pálsson, S. (1998) "Ascent of Öræfajökull": Jökull, v. **46**: p. 29-33.

Prestvik, T. (1976) "Öræfajökull, Islands störste vulkan": Naturen, v. **100**(1): p. 41-47.

— (1979) "Petrology of hybrid intermediate and silicic rocks from Öræfajökull, southeast Iceland": Geologiska Föreningens i Stockholm Forhandlingar, v. **101**: p. 299-307.

— (1982) "Petrography, chemical characteristics and nomenclature of Öræfajökull rocks (Bergfræðileg einkenni gosbergs úr Öræfajökli)": Jökull, v. **32**: p. 69-76.

Prestvik, T., Goldberg, S., Karlsson, H., and Gronvold, K. (2001) "Anomalous strontium and lead isotope signatures in the off-rift Oraefajokull central volcano in south-east Iceland : Evidence for enriched endmember(s) of the Iceland mantle plume?" Earth and Planetary Science Letters, v. **190**(3-4): p. 211-220.

The currently active off-rift central volcano Öræfajökull in south-east Iceland sits unconformably on much older (~10-12 Ma) and eroded crust. The composition of recent volcanics ranges from basalt to rhyolite, but the series is more sodic alkaline than the common rift zone tholeiitic suites. In this study we present Sr, Nd, Pb and O isotopic data for a suite of Öræfajökull samples. The complete suite shows typical *mantle values for oxygen isotopes. The 87Sr/86Sr ratios (average of 15 SAMPLES=0.703702) of the modern Öræfajökull rocks (basalts as well as rhyolites) are much higher than observed so far for any other Icelandic rocks. The 143Nd/144Nd ratios (average=0.512947; n=15) are lower than for rift rocks, but similar to rocks of the off-rift Snaefellsnes volcanic zone. Furthermore, the Öræfajökull rocks are enriched in the 207Pb/204Pb and 208Pb/204Pb isotope ratios compared to Icelandic rift basalts. The enriched nature of the suite indicates that Öræfajökull samples a source component that has characteristics common with EM2 type mantle. Furthermore, it is concluded that the silicic rocks of Öræfajökull formed by fractional crystallization from mafic melts rather than by partial melting of older crust.*

Schierbeck, C. (2000) "Ferð Schierbecks á Öræfajökul": Skaftfellingur, v. **13**: p. 75-79.

Selbekk, R.S., and Tronnes, R.G. (in press) "The 1362 AD Öræfajökull eruption, Iceland: Petrology and geochemistry of large-volume homogeneous rhyolite": Journal of Volcanology and Geothermal Research, v. **In Press, Corrected Proof**.

The ice-covered Oraefajokull stratovolcano is composed mostly of subglacial pillow lava and hyaloclastite tuff, ranging from basalt to rhyolite. A large devastating plinian eruption in 1362 AD produced 10 km3 (2 km3 DRE) rhyolitic ash and pumice from a vent within the summit caldera, with fallout mainly towards ESE. The ejected rhyolite magma with 0.5-1% crystals of oligoclase, fayalite, hedenbergite, ilmenite and magnetite was remarkably homogenous throughout the eruption.A 1.8 m thick tephra section on the SE flank of the volcano has 14 recognizable units. The tephra is dominated by fine-grained vesicular glass with bubble wall thickness of 1-5[mu]m. The high and even vesiculation of the glass indicates fast magma ascent and explains the extreme mechanical fragmentation within the eruptive column. The grain-size distribution indicates time-variable intensity of the plinian eruption with three evenly spaced phases of maximum fragmentation. An initial vent-clearing explosion produced phreatomagmatic debris with up to 35% lithic fragments. The low abundance (< 3%) of lithic fragments during the subsequent eruption indicates that the conduit and vent remained stable. The tephra fallout deposit is characterized by upwards increasing pumice dimensions and occasional bomb-like pumice blocks, indicating less mechanical fragmentation during contraction and lowering of the plinian column.A conservative estimate of 20-40 km3 for the total volume of the magma reservoir is based on the erupted volume of highly differentiated and homogeneous rhyolite. The 365-year period between 1362 and a minor benmoreitic eruption in 1727, and the absence of currently detectable magma reservoirs in the crust below Oraefajokull show that differentiated crustal magma chambers feeding large plinian eruptions can be established and disappear on a 100-500 year timescale.

Sharma, K., Self, S., Blake, S., and Larsen, G. (2004) Deposits, sequence of events and volatile degassing from the A.D. 1362 rhyolitic eruption of Öræfajökull, S.E. Iceland, IAVCEI General Assembly: Abstracts: Pucon, Chile.

Sigmarsson, O., Condomines, M., and Fourcade, S. (1992) "Mantle and crustal contribution in the genesis of Recent basalts from off-rift zones in Iceland: Constraints from Th, Sr and O isotopes": Earth and Planetary Science Letters, v. **110**(1-4): p. 149-162.

Along the two volcanic off-rift zones in Iceland, the Snaefellsnes volcanic zone (SNVZ) and the South Iceland volcanic zone (SIVZ), geochemical parameters vary regularly along the strike towards the centre of the island. Recent basalts from the SNVZ change from alkali basalts to tholeiites where the volcanic zone reaches the active rift axis, and their 87Sr/86Sr and Th/U ratios decrease in the same direction. These variations are interpreted as the result of mixing between mantle melts from two distinct reservoirs below Snaefellsnes. The mantle melt would be more depleted in incompatible elements, but with a higher 3He/4He ratio (R/Ra [approximate] 20) beneath the centre of Iceland than at the tip of the Snaefellsnes volcanic zone (R/Ra [approximate] 7.5).From southwest to northeast along the SIVZ, the basalts change from alkali basalts to FeTi basalts and quartz-normative tholeiites. The Th/U ratio of the Recent basalts increases and both (230Th/232Th) and [delta]18O values decrease in the same direction. This reflects an important crustal contamination of the FeTi-rich basalts and the quartz tholeiites. The two types of basalts could be produced through assimilation and fractional crystallization in which primary alkali basaltic and olivine tholeiitic melts `erode' and assimilate the base of the crust. The increasingly tholeiitic character of the basalts towards the centre of Iceland, which reflects a higher degree of partial melting, is qualitatively consistent with increasing geothermal gradient and negative gravity anomaly.The highest Sr isotope ratio in Recent basalts from Iceland is observed in Oraefajokull volcano, which has a 3He/4He ratio (R/Ra [approximate] 7.8) close to the MORB value, and this might represent a mantle source similar to that of Mauna Loa in Hawaii.

Sigmarsson, O., Karlsson, H.R., and Larsen, G. (2000) "The 1996 and 1998 subglacial eruptions beneath the Vatnajökull ice sheet in Iceland: contrasting geochemical and geophysical inferences on magma migration ": Bulletin of Volcanology v. **61**(7): p. 468-476

The spectacular 1996 jökulhlaup from the subglacial lake at Grímsvötn central volcano, beneath the Vatnajökull ice sheet in Iceland, was generated by a subglacial eruption at Gjálp midway between Bárdarbunga and Grímsvötn central volcanoes. This eruption was preceded by a 24-h earthquake swarm that originated at Bárdarbunga and migrated 20 km southward toward the eruption site. To test the hypothesis that a horizontal dyke fed the 1996 eruption from Bárdarbunga volcano, we measured major and trace element abundances and O, Sr, and Nd isotope compositions in the 1996 volcanic rocks and selected samples from the Bárdarbunga, Grímsvötn, and Öræfajökull volcanic systems. Lava flows and tephra from a given volcanic system beneath the Vatnajökull ice sheet have indistinguishable isotope compositions. Gjálp and Grímsvötn products have identical 87Sr/86Sr (0.70322) and i18O (~2.9‰), whereas significantly lower and higher values, respectively, are found in samples from the Bárdarbunga volcanic system (0.70307 and 3.8‰). These results strongly indicate that the Gjálp magma originated from the Grímsvötn magma system. The 1996 magma is of an intermediate composition, representing a basaltic icelandite formed by 50% fractional crystallization of a tholeiite magma similar in composition to that expelled by the 1998 Grímsvötn eruption. The differentiation that produced the Gjálp magma may have taken place in a subsidiary magma chamber that last erupted in 1938 and would be located directly beneath the 1996 eruption site. This chamber was ruptured when a tectonic fracture propagated southward from Bárdarbunga central volcano, as indicated by the seismicity that preceded the eruption. Our geochemical results are therefore not in agreement with lateral magma migration feeding the 1996 Gjálp eruption. Moreover, the results clearly demonstrate that isotope ratios are

excellent tracers for deciphering pathways of magma migration and permit a clear delineation of the volcanic systems beneath Vatnajökull ice sheet.

St. Leger, R.G.T., and Gall, A. (1952) "Climbing Hvanndalshnúkur in August": Jökull, v. **2**(28-30).

Stefánsson, Á. (1952) "Fyrsta páskaferð á Öræfajökul": Jökull, v. **2**: p. 20-21.

Stefánsson Skaftafelli, R. (1987) "Slysið á Vatnajökli 1953": Skaftfellingur, v. **5**: p. 19-31.

Stevenson, J.A., McGarvie, D.W., Smellie, J.L., and Gilbert, J.S. (2006) "Subglacial and ice-contact volcanism at the Öræfajökull stratovolcano, Iceland ": Bulletin of Volcanology, v. **68**(7-8): p. 737-752.

Eruptions of Öræfajökull have produced mafic and silicic magmas, and have taken place in both glacial and interglacial periods. The geology of the volcano records the differing response of magmas of contrasting composition to interaction with ice of variable thickness and gives insight into the development of a long-lived ice-covered stratovolcano. Vatnafjall, a ridge on the southeast flank of Öræfajökull, is the first area of the volcano to have been mapped in detail and the geological map is presented here alongside descriptions of each erupted unit. The oldest units comprise pillow lavas, hyaloclastite and jointed lava flows that were formed during subglacial basaltic eruptions involving abundant meltwater. The products of a subsequent explosive, initially phreatomagmatic, subglacial rhyolite eruption were confined by ice to form a tephra pile over 200 m thick that was intruded by dense rhyolite magma towards the end of the eruption. Confinement by ice caused a later trachydacite lava flow to form buttresses and a steep pillar. Whilst some of the meltwater produced infiltrated the lava (to generate red and black glassy breccias and cause localised steam explosions), it is likely that much of it drained down the steep topography. The most recently-erupted units are subaerial basaltic lava flows, the oldest of which were erupted during an interglacial period and have subsequently been partially eroded and scoured by advancing ice. Ice has been important in shaping the edifice by confining eruptive products to form constructional features and by later eroding parts of them to form deep valleys. Reconstructions of volcano-ice interaction allowed the local thickness of the glacier at the time of each eruption to be estimated, and demonstrates that the upper surface of the ice has varied in elevation by over ~700 m.

Sæmundsson, B. (1906) "Hæðin á Öræfajökli": Skirnir, v. **80**: p. 88.

Thoroddsen, o. (1908-1922) Vatnajökull, *in* Thoroddsen, o., ed., Lýsing Íslands: Kaupmannahöfn, Hið íslenska bókmenntafélag, p. 2.b. s. 38-68.

Þorsteinsson, P. (1992) "Rauðalækur í Héraði milli sanda": Skaftfellingur, v. **8**: p. 140-158.

Þórarinsson, S. (1957) "Hérað milli sanda og eyðing þess": Andvari, v. **82. árg.**: p. 35-47.

— (1958) "The Öræfajökull eruption of 1362": Acta Nat. Isl. , v. **II** (2): p. 1-99.

— (1959) Der Öræfajökull und die Landschaft Öræfi. , Miscellaneous papers, Volume **22**: Bonn, Museum of Natural History.Department of Geology and Geography, p. 124.-138.

— (1959) "Der Öræfajökull und die Landschaft Öræfi; die Entwicklung einer islaendischen Siedlung im Kampf gegen die Naturgewalten": Erdkunde, v. **Bd138**: p. 124-138.

— (1975) Glacier : adventure on Vatnajökull, Europe's largest ice cap: Reykjavík, Iceland Review [2], 95, [3] s. : myndir, kort p.

— (1975) Vatnajökull : tignarheimur frosts og funa: Reykjavík, Heimskringla, [2], 95, [3] s. : myndir, kort p.

— (1979) "Hérað milli sanda og eyðing þess": Lesarkir Náttúruverndarráðs v. **2**.

Þórðarson, T., and Larsen, G. (2007) "Volcanism in Iceland in historical time: Volcano types, eruption styles and eruptive history": Journal of Geodynamics, v. **43**(1): p. 118-152.

The large-scale volcanic lineaments in Iceland are an axial zone, which is delineated by the Reykjanes, West and North Volcanic Zones (RVZ, WVZ, NVZ) and the East Volcanic Zone (EVZ), which is growing in length by propagation to the southwest through pre-existing crust. These zones are connected across central Iceland by the Mid-Iceland Belt (MIB). Other volcanically active areas are the two intraplate belts of Oraefajokull (OVB) and Snaefellsnes (SVB). The principal structure of the volcanic zones are the 30 volcanic systems, where 12 are comprised of a fissure swarm and a central volcano, 7 of a central volcano, 9 of a fissure swarm and a central domain, and 2 are typified by a central domain alone.Volcanism in Iceland is unusually diverse for an oceanic island because of special geological and climatological circumstances. It features nearly all volcano types and eruption styles known on Earth. The first order grouping of volcanoes is in accordance with recurrence of eruptions on the same vent system and is divided into central volcanoes (polygenetic) and basalt volcanoes (monogenetic). The basalt volcanoes are categorized further in accordance with vent geometry (circular or linear), type of vent accumulation, characteristic style of eruption and volcanic environment (i.e. subaerial, subglacial, submarine).Eruptions are broadly grouped into effusive eruptions where >95% of the erupted magma is lava, explosive eruptions if >95% of the erupted magma is tephra (volume calculated as dense rock equivalent, DRE), and mixed eruptions if the ratio of lava to tephra occupy the range in between these two end-members. Although basaltic volcanism dominates, the activity in historical time (i.e. last 11 centuries) features expulsion of basalt, andesite, dacite and rhyolite magmas that have produced effusive eruptions of Hawaiian and flood lava magnitudes, mixed eruptions featuring phases of Strombolian to Plinian intensities, and explosive phreatomagmatic and magmatic eruptions spanning almost the entire

intensity scale; from Surtseyan to Phreatoplinian in case of "wet" eruptions and Strombolian to Plinian in terms of "dry" eruptions. In historical time the magma volume extruded by individual eruptions ranges from ~1 m3 to ~20 km3 DRE, reflecting variable magma compositions, effusion rates and eruption durations.All together 205 eruptive events have been identified in historical time by detailed mapping and dating of events along with extensive research on documentation of eruptions in historical chronicles. Of these 205 events, 192 represent individual eruptions and 13 are classified as "Fires", which include two or more eruptions defining an episode of volcanic activity that lasts for months to years. Of the 159 eruptions verified by identification of their products 124 are explosive, effusive eruptions are 14 and mixed eruptions are 21. Eruptions listed as reported-only are 33. Eight of the Fires are predominantly effusive and the remaining five include explosive activity that produced extensive tephra layers. The record indicates an average of 20-25 eruptions per century in Iceland, but eruption frequency has varied on time scale of decades. An apparent stepwise increase in eruption frequency is observed over the last 1100 years that reflects improved documentation of eruptive events with time. About 80% of the verified eruptions took place on the EVZ where the four most active volcanic systems (Grimsvotn, Bardarbunga-Veidivotn, Hekla and Katla) are located and 9%, 5%, 1% and 0.5% on the RVZ-WVZ, NVZ, OVB, and SVB, respectively. Source volcano for ~4.5% of the eruptions is not known.Magma productivity over 1100 years equals about 87 km3 DRE with basaltic magma accounting for about 79% and intermediate and acid magma accounting for 16% and 5%, respectively. Productivity is by far highest on the EVZ where 71 km3 (~82%) were erupted, with three flood lava eruptions accounting for more than one half of that volume. RVZ-WVZ accounts for 13% of the magma and the NWZ and the intraplate belts for 2.5% each. Collectively the axi l zone (RVZ, WVZ, NVZ) has only erupted 15-16% of total magma volume in the last 1130 years.

4.1.10 Sandfell

Björnsson, F. (1974) "Gosmenjar upp af Sandfellsfjalli ": Náttúrufræðingurinn, v. **44**(1.hefti): p. 95-96.

Jónsson, J.A., and Sigmundsson, S. (1997) Skaftafellssýsla : sýslu- og sóknalýsingar Hins íslenska bókmenntafélags 1839-1873: Reykjavík, Sögufélag, xvi, 296 s. : myndir, teikn. p.

Þorsteinsson, P. (1978) Þjóðlífsþættir: Reykjavík, Örn og Örlygur, 147 s. : mynd p.

Öræfin ; Ingólfshöfði ; Hrollaugur og niðjar hans ; Bústaður Kára Sölmundarsonar ; Lögsögumaðurinn ; Vísa Orms ; Þekkingarleit ; Sandfellsprestar ; Villiféð á Eystrafjalli ; Vatnajökulsferð ; Samgöngumál ; Óskaland ; Ungmennafélögin og uppeldið ; Þjóðarandinn ; Hátíð barnanna

4.1.11 Ingólfshöfði

Björnsson, H. (1950) "Gróður í Ingólfshöfða": Náttúrufræðingurinn, v. **20. árg.**: p. 185-187.

Björnsson Kvískerjum, S. (1984) "Ingólfshöfði": Skaftfellingur v. **4**: p. 67-82.

Hannesson, S.Ö. (2005) "Ingólfshöfði - heillandi heimur : slegist í för með Sigurði Bjarnasyni ferðabónda og sagnamanni ": Glettingur, v. **15 (39-40. tölubl.)**(2-3): p. 6-12.

Todtmann, E.M. (1934) "Ingólfshöfði": Sérpr. úr Island, Vierteljahrsschrift der Vereinigung der Islandfreunde: p. [2], 25.-30. s., [1] mbl.

Þorsteinsson, P. (1978) Þjóðlífsþættir: Reykjavík, Örn og Örlygur, 147 s. : mynd p.

Öræfin ; Ingólfshöfði ; Hrollaugur og niðjar hans ; Bústaður Kára Sölmundarsonar ; Lögsögumaðurinn ; Vísa Orms ; Þekkingarleit ; Sandfellsprestar ; Villiféð á Eystrafjalli ; Vatnajökulsferð ; Samgöngumál ; Óskaland ; Ungmennafélögin og uppeldið ; Þjóðarandinn ; Hátíð barnanna

4.1.12 Salthöfði

Björnsson, H., and Björnsson, S. (1978) "Salthöfðafriðland": Týli, v. **8. árg.** (1. hefti): p. 33-34.

4.1.13 Virkisjökull, Virkisá, Falljökull

Escritt, E.A. (1972) "Map of Falljökull": Jökull, v. **22**: p. 62-64.

Everest, J., and Bradwell, T. (2003) "Buried glacier ice in southern Iceland and its wider significance": Geomorphology, v. **52**(3-4): p. 347-358.

Geo-electrical resistivity surveys have been carried out at recently deglaciated sites in front of three glaciers in southern Iceland: Skeiðarárjökull, Hrútarjökull, and Virkisjökull. The results show the presence of old glacier ice beneath debris mantles of various thickness. We conclude that buried glacier ice has survived for at least 50 years at Virkisjökull and Hrútarjökull, and probably for over 200 years at Skeiðarárjökull. Additional data from a further site have identified a discontinuous ice core within 18th-century jokulhlaup deposits. Photographic and lichenometric evidence show that the overlying debris has been relatively stable, and hence melting of the ice at all four sites is proceeding slowly due to the heat-shielding properties of the overburden. The geomorphic implications are pertinent when considering the potential longevity of buried ice. The possible implications for dating techniques, such as lichenometry, radiocarbon dating and cosmogenic surface-exposure dating are also important, as long-term readjustments of surface forms may lead to dating inaccuracy. Finally, it is recognised that landscape development in areas of stagnant ice topography may post-date initial deglaciation by a considerable degree. (C) 2002 Elsevier Science B.V. All rights reserved.

Guðmundsson, H.J. (1998) Holocene glacier fluctuations and tephrochronology of the Öræfi district, Iceland [**PhD thesis**], University of Edinburgh, Scotland.

Nicholas, A.P., and Sambrook Smith, G.H. (1998) "Relationships Between Flow Hydraulics, Sediment Supply, Bedload Transport and Channel Stability in the Proglacial Virkisá River, Iceland": Geografiska Annaler, v. **80A**(2): p. 111-122.

We present data from a proglacial river in Iceland that exhibits very different sedimentological characteristics when compared to its alpine counterparts. The braidplain is characterised by coarse outburst gravels that inhibit sediment transport and channel change. Bedload transport is restricted to the movement of fine-grained gravels that pass through the channel system without promoting significant changes in channel geometry. Bar forms are erosional features, inherited from the last major peak flow, rather than depositional in nature. On the basis of our observations we conclude that braidplain morphology is controlled by low frequency, high magnitude flow events, possibly associated with glacial outburst floods. This is in marked contrast to process-form relationships in more dynamic alpine proglacial channels that are characterised by high rates of sediment transport and channel change.

4.1.14 Háalda

Engar heimildir fundust

4.1.15 Kotárjökull, Kotá

Guðmundsson, H.J. (1998) Holocene glacier fluctuations and tephrochronology of the Öræfi district, Iceland [**PhD thesis**], University of Edinburgh, Scotland.

Morse, A., and Hunt, C. (1989) University of Liverpool and Liverpool Polytechnic Iceland Research Expedition, 1989. Final Report.: Liverpool, University of Liverpool and Liverpool Polytechnic.

A scientific research and teaching expedition to study the glaciers, the fluvial-glacial systems, proglacial landforms, sediments, meteorology, soils and natural vegetation in teh Öræfi district of south-east Iceland

4.1.16 Stígárjökull, Stígá

Björnsson, S. (1989) "Stigafoss": Skaftfellingur, v. **6**: p. 153-154.

Harris, T., Tweed, F.S., and Knudsen, O. (2004) "A Polygenetic Landform At Stígá;Öræfajökull, Southern Iceland": Geografiska Annaler, v. **86A**(2): p. 143-154.

Abstract Recent research has identified problems inherent in the identification and description of landforms. Morphologically similar small-scale glacial and periglacial landforms can be misinterpreted, thus hindering environmental reconstruction. This *study reveals that a landform resembling a moraine at Stigarjokull, southern Iceland, is the product of both glacial deposition and mass movement. The landform has two distinct morphological and sedimentological components: a basal, lithologically diverse component, and an upper, lithologically homogenous component. Clast lithological analysis, particle shape and particle size measurements demonstrate that the basal component of the landform consists of sediment whose characteristics match nearby moraines. In contrast, the source of the upper component is a narrow outcrop of rock above the valley floor. Evidence suggests that frost-shattered material was transported across a perennial snow patch to a small moraine, leading to growth of the 'moraine'. This combination of processes is unlikely to be unique, but the geological peculiarities of the field site permitted their identification. It is possible that many similar 'moraines' could be enlarged by subaerial feeding, leading to false reconstruction of glacier form and/or associated rates of erosion and sedimentation. Such polygenetic landform genesis therefore has implications for environmental reconstruction.*

4.1.17 Hólárjökull, Hólá

Evans, D.J.A., Archer, S., and Wilson, D.J.H. (1999) "A comparison of the lichenometric and Schmidt hammer dating techniques based on data from the proglacial areas of some Icelandic glaciers": Quaternary Science Reviews, v. **18**(1): p. 13-41.

Measurements of Rhizocarpon section and Schmidt hammer R-values are reported from the proglacial geomorphic features on the forelands of the Icelandic glaciers of Kvíárjökull, Hólárjökull and Heinabergsjökull (Öræfi and south Vatnajökull), Sandfellsjökull and Öldufellsjökull (east Mýrdalsjökull), and Brúárjökull, Eyjabakkajökull and west Snæfell (north Vatnajökull). These data are used in reconstructions of patterns of glacier recession since the Little Ice Age maximum, and the geomophic signals of climatic versus non-climatic events are discussed. Age control was obtained from various dated substrates by utilizing historical accounts, aerial photographs and grave stones. Three lichen growth rates are calculated: (a) 0.51 mm a−1 (corrected to 0.50 mm a−1) with a colonization lag time of < 16 yr for the arid forelands of north Vatnajökull; (b) 0.56 mm a−1 with a colonization lag time of 5 yr for the Icelandic southeast coast; and (c) 0.80 mm a−1 with a colonization lag time of 6.5 yr for the south Vatnajökull and east Mýrdalsjökull forelands. These compare favourably with a previously published growth rate of 0.44 mm a−1 for the arid north of Iceland. This regional coverage of data allows a comparison between annual precipitation totals and lichen growth rates and the construction of a growth rate prediction curve for Iceland. The success of the Schmidt hammer in differentiating moraines based upon age varied according to the geomorphological setting. Reasonable R-value/lichen size correlations were obtained on the east Mýrdalsjökull and Heinabergsjökull forelands where unrestricted glacier advance into lowlands allows for a higher degree of debris surface freshening by direct glacial processes. Weak correlations were obtained at Kvíárjökull, where the glacier was restricted by a precursor latero-frontal moraine loop and therefore the debris comprising the Little Ice Age recessional moraines was diluted with material of various ages being reworked by mass movement from the precursor moraine loop. Similar problems arise in areas affected by surging glaciers, such as Brúárjökull and Eyjabakkajökull. It appears that an accurate R-value age-prediction curve can not be constructed for a timescale of < 100 yr in Iceland.

4.1.18 Kvíárjökull, Kvíá, Kvíármýrarkambur

Ástvaldsson, L.R. (1984) Athuganir við sporð Kvíárjökuls [**Lokaritgerð H.Í.**], Háskóli Íslands.

Björnsson, F. (1956) "Kvíárjökull": Jökull v. **6**: p. 20-22.

— (1987) "Gosminjar í grennd við Kvíárjökul": Náttúrufræðingurinn, v. **57. árg.**(3. hefti): p. bls. 131-135.

Björnsson, S. (1993) "Hvað gerðist við Kvíárjökull í lok ísaldar": Náttúrufræðingurinn v. **62**(1-2): p. bls. 21-33.

Black, T. (1990) The Late Holocene Fluctuations of Kvíárjökull, Southeastern Iceland [**Unpublished Master´s thesis**]: Boulder, Colorado, University of Colorado.

Domínguez, M.C., and Eraso, A. (1999) "Distribution law of directional anisotropy in Kviarjökull ice tongue (Iceland)": NIMBUS v. **23-24**: p. 108-110.

Domínguez, M.C., Eraso, A., and Jonsson, S. (1999) "Kviarjökull glacier (Iceland): result of glaciological expeditions1996-97-99 ": NIMBUS v. **23-24**: p. 111-112.

Domínguez, M.C., Eraso, A., and Jónsson, A. (2002) "Kvíárjökull glacier (Iceland): result of glaciological expeditions 1996-97-99": Nimbus, v. **23-24**: p. 111-112.

Ebert, T. (2003) Identifying Glaciohydraulic Supercooling at Hoffelsjökull and Kvíárjökull, Iceland [**Unpublished MSc thesis**], Lehigh University.

Eraso, A., and Domínguez, M.C. (2005) Hydrological year 2003/2004 of discharge in Kvíárjökull Glacier catchment pilot area (CPE-KVIA-64°N), *in* Mavlyudov, B.R., ed., Glacier Caves and Glacial Karst in High Mountains and Polar Regions. 7th GLACKIPR Symposium: Moscow, Institute of geography of the Russian academy of Sciences, p. 27-35.

Eraso, A., and Domínguez, M.C. (2003) Implementation of experimental pilot catchment areas for the study of the discharge of subpolar glaciers, Proceedings of the 6th International Symposium on Glacier Caves and Karst in Polar Regions: Ny-Alesund.

Eraso, A., Domínguez, M.C., and Jónsson, S. (2003) Necessary strategy to study glacier discharge continuously: pilot catchment areas implemented in Iceland, Proceedings of the 6th International Symposium on Glacier Caves and Karst in Polar Regions: Ny-Alesund, p. 109-116.

Eiríksson, J., and others (1994) Roadlog : Nordic geological excursion in Iceland : quaternary geology - glaciology Reykjavík, myndir, kort, línurit p.

Evans, D.J.A., Archer, S., and Wilson, D.J.H. (1999) "A comparison of the lichenometric and Schmidt hammer dating techniques based on data from the proglacial areas of some Icelandic glaciers": Quaternary Science Reviews, v. **18**(1): p. 13-41.

Measurements of Rhizocarpon section and Schmidt hammer R-values are reported from the proglacial geomorphic features on the forelands of the Icelandic glaciers of Kvíárjökull, Hólárjökull and Heinabergsjökull (Öræfi and south Vatnajökull), Sandfellsjökull and Öldufellsjökull (east Mýrdalsjökull), and Brúárjökull, Eyjabakkajökull and west Snæfell (north Vatnajökull). These data are used in reconstructions of patterns of glacier recession since the Little Ice Age maximum, and the geomophic signals of climatic versus non-climatic events are discussed. Age control was obtained from various dated substrates by utilizing historical accounts, aerial photographs and grave stones. Three lichen growth rates are calculated: (a) 0.51 mm a−1 (corrected to 0.50 mm a−1) with a colonization lag time of < 16 yr for the arid forelands of north Vatnajökull; (b) 0.56 mm a−1 with a colonization lag time of 5 yr for the Icelandic southeast coast; and (c) 0.80 mm a−1 with a colonization lag time of 6.5 yr for the south Vatnajökull and east Mýrdalsjökull forelands. These compare favourably with a previously published growth rate of 0.44 mm a−1 for the arid north of Iceland. This regional coverage of data allows a comparison between annual precipitation totals and lichen growth rates and the construction of a growth rate prediction curve for Iceland. The success of the Schmidt hammer in differentiating moraines based upon age varied according to the geomorphological setting. Reasonable R-value/lichen size correlations were obtained on the east Mýrdalsjökull and Heinabergsjökull forelands where unrestricted glacier advance into lowlands allows for a higher degree of debris surface freshening by direct glacial processes. Weak correlations were obtained at Kvíárjökull, where the glacier was restricted by a precursor latero-frontal moraine loop and therefore the debris comprising the Little Ice Age recessional moraines was diluted with material of various ages being reworked by mass movement from the precursor moraine loop. Similar problems arise in areas affected by surging glaciers, such as Brúárjökull and Eyjabakkajökull. It appears that an accurate R-value age-prediction curve can not be constructed for a timescale of < 100 yr in Iceland.

Guðmundsson, H.J. (1998) Breytingar á Kvíárjökli á Nútíma. , *in* (ritstj.):, G.S.A., ed., Kvískerjabók: rit til heiðurs systkinunum á Kvískerjum: Höfn í Hornafirði, Sýslusafn Austur-Skaftafellssýslu, p. bls. 49-55.

— (1998) Holocene glacier fluctuations and tephrochronology of the Öræfi district, Iceland [**PhD thesis**], University of Edinburgh, Scotland.

Henderson, E. (1957) Ferðabók : frásagnir um ferðalög um þvert og endilangt Ísland árin 1814 og 1815 með vetursetu í Reykjavík Reykjavík, Snæbjörn Jónsson.

Hoppe, G. (1953) "Nagra iakttagelser vid islandska joklar sommaren 1952": Ymer, v. **73**(4): p. 241-265.

— (2004) Svíar í rannsóknaferðum til Íslands fyrr og nú, *in* Björnsson, H., ed., Jöklaveröld, náttúra og mannlíf: Reykjavík, Skrudda, p. 265-318.

Spedding, N., and Evans, D.J.A. (2002) "Sediments and landforms at Kvíárjokull, southeast Iceland: a reappraisal of the glaciated valley landsystem": Sedimentary Geology, v. **149**(1-3): p. 21-42.

Eyles identified Kvíárjökull, an outlet of the icecap Öræfajökull, southeast Iceland, as an exemplar of the glaciated valley landsystem, emphasising rockfall debris supply, passive transport and reworking of a thick cover of supraglacial morainic till. In this paper, we take a fresh look at the sediments and landforms of Kviarjokull, focusing on clast form analysis to reconstruct primary transport pathways. New data demonstrate the importance of active transport of debris derived from the glacier bed. Substantial portions of the supraglacial debris cover can be traced back to englacial channel fill deposits or anomalously thick exposures of basal ice. These two types of sediments also make up much of Kviarjokull's large Neoglacial moraine rampart. We attribute the abundance of these non-rockfall sediments to the presence of a terminal overdeepening, and the switch from predominantly subglacial to predominantly englacial drainage that this induces. This hydrological switch enhances retention of debris within ice transport, preventing it from being washed away and making it available to feed ice-marginal moraine formation. The complexity of sediment transport processes observed at Kviarjokull and the contrast between it and alpine glaciers undermines any single concept of the glaciated valley landsystem; accordingly, we propose Kvíárjokull as the type example of a distinct subclass, defined by its moderate relief, high-debris turnover, and drainage behaviour characteristic of an overdeepened basin.

Swift, D.A., Evans, D.J.A., and Fallick, A.E. (2006) "Transverse englacial debris-rich ice bands at Kvíárjökull, southeast Iceland." Quaternary Sciences Reviews v. **25**(13-14): p. 1708-1718

Thick exposures of debris-rich ice at various Icelandic glaciers are central to the debate over the prevalence of glacial sediment transfer by glaciohydraulic supercooling. We present physical analyses of ice and debris at Kvíárjoǩull, a temperate glacier in southeast Iceland with a terminal glacier-bed overdeepening, where stratified debris-rich ice forms up to metre-thick transverse englacial bands. Our results are not consistent with debris-rich ice formation predominantly by supercooling because: (1) 137Cs was absent from sediment filtered from debris-rich ice; (2) isotopic analysis (δD and δ18O) demonstrated no clear pattern of isotopic enrichment of debris-rich ice with respect to englacial ice; and (3) melt-out debris from debris-rich ice included large striated clasts from both fluvial and basal sources. We support transverse englacial debris-rich ice band formation by the thickening and elevation of basal materials in a region of longitudinally compressive ice flow situated between the reverse slope of the overdeepening and the base of an ice fall. Debris band form and distribution are likely to be controlled by thrusting along transverse englacial foliae associated with the formation of band ogives on the glacier surface.prevalence of glacial sediment transfer by glaciohydraulic supercooling. We present physical analyses of ice and debris at Kvíárjoǩull, a temperate glacier in southeast Iceland with a terminal glacier-bed overdeepening, where stratified debris-rich ice forms up to metre-thick transverse *englacial bands. Our results are not consistent with debris-rich ice formation predominantly by supercooling because: (1) 137Cs was absent from sediment filtered from debris-rich ice; (2) isotopic analysis (δD and δ18O) demonstrated no clear pattern of isotopic enrichment of debris-rich ice with respect to englacial ice; and (3) melt-out debris from debris-rich ice included large striated clasts from both fluvial and basal sources. We support transverse englacial debris-rich ice band formation by the thickening and elevation of basal materials in a region of longitudinally compressive ice flow situated between the reverse slope of the overdeepening and the base of an ice fall. Debris band form and distribution are likely to be controlled by thrusting along transverse englacial foliae associated with the formation of band ogives on the glacier surface.*

Þórarinsson, S. (1956) "On the variations of Svínafellsjökull, Skaftafellsjökull and Kvíárjökull in Öræfi (Ágrip)." Jökull v. **6**: p. 1-15.

4.1.19 Hrútárjökull, Hrútá

Björnsson, F. (1959) "Göngin í Hrútárjökli": Jökull, v. **9**: p. 30-32.

Björnsson, S. (1958) "Úr bréfum. Hrútárjökull og draumur Guðrúnar Bjarnadóttir ": Jökull v. **8**(bls. 36).

Everest, J., and Bradwell, T. (2003) "Buried glacier ice in southern Iceland and its wider significance": Geomorphology, v. **52**(3-4): p. 347-358.

Geo-electrical resistivity surveys have been carried out at recently deglaciated sites in front of three glaciers in southern Iceland: Skeiðarárjökull, Hrútarjökull, and Virkisjökull. The results show the presence of old glacier ice beneath debris mantles of various thickness. We conclude that buried glacier ice has survived for at least 50 years at Virkisjökull and Hrútarjökull, and probably for over 200 years at Skeiðarárjökull. Additional data from a further site have identified a discontinuous ice core within 18th-century jokulhlaup deposits. Photographic and lichenometric evidence show that the overlying debris has been relatively stable, and hence melting of the ice at all four sites is proceeding slowly due to the heat-shielding properties of the overburden. The geomorphic implications are pertinent when considering the potential longevity of buried ice. The possible implications for dating techniques, such as lichenometry, radiocarbon dating and cosmogenic surface-exposure dating are also important, as long-term readjustments of surface forms may lead to dating inaccuracy. Finally, it is recognised that landscape development in areas of stagnant ice topography may post-date initial deglaciation by a considerable degree.

4.1.20 Fjalls(ár)jökull, Fjallsá, Fjallsárlón

Björnsson, F. (1962) "Fjallsárhlaupið 1962 og athuganir á lóninu í Breiðamerkurfjalli. (The glacier burst in Fjallsá 1962)": Jökull, v. **12**: p. 42-43.

Björnsson, S. (1963) "Jökulbogi við Fjallsjökul": Jökull, v. **13**(3. hefti): p. 18.

Evans, D.J.A., and Twigg, D.R. (2002) "The active temperate glacial landsystem: a model based on Breiðamerkurjökull and Fjallsjökull, Iceland": Quaternary Science Reviews, v. **21**(20-22): p. 2143-2177.

Accurate interpretations of ancient glaciated terrains rely heavily on our knowledge of process-form relationships in contemporary glacierized basins. A landsystems model for temperate, actively receding glaciers is presented based upon Breiðamerkurjökull and Fjallsjökull, Iceland. Historical documentation, maps and/or aerial photography documenting recession since 1903 provide a unique series of "snapshots" of the evolving glacial geomorphology at these snouts. This documentation is employed in association with sedimentological investigations to assess the evolution of sediment-landform assemblages at active temperate glacier margins, using the wealth of geomorphological and sedimentological information produced during the recent recession of Breðamerkurjokull and Fjallsjökull. Three depositional domains are recognized: (1) areas of extensive, low amplitude marginal dump, push and squeeze moraines derived largely from material on the glacier foreland and often recording annual recession of active ice; (2) incised and terraced glacifluvial forms, such as recessional ice-contact fans and hochsandur fans, and simple and complex, anabranched eskers and small areas of pitted outwash; (3) subglacial landform assemblages of flutes, drumlins and overridden push moraines located between ice-marginal glacifluvial depo-centres. The lack of supraglacial sediment in active temperate glaciers like Brei[eth]amerkurjokull and Fjallsjokull generally precludes the widespread development of chaotic hummocky moraine. The hummocky terrain previously termed "kame and kettle topography" has mostly evolved by melt-out into a complex network of anabranched eskers over the period 1945-1998 or actually comprises pitted or kettled outwash (sandar). The tills across the foreland were emplaced by subglacial deformation and lodgement, and comprise materials derived from pre-existing stratified sediments in addition to localized abrasion of rock surfaces and patches of lake sediments. Till sequences thicker than 2 m have been constructed by the sequential plastering of till layers onto stratified sediments and bedrock. Because this stacking is a sub-marginal process, it is suggested that complex till sequences similar to those observed at Breiðamerkurjökull/Fjallsjökull may be employed in the reconstruction of ancient glacier margins. Additionally, the geomorphology of the active, temperate landsystem at east Breiðamerkurjokull may contain subtle surge signatures, verifying the historical record of small surges by this part of the glacier. This illustrates the danger of employing landform-sediment associations from restricted study areas (e.g. parts of landsystems) as representative process-form models for glaciated terrains.

Eyþórsson, J. (1951) "Breiðamerkurfjall ": Náttúrufræðingurinn, v. **21. árg**(1 hefti): p. 46-47.

— (1951) "Lónin", v. **21. árg**(1 hefti): p. 46

Guðmundsson, A.T. (1997) "Land úr lofti": Náttúrufræðingurinn, v. **66**(2): p. 88-90.

Hart, J.K., Khatwa, A., and Sammonds, P. (2004) "The effect of grain texture on the occurrence of microstructural properties in subglacial till": Quaternary Science Reviews v. **23**(23-24): p. 2501-2512.

In this paper, we examine whether till grain size affects the range and occurrence of micromorphological features associated with subglacial shear. Our till samples were collected from two glaciers in Iceland, and varied in texture from a coarse, sandy clast-rich till (Fjallsjökull) to a fine-grained silty-sandy till (Vestari-Hagafellsjökull). We found a wide range of deformational microstructures that included skelsepic plasmic fabric, intraclasts of pre-existing eroded bedrock (basalt) and weathered clay and 'mini-shear zones' between clasts. We classified our micromorphological data into three classes; rotational, intermediate and linear. In addition to these observations, we performed extensive microfabric analysis at different scales on all of our samples. We found that the coarse-grained till contained a greater number and variety of microstructures than the fine-grained till. In addition, the fine-grained till showed a distinct lack of rotational structures that we attribute to the lack of significantly sized clasts in the matrix. We argue that the varied texture of the coarse-grained till provides a greater degree of perturbation within the shearing layer and so more distinct microstructures form. In a more fine-grained till, shearing is more homogeneous since there are less perturbations in the matrix and this leads to a more singular kind of microstructure. Our observations suggest that subglacial shear occurs within a multi-layered patchwork of different grain sizes, competence and pore water pressures. It is these factors that are so crucial in determining the occurrence and type of microstructural evidence we see in subglacial tills.

Price, R.J. (1970) "Moraines at Fjallsjökull, Iceland. " Journal of Arctic and Alpine Research, v. **2**: p. pp.27-42.

4.1.21 Breiðamerkurfjall

Björnsson, F. (1962) "Fjallsárhlaupið 1962 og athuganir á lóninu í Breiðamerkurfjalli. (The glacier burst in Fjallsá 1962)": Jökull, v. **12**: p. 42-43.

Björnsson, S. (1982) "Breiðamerkurfjall": Skaftfellingur, v. **3**: p. 133-137.

Eyþórsson, J. (1951) "Breiðamerkurfjall ": Náttúrufræðingurinn, v. **21. árg**(1 hefti): p. 46-47.

Hjálmarsson, J.R. (1997) Í kaldri vist undir jökli : Sigurður Björnsson á Kvískerjum segir frá eftirminnilegri ferð í Breiðamerkurfjall 1936, Sunnan jökla, p. 131-140.

Sigurðsson, O. (2001) Jöklabreytingar á Islandi undanfarnar fjórar aldir, Vorráðstefna 2001: ágrið erinda og veggspjalda: Hótel Loftleiðum, Reykjavík, Jarðfræðifélag Íslands.

Þorsteinsson, M. (1982) "Fjárleitarferð í Breiðamerkurfjall": Skaftfellingur v. **3**: p. 119-132.

4.1.22 Breiðamerkurjökull, Breiðamerkursandur, Breiðá

Arnórsdóttir, T. (2006) Síðasta ferð yfir Breiðamerkurjökul.

Árnason, S. (1998) Mæling á rennsli og hitastigi í Jökulsá á Breiðamerkursandi, *in* Orkustofnun, ed., Vatnamælingar, greinargerð 1998-12-10, Orkustofnun.

Benn, D.I. (1995) "Fabric signature of subglacial till deformation, Breidamerkurjökull, Iceland ": Sedimentology, v. **42**(5): p. 735-747.

The foreland of Breidamerkurjökull, Iceland, is the only locality where tills known to have undergone subglacial deformation are exposed. Till on the foreland has a two-tiered structure, consisting of a dilatant upper horizon c 0.5 m thick and a compact lower till; these horizons correspond to the ductile deforming A horizon and the brittle-ductile B horizon observed below the glacier by G. S. Boulton and co-workers. The relationship between known strain history and a variety of macrofabric elements is examined for these two genetic facies of deformation till. The upper horizon exhibits variable a-axis fabrics and abundant evidence for clast re-alignment, reflecting ductile flow and rapid clast response to transient strains. In contrast, the lower horizon has consistently well organized a-axis fabrics with a narrow range of dip values, recording clast rotation into parallel with strain axes during brittle or brittle-ductile shear. The data indicate that till strain history imparts identifiable macrofabric signatures, providing important analogues to guide the interpretation of Pleistocene tills.

Benn, D.I., and Evans, D.J.A. (1996) "The interpretation and classification of subglacially-deformed materials": Quaternary Science Reviews, v. **15**(1): p. 23-52.

A general classification of subglacially-deformed materials is proposed, based on sediment properties and their relationship to styles of subglacial strain. Deformation till is defined as homogenized, usually diamictic material formed by glacially-induced shear of subsole materials. Three types are recognized: Type A, formed by pervasive, ductile deformation: Type B, formed by brittle shear; and comminution till, produced by the reduction of void space by in situ crushing and abrasion. The term glacitectonite is adopted for materials that have undergone subglacial shear but retain some of the structural characteristics of the parent material. Original structures may be truncated by glacitectonic fabric elements (Type A) or distorted but not truncated (Type B). The principles of strain and material response, particle orientation mechanisms, fabric development and drainage conditions are reviewed. Examples of deformation tills and glacitectonites from Breidamerkurjokull, Iceland; Slettmarkbreen, Norway; Loch Lomond, Scotland; and East Yorkshire, England, are used to illustrate the nature of subglacially-deformed materials and their relationship to former subglacial strain and drainage conditions. The geologic evidence suggests a continuum of bed strengths can be recognized in deforming substrata, ranging from high strength, low-strain Type B deformation till and comminution till to low strength, high strain Type A deformation till.

Björnsson, F. (1955) "Breiðárlón": Jökull, v. **5**: p. 42.

— (1977) "Veðurfar og snjóálag á Breiðamerkursandi": Veðrið, v. **1. hefti**: p. 27-30.

— (1993) "Samtíningur um Jökulsá á Breiðamerkursandi og Jökulsárlón": Eystrahorn, v. **11. árg.**(2. tbl.): p. 4-5.

— (1996) "Þættir um Breiðamerkursand": Skaftafellingur, v. **11. árgangur**: p. bls. 105-125.

Björnsson, H. (1996) "Scales and rates of glacial sediment removal: a 20 km long and 300 m deep trench created beneath Breiðamerkurjökull during the Little Ice Age": Annals of Glaciology, v. **22**: p. bls. 141-146.

— (1998) Frá Breiðumörk til jökulsands: mótun lands í þúsund ár. , *in* Árnason, G.S., ed., Kvískerjabók, Rit til heiðurs systkinunum á Kvískerjum: Höfn í Hornafirði, Sýslusafn Austur-Skaftafellssýslu, p. bls. 164-176.

Björnsson, H., and Ólafsson, E. (1986) "Fuglar í fjöllum og skerjum í Breiðamerkurjökli": Bliki. Tímarit um fugla, v. **5. árg.**: p. 6-18.

Björnsson, H., Pálsson, F., and Guðmundsson, M.T. (1992) Breiðamerkurjökull, niðurstöður íssjármælinga 1991, RH-92-12,, Raunvísindastofnun Háskólans p. 19 bls. + kort.

— (1992) Breiðamerkurjökull, results of radio echo soundings 1991, RH-92-12, Science Institute, University of Iceland, p. 19 bls.

Björnsson, S. (1971) "Jökulsá á Breiðamerkursandi": Tíminn-Sunnudagsblað, v. **10. árg.**: p. 244-246.

— (1977) "Hlaupið í Jökulsá á Breiðamerkursandi árið 1927 (The jökulhlaup in Jökulsá on Breiðamerkursandur in 1927) ": Jökull, v. **27. árg.**: p. bls. 94-95.

— (1978) "Hlaupið í Jökulsá á Breiðamerkursandi árið 1927. Athugasemd": Jökull, v. **28**: p. 90.

— (1982) "Breiðamerkurfjall": Skaftfellingur, v. **3**: p. 133-137.

— (1993) "Breiðamerkursandur (endurprentun í 44. árgangi Jökuls vegna mistaka í prentun)": Jökull, v. **43**: p. 67-69.

— (1994) "Breiðamerkurjökull." <u>Jökull</u>, v. **44**: p. bls. 57-60.

— (1994) "Breiðamerkursandur (endurprentun á grein úr 44. árgangi Jökuls vegna mistaka í prentun)": <u>Jökull</u>, v. **44**: p. 57-59.

Blaðamaður(DV) (2002) "Váin sem blasir við á Breiðamerkursandi: Tel best að stífla Jökulsá ": <u>DV</u>,**40. tbl. 92. og 28. árg.**(16. febr. 2002): p. 6.

Viðtal J.I. við P.I. um rofið og vána á Breiðamerkusandi

Bogadóttir, H., Boulton, G., Tómasson, H., and Thors, K. (1986) The structure of sediments beneath Breiðamerkursandur and the form of the underlying bedrock, *in* (ritstj.), G.S., ed., <u>Icelandic Coastal and River Symposium</u>: Reykjavík, Orkustofnun, p. p. 295-303.

Boulton, G., and Zatsepin, S. (2006) "Hydraulic impacts of glacier advance over a sediment bed": <u>Journal of Glaciology</u>, v. **52**(179): p. 497 - 527.

A sedimentary sequence of till overlying a gravel aquifer was instrumented wit waterpressure transducers prior to a small, anticipated surge of the margin of the glacier Breiðamerkurjökull in Iceland. The records of water pressure at each transducer site show a well-define temporal sequence of hydraulic regimes that reflect the changing recharge of surface-derive meltwater, the pressure drop along the drainage pathway and the pattern of ice loading. The poroelastic and water-pressure response of glacially overridden sediments to the recharge rate is determined in the frequency domain through an analytic solution. This permits the in situ conductivity, compressibility and consolidation states of subglacial sediments to be derived, and reveals aquifer-scale compressibility that produces an important water-pressure wave associated with the advancing glacier. The model is then used to explore how varying conductivity/compressibility, largely determined by granulometry, can determine drainage states and instabilities that may have a large impact on glacier/ice-sheet dynamics, and how the drainage time of surface water to the bed can determine the frequency response of subglacial groundwater regimes and their influence on subglacial sediment stability. Mismatches between model predictions and specific events in water-pressure records are used to infer processes that are not incorporated in the model: hydrofracturing that changes the hydraulic properties of subglacial sediments; the impact on groundwater pressure of subglacial channel formation; upwelling beyond the glacier margin; and rapid variations in the state of consolidation. The poroelastic model also suggests how seismic methods can be developed further to monitor hydraulic conditions at the base of an ice sheet or glacier.

Boulton, G.S., Dobbie, K.E., and Zatsepin, S. (2001) "Sediment deformation beneath glaciers and its coupling to the subglacial hydraulic system": <u>Quaternary International</u>, v. **86**(1): p. 3-28.

The extent and style of shear deformation in sediments beneath modern glaciers and the geological evidence for such deformation in deposited sediments are reviewed. New evidence is presented from beneath a modern glacier of the spatial and temporal patterns of water pressure fluctuation and of time dependent patterns of deformation in sediments. It is concluded that in most experimental sites beneath soft-bedded *modern glaciers, deformation is a significant or major contributor to glacier movement and the resultant discharge of till is large enough to make sediment deformation a major till forming process.Particular modes of deformation facilitate incorporation of underlying material into the till, whilst the capacity of a deforming till to absorb strain can protect the underlying strata from deformation, leading to the commonly found relationship where till overlies other strata with a sharp planar interface. It is argued that the almost ubiquitous occurrence of drumlins on the beds of former ice sheets is a reflection of the widespread occurrence of sediment deformation beneath them, with important implications for the coupling of ice sheet flow and bed properties.It is argued that the mechanical behaviour of the subglacial system is not simply determined by till properties but largely controlled by the subglacial water pressure regime determined by the nature of subglacial drainage. Results of field experiments show how the nature of the basal hydraulic system can play a vital role in controlling the coupling between the glacier and till deformation processes. They show that rapid glacier advances can produce undrained loading of sediments, that effective pressure may increase either upwards or downwards in a till according to the direction of drainage and that interstitial water pressures in subglacial sediments can show large and rapid variations, producing strong variations in the rate and distribution of strain and in the partitioning of basal movement between sliding and deformation.*

Denby, B., and Snellen, H. (2002) "A comparison of surface renewal theory with the observed roughness length for temperature on a melting glacier surface": Boundary-Layer Meteorology, v. **103**(3): p. 459-468.

The roughness lengths for momentum and temperature are calculated using the profile method on a melting glacier surface. Data from a 5-level 9-m meteorological mast positioned near the edge of Breidamerkurjokull, an outlet glacier of the Vatnajokull ice cap Iceland, are used for the calculations. The data are selected to avoid the presence of the katabatic wind speed maximum which would otherwise alter the scaling laws of the surface layer. The surface roughness length for momentum is determined to be 1.0 mm, similar to other estimates made on flat melting ice surfaces. The surface roughness length for temperature is found to be in good agreement with previously proposed surface renewal theories for the observed roughness Reynolds number range of 30 < Re- < 70.*

Einarsson, E. (1998) Ung og gömul jökulsker í Breiðamerkurjökli, *in* Árnason, G.S., ed., Kvískerjabók: Höfn, Sýslusafn Austur-Skaftafellssýslu, p. 222-254.

Einarsson, Eyþór., and others (1987) Skaftafell og Öræfi : þættir um náttúru og sögu, Hið íslenska náttúrufræðifélag, 20 s.: myndir, kort p.

Eiríksson, J., and others (1994) Roadlog : Nordic geological excursion in Iceland : quaternary geology - glaciology Reykjavík, myndir, kort, línurit p.

Evans, D.J.A., Lemmen, D.S., and Rea, B.R. (1999) "Glacial landsystems of the southwest Laurentide Ice Sheet: modern Icelandic analogues": Journal of Quaternary Science, v. **14**(7): p. 673-691.

Landform assemblages and associated stratigraphy, sedimentology and structure are used in the reconstruction of palaeo-ice-sheet dynamics in Alberta, western Canada. Interpretations are based upon the modern analogues from four outlet glaciers at the margins of Vatnajökull and Mýrdalsjökull, Iceland. In the area between Lloydminster and Lac la Biche, central Alberta, an extensive landform assemblage of megaflutings, crevasse-squeeze ridges and thrust-block-moraine arcs document the former surging of part of the margin of the Laurentide Ice Sheet during later stages of recession. This and form assemblage, including numerous exposures of glacitectonised bedrock and Quaternary sediments, is comparable to the landsystem of the surging glaciers Eyjabakkajökull and Brúarjokull in Iceland. Near High River southern Alberta, the former existence of an ice lobe characterised by active recession is recorded by closely spaced, low-amplitude recessional push moraines that drape tunnel valleys. These are comparable in form and pattern to annual push moraines and fluted till surfaces produced by Breidamerkurjokull and Sandfellsjokull, Iceland, and also include rimmed depressions produced by the escape of artesian water during ice-marginal pushing. This study provides interpretations of the regional glacial geomorphology of Alberta based upon comparisons of form and stratigraphy with modern glacial analogues, and provides an alternative to recent models which invoke large floods of subglacial meltwater to explain many of these same features. Implications for ice dynamics and regional till stratigraphies are discussed.

Evans, D.J.A., and Twigg, D.R. (2002) "The active temperate glacial landsystem: a model based on Breiðamerkurjökull and Fjallsjökull, Iceland": Quaternary Science Reviews, v. **21**(20-22): p. 2143-2177.

Accurate interpretations of ancient glaciated terrains rely heavily on our knowledge of process-form relationships in contemporary glacierized basins. A landsystems model for temperate, actively receding glaciers is presented based upon Breiðamerkurjökull and Fjallsjökull, Iceland. Historical documentation, maps and/or aerial photography documenting recession since 1903 provide a unique series of "snapshots" of the evolving glacial geomorphology at these snouts. This documentation is employed in association with sedimentological investigations to assess the evolution of sediment-landform assemblages at active temperate glacier margins, using the wealth of geomorphological and sedimentological information produced during the recent recession of Breðamerkurjokull and Fjallsjökull. Three depositional domains are recognized: (1) areas of extensive, low amplitude marginal dump, push and squeeze moraines derived largely from material on the glacier foreland and often recording annual recession of active ice; (2) incised and terraced glacifluvial forms, such as recessional ice-contact fans and hochsandur fans, and simple and complex, anabranched eskers and small areas of pitted outwash; (3) subglacial landform assemblages of flutes, drumlins and overridden push moraines located between ice-marginal glacifluvial depo-centres. The lack of supraglacial sediment in active temperate glaciers like Brei[eth]amerkurjokull and Fjallsjokull generally precludes the widespread development of chaotic hummocky moraine. The hummocky terrain previously termed "kame and kettle topography" has mostly evolved by melt-out into a complex network of anabranched eskers over the period 1945-1998 or actually comprises pitted or kettled outwash (sandar). The tills across the foreland were emplaced by subglacial deformation and lodgement, and comprise materials derived from pre-existing stratified sediments in addition to localized abrasion of rock surfaces and patches of lake sediments. Till sequences thicker than 2 m have been constructed by the sequential plastering of till layers onto stratified sediments and bedrock. Because this stacking is a sub-marginal process, it is suggested that complex till

sequences similar to those observed at Breiðamerkurjökull/Fjallsjökull may be employed in the reconstruction of ancient glacier margins. Additionally, the geomorphology of the active, temperate landsystem at east Breiðamerkurjokull may contain subtle surge signatures, verifying the historical record of small surges by this part of the glacier. This illustrates the danger of employing landform-sediment associations from restricted study areas (e.g. parts of landsystems) as representative process-form models for glaciated terrains.

Eyþórsson, J. (1934) "Skeiðarársandur hækkar : athuganir Helga Arasonar á Fagurhólsmýri": Náttúrufræðingurinn, v. **4**: p. 178-180.

— (1951) "Breiðamerkurfjall ": Náttúrufræðingurinn, v. **21. árg**(1 hefti): p. 46-47.

— (1951) "Breiðá": Jökull, v. **1**: p. 9.

— (1951) "Lónin", v. **21. árg**(1 hefti): p. 46

— (1952) "Þættir úr sögu Breiðár": Jökull, v. **2**: p. 17-20.

— (1953) Banaslys á Breiðamerkurjökli, frásögn Björns Pálssonar á Kvískerjum., *in* Hannesson, P., and Eyþórsson, J., eds., Hrakningar og heiðavegir, Volume **III**: Akureyri, Norðri, p. bls. 65-69.

— (1960) Vatnajökull: Reykjavík, Almenna bókafélagið, 44 s., [62] mbls. : teikn., ritsýni, uppdr. p.

Gavin, J.B., and Williams Jr., R.S. (1993) "Geodetic airborne laser altimetry of Breiðamerkurjökull and Skeiðarárjökull, Iceland and Jakobshavns Isbræ, West Greenland": Annals of Glaciology v. **17**: p. p. 379-385.

Guðmundsson, A.T. (1997) "Land úr lofti": Náttúrufræðingurinn, v. **66**(2): p. 88-90.

Guðmundsson, S., Björnsson, H., Pálsson, F., and Berthier, E. (2005) Rapid evolution of a proglacial coastal lake: 20th century changes in Jökulsárlón at Breiðamerkursandur, Vatnajökull, Iceland, Second international costal symposium in Iceland: Höfn í Hornafirði.

— (2006) Rapid evolution of a proglacial coastal lake: 20th century changes in Jökulsárlón at Breiðamerkursandur, Vatnajökull, Iceland, Opinn Háskóli.

Harðardóttir, J., Víkingsson, S., and Pálsson, S. (2006) Niðurstöður kornastærðargreininga og bergflokkunar sýna af Skeiðarár- og Breiðamerkursandi; Greinargerð, unnið fyrir Vegagerðina JHa-SV-SvP-2006/001: Reykjavík, Orkustofnun, p. 19 s. gröf, töflur.

Þrjú sýni af Skeiðarár- og Breiðamerkursandi voru kornastærðargreind og bergflokkuð á Vatnamælingum Orkustofnunar og niðurstöðurnar bornar saman við niðurstöður samskonar greiningar eldri sýna frá svæðinu. Meginmarkmið ransóknanna var að meta hvort hægt væri að útskýra minna strandrof við Jökulsá á Breiðamerkursandi síðastliðin ár með auknum efnisflutningum austur fyrir Ingólfshöfða í kjölfar hamfarahlaupsins á Skeiðarársandi árið 1996. Niðurstöður benda til að sandur austan við Jökulsá sé að öllum líkindum að hluta til kominn frá Skeiðarársandi, en þar gefa kornastærðargreiningar afdráttarlausari niðurstöður en bergflokkunin. Samanburður við eldri sýni er þó erfiður vegna mismunandi kornastæðrar nýrri og eldri bergflokkunarsýna og þar sem engin sýni voru tekin úr hlaupinu 1996 sem hægt er að bera saman við

Hoppe, G. (1953) "Nagra iakttagelser vid islandska joklar sommaren 1952": Ymer, v. **73**(4): p. 241-265.

— (2004) Svíar í rannsóknaferðum til Íslands fyrr og nú, *in* Björnsson, H., ed., Jöklaveröld, náttúra og mannlíf: Reykjavík, Skrudda, p. 265-318.

Howarth, P.J., and Price, R.J. (1969) "The proglacial lakes of Breiðamerkurjökull and Fláajökull, Iceland": Geographical Journal v. **135**(part 4): p. 573-581.

Imsland, P. (2000) The risk at Breiðamerkursandur Reykjavík, p. 60

— (2000) Váin á Breiðamerkursandi: náttúrufarslýsing, þróun, orsakir og eðli núverandi ástands ásamt framtíðarlausn á vandanum: Reykjavík, p. 60.

Jóhannesson, H. (1994) Coastal erosion near the bridges across Jökulsá á Breiðamerkursandi in southeastern Iceland, *in* Viggósson, G., ed., Proceedings of the International Coastal Symposium: Höfn, The Icelandic Harbour Authority, p. bls. 405-414.

— (1995) Landbrot framan við brúna yfir Jökulsá á Breiðamerkursandi, Árbók Verkfræðingafélags Íslands 1993/1994, p. bls. 311-319.

— (2004) "Rannsóknir og framkvæmdir við Jökulsá á Breiðamerkursandi. " Framkvæmdafréttir Vegagerðarinnar, v. **3. tbl., 12. árg.**(nr. 360, 16. febr. 2004).

Jóhannesson, H., and Sigurðarson, S. (2005) Strandrof og strandvarnir við brúna yfir Jökulsá á Breiðamerkursandi, Rannsóknir Vegagerðarinnar: Hótel Nordica, Reykjavík, Vegagerðin.

Jónsson, E. (2004) Í veröld jökla, sanda og vatna, *in* Björnsson, H., ed., Jöklaveröld, náttúra og mannlíf: Reykjavík, Skrudda, p. 11-86.

Jónsson, J. (1951) Breiðamerkursandur, Sandur-sandar: nokkrar athuganir: Hveragerði, Rannsóknastofnunin Neðri-Ás, p. bls. 32-33.

Kaltenbock, R., and Obleitner, F. (1999) "On a low cloud phenomenon at the Breiðamerkurjökull Glacier, Iceland": Boundary-Layer Meteorology, v. **92**(1): p. 145-162.

An impressive cloud wall has frequently been observed on the southern slopes of the Vatnajökull ice sheet, which is located in south-eastern Iceland. Its optical and dynamic features suggest a delicate balance of the atmospheric agents involved. This has been confirmed by a thorough analysis of a well documented event and by statistics covering a whole summer season. As an exemplary event, the regional development of the associated cloud has basically been documented with synchronous surface data along a suitable transect of the glacier. Data from tethered balloons, radiosoundings and routine synoptic data have also been exploited extensively. Cloud development was generally aided by a high moisture potential because of proximity to the open seas and the remnants of a frontal system. Furthermore the occurrence of the cloud phenomenon was associated with onshore (southerly) surface winds, assisting advection and lifting of the associated air masses above the slopes of the ice sheet. Northward protrusion of the associated cloud was apparently opposed by continuous katabatic winds and topographically induced lee effects.

Lister, H. (1953) "Report on glaciology at Breiðamerkurjökull 1951": Jökull v. **3**: p. p. 23-31.

Obleitner, F. (2000) "The energy budget of snow and ice at Breiðamerkurjökull, Vatnajökull, Iceland": Boundary-Layer Meteorology, v. **97**(3): p. 385-410.

Measurements of the energy and mass budgets have been made at the equilibrium line of Breidamerkurjokull, a southern outlet glacier of Vatnajokull, Iceland. The glacier`s surface was melting for most of the measurement period, which allowed for a reliable closure of the energy budget. Sensitivity studies focussed mainly on potential effects of measurement errors, site-specific micrometeorological conditions, surface development and different parameterization of the turbulent fluxes. Although the high stability and a roughness disturbance imposed certain restrictions, these studies confirmed the applicability of the Monin-Obukhov framework for the evaluation of turbulent fluxes The characteristics of the energy and mass budgets are discussed with respect to various time scales and significant weather conditions. Due to the masking glacial boundary layer, warm fronts appeared comparatively weak compared to the more vigorous cold fronts. The latter were often associated with lee effects and give striking signals in the turbulent fluxes. Transition from snow to ice induced a distinct change in the regime because of related albedo and roughness effects. A compilation of the major energy budget components at glaciers all over the world confirms the maritime regime at Vatnajokull.

Óla, Á. (1944) Öræfaferð Ferðafélagsins, *in* Óla, Á., ed., Landið er fagurt og frítt: Reykjavík, Bókfellsútgáfan, p. 138-172.

Parmhed, O., Oerlemans, J., and Grisogono, B. (2004) "Describing surface fluxes in katabatic flow on Breiðamerkurjökull, Iceland": Quarterly Journal of the Royal Meteorological Society, v. **130**(598): p. 1137-1151.

For very stable boundary layers there is no well-accepted theory today. In this study, an improved Prandtl model with varying diffusivity is applied to less than ideal conditions for pure katabatic flow pertaining to very stable boundary layers. We find that the improved Prandtl model adequately describes the usual and persistent katabatic glacier wind on Breiðamerkurjökull. This is true even for flows with very different heights and strengths of the jet. A theoretical estimate of the katabatic jet height, based on temperature deficit mid lapse rate, is verified. The calculated surface fluxes compare well with the measured turbulence parameters. A possible reason for the robustness of the katabatic jet (and other low-level jets) is given in terms of the Scorer parameter.

Pálsson, B. (1953) Banaslys á Breiðamerkurjökli; frásögn Björns Pálssonar á Kvískerjum, Jón Eyþórsson færði í letur, *in* Hannesson, P., and Eyþórsson, J., eds., Hrakningar og heiðarvegir, Volume **3.b.**: Akureyri, Norðri, p. 65-69

Pennington, N.R. (1978) A study of esker forms near the margin of the Breiðamerkurjökull glacier, southeast Iceland [**Unpublished Ph.D. thesis**], University of St. Andrews.

Price, R.J. (1968) "The University of Glasgow Breiðamerkurjökull project (1964-67). A progress report": Jökull, v. **18**: p. 389-394.

— (1969) "Moraines, sandur, kames and eskers near Breiðamerkurjökull, Iceland." Transactions of the Institute of British Geographers, v. **46** p. p. 17-43.

— (1971) "The development and destruction of a sandur, Breiðamerkurjökull, Iceland": Arctic and Alpine Research, v. **3**: p. p. 225-237.

— (1982) "Changes in the proglacial area of Breiðamerkurjökull, southern Iceland: 1890-1980. (Breytingar á jaðarsvæði Breiðamerkurjökuls)": Jökull v. **32**: p. p. 29-35.

Price, R.J., and Howarth, P.J. (1970) "Evolution of the drainage system (1904-1965) in front of Breiðamerkurjökull, Iceland": Jökull, v. **20**: p. 27-37.

Sigurðsson, B.D. (2005) "Mörg eru náttúruundrin : nýtt jökullón í Esjufjöllum og landnám gróðurs á Breiðamerkurjökli ": Glettingur, v. **15**(2-3): p. 48-52.

Sigurðsson, O. (1998) Landmótun á Breiðamerkursandi, *in* Árnason, G.S., ed., Kvískerjabók. Rit til heiðurs systkinunum á Kvískerjum: Höfn í Hornafirði, Sýslusafn Austur-Skaftafellssýslu, p. bls. 76-81.

— (2001) Jöklabreytingar á Islandi undanfarnar fjórar aldir, Vorráðstefna 2001: ágrið erinda og veggspjalda: Hótel Loftleiðum, Reykjavík, Jarðfræðifélag Íslands.

Soderberg, S., and Parmhed, O. (2006) "Numerical modelling of katabatic flow over a melting outflow glacier": Boundary-Layer Meteorology, v. **120**(3): p. 509-534.

A realistic simulation of katabatic flows is not a straightforward task for numerical models. One complicating factor is that katabatic flows develop within a stably stratified boundary layer, which is poorly resolved and described in many numerical models. To capture the jet-shaped shallow flow a model set-up with high vertical resolution is also required. In this study, 'a state of the art' mesoscale numerical model is applied in a simulation of katabatic flow over a melting glacier. A basic agreement between observations and model results is found. From scale analysis, it is concluded that the simulated flow can be classified as katabatic. Although the background flow varies in strength and direction, the simulated katabatic flow over Breiðamerkurjökull is persistent. Two factors vital for this persistence are identified. First, the melting snow maintains the surface temperature close to 0 degrees C while the air temperature warms adiabatically as it descends the slope. This provides a 'self enhanced' negative buoyancy that drives the flow to a balance with local friction. Second, the jet-like shape of the resulting flow gives rise to a large 'curvature term' in the Scorer parameter, which becomes negative in the upper jet. This prevents vertical wave propagation and isolates the katabatic layer of the influence from the free troposphere aloft. Our results suggest that the formation of local microclimates dominated by katabatic flow is a general feature over melting glaciers. The modelled turbulence structure illustrates the importance of non-local processes. Neglecting the vertical transport of turbulence in katabatic flows is not a valid assumption. It is also found that the local friction velocity remains larger than zero through the katabatic jet, due to directional shear where the scalar wind speed approaches its maximum.

Torfason, F. (2005) "Breiðamerkursandur, landmótun og byggðaþróun": Skaftfellingur, v. **18**: p. 127-148.

van der Veen, C.J. (2002) "Calving glaciers": Progress in Physical Geography v. **26**(No. 1): p. 96-122.

Based on a review of observations on different types of calving glaciers, a simple calving model is proposed. Glaciers that exist in a sufficiently cold climate can form floating ice shelves and ice tongues that typically do not extend beyond confinements such as lateral fjord walls or mountains, and ice rises. If the local climate exceeds the thermal limit of ice shelf viability, as is the case for temperate glaciers, no floating tongue can be maintained and the position of the terminus is determined by the thickness in excess of flotation. If the snout is sufficiently thick, a stable terminus position at the mouth of the confining fjord - usually marked by a terminal shoal - can be maintained. Further advance is not possible because of increasing sea-floor depth and diverging *flow resulting from lack of lateral constraints. If a mass balance deficiency causes the terminal region to thin, retreat is initiated with the calving front retreating to where the thickness is slightly in excess of flotation. In that case, the calving rate is determined by glacier speed and thickness change at the glacier snout. Advance or retreat of the calving front is not driven by changes in the calving rate, but by flow-induced changes in the geometry of the terminal region. This model is essentially different from prior suggestions in which some empirical relation - most commonly the water-depth model - is used to calculate calving rate and the rate of retreat or advance of the terminus.*

Þorsteinsson, P. (1985) Jökulsá á Breiðamerkursandi, Samgöngur í Skaftafellssýslum, p. bls. 78-93.

— (1985) Samgöngur í Skaftafellssýslum: Hornafirði, 240 s., [3] mbl., [14] mbls. : kort p.

Ferðalög á liðnum öldum ; Landslag ; Þjóðbrautin sunnan jökla ; Núpsvötn ; Skeiðará ; Jökulsá á Breiðamerkursandi ; Verzlunarferðir ; Póstferðir ; Ýmsar langferðir á hestum ; Skipaferðir ; Bílferðir ; Hringvegurinn ; Landmælingar 1904 ; Vatnajökulsferðir að fornu ; Vatnajökulsferðir sumarið 1912

Þorvaldsson, B. (2004) "Breiðamerkursandur og brýrnar ": Framkvæmdafréttir Vegagerðarinnar, v. **8. tbl.**(04).

4.1.23 Jökulsárlón

Björnsson, F. (1993) "Samtíningur um Jökulsá á Breiðamerkursandi og Jökulsárlón": Eystrahorn, v. **11. árg.**(2. tbl.): p. 4-5.

Björnsson, H., Pálsson, F., and Guðmundsson, E. (1999) Breytingar á Jökulsárlóni 1934-1998, RH-29-99, Science Institute, University of Iceland, p. 26 bls.

Björnsson, H., Pálsson, F., and Guðmundsson, S. (2001) "Jökulsárlón at Breiðamerkursandur, Vatnajökull, Iceland: 20th century changes and future outlook": Jökull, v. **50**(1): p. 1-18.

Björnsson, H., Pálsson, F., and Magnússon, E. (1999) Breytingar á Jökulsárlóni 1934-1998, RH-29-99: Reykjavík, Raunvísindastofnun Háskólans.

Blaðamaður(DV) (2002) "Váin sem blasir við á Breiðamerkursandi: Tel best að stífla Jökulsá ": DV,**40. tbl. 92. og 28. árg.**(16. febr. 2002): p. 6.

Viðtal J.I. við P.I. um rofið og vána á Breiðamerkusandi

Boulton, G.S. (1982) "Stratigraphy and structure of a coastal sediment wedge of glacial origin inferred from sparker measurements in glacial lake Jökulsárlón in southeastern Iceland (Lagskipting setmyndana undir Jökulsárlóni)": Jökull, v. **32**: p. 37-47.

Guðmundsson, S., Björnsson, H., Pálsson, F., and Berthier, E. (2005) Rapid evolution of a proglacial coastal lake: 20th century changes in Jökulsárlón at Breiðamerkursandur, Vatnajökull, Iceland, Second international costal symposium in Iceland: Höfn í Hornafirði.

— (2006) Rapid evolution of a proglacial coastal lake: 20th century changes in Jökulsárlón at Breiðamerkursandur, Vatnajökull, Iceland, Opinn Háskóli.

Imsland, P. (2000) The risk at Breiðamerkursandur Reykjavík, p. 60

— (2000) Váin á Breiðamerkursandi: náttúrufarslýsing, þróun, orsakir og eðli núverandi ástands ásamt framtíðarlausn á vandanum: Reykjavík, p. 60.

Jóhannesson, H. (1994) Coastal erosion near the bridges across Jökulsá á Breiðamerkursandi in southeastern Iceland, *in* Viggósson, G., ed., Proceedings of the International Coastal Symposium: Höfn, The Icelandic Harbour Authority, p. bls. 405-414.

— (1995) Landbrot framan við brúna yfir Jökulsá á Breiðamerkursandi, Árbók Verkfræðingafélags Íslands 1993/1994, p. bls. 311-319.

— (2004) "Rannsóknir og framkvæmdir við Jökulsá á Breiðamerkursandi. " Framkvæmdafréttir Vegagerðarinnar, v. **3. tbl., 12. árg.**(nr. 360, 16. febr. 2004).

Jóhannesson, H., and Sigurðarson, S. (2005) Strandrof og strandvarnir við brúna yfir Jökulsá á Breiðamerkursandi, Rannsóknir Vegagerðarinnar: Hótel Nordica, Reykjavík, Vegagerðin.

Kjartansson, G. (1957) "Frá Jökulsárlóni á Breiðamerkursandi": Náttúrufræðingurinn v. **27. árg.**(2. hefti): p. bls. 62-67.

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Landl, B., Björnsson, H., and Kuhn, M. (2003) "The energy balance of calved ice in Lake Jökulsarlón, Iceland": Arctic Antarctic and Alpine Research, v. **35**(4): p. 475-481.

We describe energy fluxes involved in melting ice in the proglacial lake Jokulsarlon and the transport of thermal energy into the lake from the atmosphere and the sea. Data from earlier fieldwork and campaigns have been used to estimate the net radiation balance, the turbulent fluxes, the heat provided by inflowing seawater, and the glacial meltwater flux, From aerial photographs, DGPS measurements, and mass balance measurements, we calculated a calving flux of 260 x 10(6) m(3) yr(-1) for the present. The total energy required to melt all the ice in the lake is approximately 160 W m(-2) assuming that all the calved ice is melted during 1 yr. The most important contribution is heat from seawater. Radiation provides approximately 70 W m(-2). The albedo depends on the ice-covered fraction of the lake and ranges from 22% in summer to 41% in winter. The turbulent fluxes are around 10 W m(-2). Difficulties occurred in finding an appropriate range for the roughness parameter z(o), but the most likely values are in the range of a few centimeters. We considered different future scenarios with respect to inflow of seawater and air temperature, albedo, and even inhibition of seawater intrusion, which would have a significant impact on ice cover in the lake.

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4.1.24 Esjufjöll

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Björnsson, H., Björnsson, F., and Hallgrímsson, H. (1979) "Esjufjöll": Týli, v. **9. árg.**(1. hefti): p. 21-23.

Björnsson Kvískerjum, H. (1951) "Esjufjöll og Mávabyggðir": Náttúrufræðingurinn, v. **21.árg.**(3.hefti): p. 99-108

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Björnsson, S. (1977) "Hlaupið í Jökulsá á Breiðamerkursandi árið 1927 (The jökulhlaup in Jökulsá on Breiðamerkursandur in 1927) ": Jökull, v. **27. árg.**: p. bls. 94-95.

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Eyles, N. (1978) "Rock glaciers in Esjufjöll nunatak area, south-east Iceland": Jökull, v. **28**: p. 53-56.

Eyþórsson, J. (1951) "Esjufjöll": Jökull, v. **1**: p. 8-9.

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Holm, F., Trønnes, R.G., Grönvold, K., Karlsson, H., and Torfason, H. (2004) Petrology and geochemistry of the Esjufjöll central volcano, SE Iceland, Geoscience Soc. Iceland. Spring Meeting, p. 30-31.

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Sigurðsson, B.D. (2005) "Mörg eru náttúruundrin : nýtt jökullón í Esjufjöllum og landnám gróðurs á Breiðamerkurjökli ": Glettingur, v. **15**(2-3): p. 48-52.

4.1.25 Mávabyggðir

Björnsson Kvískerjum, H. (1951) "Esjufjöll og Mávabyggðir": Náttúrufræðingurinn, v. **21.árg.**(3.hefti): p. 99-108

4.1.26 Kárasker

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4.1.27 Suðursveit

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EinarBragi, and (1973) 1: Síðasta aftaka á Austfjörðum og tildrög hennar ; Sumardagar í Suðursveit ; Galdra-Fúsi, samantekt um séra Vigfús Benediktsson ; Sumardagar á Hornbjargsvita Þá var öldin önnur: Reykjavík, Ísafoldarprentsmiðja.

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Þórðarson, T. (1956) Steinarnir tala: Reykjavík, Helgafell.

— (1957) Um lönd og lýði: Reykjavík, Helgafell.

— (1958) Rökkuróperan Reykjavík Helgafell.

— (1974) Fjórða bók: Reykjavík, ?

— (1975) Í Suðursveit Reykjavík, Mál og menning.

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— (1986) Ljóri sálar minnar : úr dagbókum, bréfum og öðrum óprentuðum ritsmíðum frá árunum 1909-1917 / Þórbergur Þórðarson: Reykjavík, Mál og menning.

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4.1.28 Veðurárdalur, Veðurá

Björnsson, F. (1993) "Samtíningur um jökla milli Fells og Staðarfjalls": Skaftfellingur, v. **9. árgangur**: p. bls. 8-24.

— (1998) "Samtíningur um jökla milli Fells og Staðarfjalls": Jökull, v. **46**: p. 49-61.

Guðmundsson, Þorsteinn (1993) "Ferð í Innri-Veðurárdal 19. júní 1928": Skaftfellingur, v. **9**: p. 34-38.

4.1.29 Brókarjökull, Kálfafellsdalur, Kálfafell

Jónsson, E. (2004) Í veröld jökla, sanda og vatna, *in* Björnsson, H., ed., Jöklaveröld, náttúra og mannlíf: Reykjavík, Skrudda, p. 11-86.

Sigurðsson, S. (2004),,Lífið er enn dásamlegt", *in* Björnsson, H., ed., Jöklaveröld, náttúra og mannlíf: Reykjavík, Skrudda, p. 319-390.

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4.1.30 Þverártindur

Björnsson, F. (1993) "Samtíningur um jökla milli Fells og Staðarfjalls": Skaftfellingur, v. **9. árgangur**: p. bls. 8-24.

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— (2004) "Geometry and mode of emplacement of the Þverártindur cone sheet swarm, SE Iceland": Journal of Volcanology and Geothermal Research, v. **138**(3-4): p. 185-204.

The exposed interior of the Þverártindur igneous centre is dominated by a dense circumferential swarm of centrally inclined sheets. The swarm is hosted by a stratified lava-hyaloclastite sequence that is tectonically rotated into a rift-parallel monocline, shown by an increased degree of tilting (~5-25[deg]) towards the neovolcanic zone of Iceland. In this paper, measured orientations and thicknesses of a total of 745 mafic cone sheets from nine sampling locations are statistically constrained and spatially analysed in both their present configuration and corrected for a uniform 13[deg]NW tilt of the swarm. Eight sheet dip trajectories, back-rotated to different levels of erosion, indicate a bowl- and slightly fan-shaped swarm geometry that converges onto a common magma source located ~3 km below the pre-erosional surface; a geometry that bears striking resemblance to Gudmundsson's [J. Volc. Geotherm. Res. 35 (1998) 179-194] boundary element model of the maximum compressive stress field around a pressurised sphere. An estimated ~7.2-km-wide and subcircular model source zone at such shallow crustal depth predicts a slightly flattened and 4.0+/-0.5-km-thick *spheroidal magma chamber with a maximum volume of 140+/-50 km3. Marked declines in sheet densities along the inner and outer margins of the swarm suggest that most sheets originated from a relatively narrow source zone, compared to the swarm's estimated ~2-3 km width at the surface. Improved statistical analysis, furthermore, reveals systematic spatial variations in sheet thickness distributions which behave in accordance with the bowl-shaped geometry for the Þverártindur swarm. Thus, a significant ~0.1 m/km decrease in the average sheet thickness up through the swarm is thought to reflect an overall upward narrowing of sheets, while a relatively low number of <0.5-m-thick sheets in the uppermost part of the swarm arguably reflects the subsurface thermal arrest of more than a third of all sheets injected from the model source.*

— (2006) "Similar dyke thickness variation across three volcanic rifts in the North Atlantic region: Implications for intrusion mechanisms": Lithos, v. **92**(1-2): p. 137-153.

The thicknesses of 1935 mafic dykes have been recorded through meticulous mapping across (1) the East Greenland coastal dyke swarm, (2) an extinct rift zone in SE Iceland and (3) an obducted dyke swarm segment within the Swedish Caledonides. In all three cases, the thickness of almost every dyke along well-exposed and coherent profile segments could be measured and analyzed. Statistics show that dyke thickness distributions more often are negative exponential (i.e., random) than log-normal within any given segment, with a regression's inverse exponential coefficient representing a more sophisticated average thickness. For all three dyke profiles, there is a similar decrease in average thickness from thicker dykes along the margin of the swarm to narrower dykes along its axis. Cross cutting relationships within two profiles, furthermore, suggest that the average dyke thickness decreased with time.The random thickness distribution of dykes is most likely governed by dyke initiations, releasing differential stresses at random time intervals during constant rates of plate separation. It is argued that the thickness of a dyke does not change significantly within the depth ranges that these dyke swarms are exposed, allowing systematic spatial and temporal changes in average dyke thicknesses to be related to other factors. Results are primarily related to the depth of an underlying sub-crustal magma reservoir, which progressively rose to shallower elevations beneath an active volcanic rift. As an alternative, or in conjunction with this model, stress concentrations towards the rising crest of a sub-crustal magma reservoir might increase the average frequency of randomly released differential stresses, leading to move rapid injections of thinner dyke toward swarm centres and with time. Correlating average dyke thicknesses to crustal depths, I end up with an empirical dyke thickness/height ratio of ~ 2 x 10-[no-break space]4, yet variable thickness/length ratio in order to accommodate the elliptical surface outline of swarms.

Soesoo, A. (1995) "Diversity of plutonic rocks in the oceanic crust: The Þverártindur central volcanic complex, SE Iceland": Proc. Estonian Acad.Sci. Geol., v. **44**: p. 234-248.

— (1998) "Episodic magmatism and diverse plutonic products within the Þverártindur central volcanic complex at the former Icelandic plate margin ": Journal of the Geological Society, v. **155**(5): p. 801-812.

4.1.31 Birnudalstindur

Klausen, M.B. (2006) "Geometry and mode of emplacement of dike swarms around the Birnudalstindur igneous centre, SE Iceland": Journal of Volcanology and Geothermal Research, v. **151**(4): p. 340-356.

Dike geometries around the well-exposed periphery of the Birnudalstindur igneous centre (SE Iceland) are constrained by moving averages of strike, dip, thickness and dilation by 775 mafic dikes, mapped along three strategically placed transects. On the basis of spatial analysis of dike strikes, a rift-parallel swarm is distinguished from a cross-cutting tri-axial swarm pattern of `brown dolerites' that clearly post-dates the volcano's cone sheet swarm. Dikes are on average orientated at right angles to the lava pile and consequently used to constrain the `flexured' geometry of the host lava pile, subsequently back-rotated to horizontal. This produces two end-member scenarios, which can be tentatively used to evaluate the dynamic formation of Icelandic crust. Dike dilations above a prominent stratigraphical transition into hyaloclastite breccias are markedly lower than in the underlying plateau lava pile, suggesting that vertical dike propagations were inhibited along this density/stress boundary. Lined up with the Birnudalstindur igneous centre, average dike thicknesses decrease towards the axes of both the rift-parallel dike swarm and the rift-perpendicular branch of the tri-axial swarm. This arguably links all dike swarms to the Birnudalstindur igneous centre, even if it remains inconclusive whether rift-parallel dikes fed and/or were injected laterally away from its sub-volcanic magma chamber. It seems more likely that the slightly offset tri-axial swarm of brown dolerites was preferentially emplaced along a peripheral bulge that was created around the `down-sagging' volcano.

4.1.32 Skálafellsjökull

Bradwell, T. (2001) "A new lichenometric dating curve for southeast Iceland": Geografiska Annaler v. **83 A**: p. 91-101.

This paper presents a new lichenometric dating curve for southeast Iceland. The temporal framework for the curve is based on reliably dated surfaces covering the last 270 years, making it the best constrained study of this nature conducted in Iceland. The growth of lichen species within Rhizocarpon Section Rhizocarpon is non-linear over time, with larger (older) thalli apparently growing more slowly. The linear 'growth' curves derived previously by former authors working in Iceland represent only part of a curve which has an overall exponential form. Reasons for the non-linearity of the new dating curve are probably physiological, although climatic change over the last three centuries cannot be ruled out. Use of linear 'growth' curves in Iceland is problematic over time-spans of more than c. 80 years. Pre-20th century moraines dated using a constant, linear relationship between lichen size and age are probably older than previously believed. Those moraines lichenometrically 'dated' to the second half of the 19th century in Iceland may actually pre-date this time by several decades (30–100 years), thus throwing doubt on the exact timing of maximum glaciation during the 'Little Ice Age'.

Evans, D. (2000) "A gravel outwash/deformation till continuum, Skálafellsjökull, Iceland": Geografiska Annaler v. **82 A**(4): p. bls. 499-512.

A stratigraphic sequence exposed by river erosion in the foreland of Skalafellsjokull, southern Iceland, displays five lithofacies documenting glaciofluvial deposition followed by glaciotectonic disturbance and subglacial deformation. Lithofacies 1a and 1b are glaciotectonically thrust glaciofluvial outwash and subglacial deformation till respectively from an early advance of Skalafellsjokull. Lithofacies 2, massive gravels and clast–supported diamictons, documents the deposition of glaciofluvial outwash in the proto–River Skala prior to overriding by Skalafellsjokull during the Little Ice Age. During overriding, lithofacies 2 was glaciotectonically disturbed and now possesses the clast fabric and structural characteristics of G B (non–penetratively deformed) and G A (penetratively deformed) type glaciotectonites. A shear zone separates lithofacies 2 from overlying lithofacies 3, the latter possessing the clast fabric signature of a D A (dilatant) type deformation till although it was originally deposited as a discontinuous diamicton within a glaciofluvial sequence, probably as a hyperconcentrated flow, and appears to have been at least partially derived from underlying materials by glaciotectonic cannibalization. Lithofacies 4 is a glaciofluvial deposit comprising two coarseningupward sequences of gravel and diamicton. These facies have been overprinted with G B glaciotectonite and D AB (dilatant to non–dilatant) deformation till structures and clast fabrics recording a vertical progression towards more pervasively deformed material. The sequence is capped by lithofacies 5, a two–tiered deformation till possessing the characteristics of D A and D B horizon subglacial tills previously reported from Icelandic glacier snouts. The whole sequence comprising lithofacies 2–5 represents a gravel outwash/deformation till continuum displaying variable strain signaturesproduced in response to stress induced by the overriding of Skalafellsjokull during the Little Ice Age. These signatures are dictated by the sediment rheology and a vertical strain profile for the sediment pile during glacier overriding is reconstructed.

McKinzey, K.M., J.F., O., and Bradwell, T. (2004) "Re-dating the moraines at Skálafellsjökull and Heinabergsjökull using different lichenometric methods: implications for the timing of the Icelandic Little Ice Age Maximum": Geografiske Annaler, v. **86A**: p. p.319-335.

Little Ice Age (LIA) moraines along the margins of Skálafellsjökull and Heinabergsjökull, two neighbouring outlet glaciers flowing from the Vatnajökull ice-cap, have been re-dated to test the reliability of different lichenometric approaches. During 2003, 12 000 lichens were measured on 40 moraine fragments at Skálafellsjökull and Heinabergsjökull to provide surface age proxies. The results are revealing. Depending on the chosen method of analysis, Skálafellsjökull either reached its LIA maximum in the early 19th century (population gradient) or the late 19th century (average of five largest lichens), whereas the LIA maximum of Heinabergsjökull occurred by the mid-19th century (population gradient) or late-19th century (average of 5 largest lichens). Discrepancies (c. 80 years for Skálafellsjökull and c. 40 years for Heinabergsjökull) suggest that the previously cited AD 1887 LIA maxima for both glaciers should be reassessed. Dates predicted by the lichen population gradient method appear to be the most appropriate, as mounting evidence from other geochronological reconstructions and sea-ice records throughout Iceland tends to support an earlier LIA glacier maximum (late 18th to mid-19th century) and probably reflects changes in the North Atlantic Oscillation. These revised chronologies shed further light on the precise timing of the Icelandic LIA glacier maximum, whilst improving our understanding of glacier-climate interactions in the North Atlantic.

McKinzey, K.M., Orwin, J.F., and Bradell, T. (2005) "A revised chronology of key Vatnajökull outlet glaciers during the little ice age": Annals of Glaciology, v. **Vol. 42**(1): p. 171-179.

Glacier fluctuations from key Vatnajökull outlets have been redated using tephrochronology coupled with two lichenometric techniques to ascertain the timing of the Little Ice Age (LIA) maximum in southeast Iceland. An updated tephrochronology for southeast Iceland (both the number of tephra layers present and their geochemical signatures) indicates a LIA maximum for both glaciers between AD 1755 and 1873. Based on a population gradient approach, lichenometrically dated moraines along the margins of Skálafellsjökull and Heinabergsjökull narrow this window to the early to mid-19th century respectively. These revised chronologies, in addition to emerging evidence from elsewhere in Iceland, support a late 18th- to early 19th-century LIA glacier maximum. In contrast, the Norwegian LIA glacial maximum is strongly centred around AD 1750. This implies differing glaciological responses to secular shifts in the North Atlantic Oscillation. Such revisions to the Vatnajökull record are crucial, as accurately identifying the timing and delimiting the spatial extent of the Icelandic LIA glacier maximum will allow further light to be shed on glacier-climate interactions in the North Atlantic.

Sharp, M. (1984) "Annual moraine ridges at Skálafellsjökull, south-east Iceland." Journal of Glaciology v. **30**(104): p. 82-93.

Sharp, M.J., and Dugmore, A. (1985) "Holocene glacier fluctuations in eastern Iceland. " Zeitschrift fuer Gletscherkunde und Glazialgeologie, v. **21**: p. 341-349.

Stratigraphic investigations at two outlet glaciers of Vatnajökull: Skálafellsjökull (non-surging) and Eyjabakkajökull (surging). Follows pattern of glacier fluctuations from Holocene to Little Ice Age.

Snorrason, S. (1979) Mýrajöklar og Vatnsdalur í A-Skaftafellssýslu. [**4. árs ritgerð thesis**]: Reykjavík, Háskói Íslands.

— (1984) Mýrajöklar og Vatnsdalur (+ jarðfræðikort af svæðinu fyrir framan Skálafells-, Heinabergs- og Fláajökul), Háskólinn í Oslo.

4.1.33 Mýrar

Benediktsson, G. (1944) Hinn gamli Adam í oss : ritgerðir Reykjavík, Víkurútgáfan.

— (1954) Hinn gamli Adam í oss : ritgerðir Reykjavík, Víkingsútgáfan.

— (1977) Í flaumi lífsins fljóta : bernsku- og æskuminningar: Reykjavík, Örn og Örlygur.

— (1978) Að leikslokum : áhugaefni og ástríður: Reykjavík, Örn og Örlygur.

Ólafsdóttir, R., and Þórhallsdóttir, J.K. (2004) "Varnir og sóknir : saga varnaraðgerða heimamanna og Vegagerðarinnar við Hólmsá á Mýrum frá lokum litlu ísaldarinnar": Skaftfellingur, v. **17**: p. 37-50; myndir, kort, línurit, tafla.

Sigurjónsson, B. (2004) "Mýrasveit og Mýramenn á þriðja og fjórða áratug tuttugustu aldar ": Skaftfellingur, v. **17**: p. 125-140.

Þórhallsdóttir, J.K. (2004) Flóðahætta á Mýrum í Austur-Skaftafellssýslu : orsakir, áhrif og varnaraðgerðir [**BSc thesis**]: Reykjavík, Háskóli Íslands.

4.1.34 Heinabergsjökull

Bennett, M.R., Huddart, D., and McCormick, T. (2000) "The glaciolacustrine landform-sediment assemblage at Heinabergsjökull, Iceland": Geografiska annaler, v. **Vol. 82A**(Nr. 1): p. p.1-16.

Landform–sediment assemblages associated with two ice-dammed lakes, one active and one fossil, at Heinabergsjökull in southeast Iceland are described. The current ice-dammed lake (Vatnsdalur) is dominated by a large aggradational terrace, as well as an excellent suite of shorelines. The second fossil ice-dammed lake dates from the Neoglacial maximum of Heinabergsjökull (c. 1887) and drained during the late 1920s. This lake is associated with a suite of shorelines and ice-marginal glaciolacustrine fans. The sedimentology of one of these fans is described. Between 50 and 70% of the sediment succession is dominated by ice-rafted sediment, although rhythmites, matrix-rich gravels, sands and graded sand–silt couplets are also present. A range of intra-formational, soft-sediment deformation structures are present, consistent with liquefaction and deformation associated with loading, current shear, and iceberg calving. The landform–sediment assemblages described from Heinabergsjökull provide important data for the interpretation of Pleistocene ice-dammed lakes.

Eiríksson, H.H. (1932) "Observations and measurements of some glaciers in Austur-Skaftafellssýsla: in the summer 1930": Societas Scientiarum Islandica v. **Rit 12**: p. 24

Eiríksson, J., and others (1994) Roadlog : Nordic geological excursion in Iceland : quaternary geology - glaciology Reykjavík, myndir, kort, línurit p.

Evans, D.J.A., Archer, S., and Wilson, D.J.H. (1999) "A comparison of the lichenometric and Schmidt hammer dating techniques based on data from the proglacial areas of some Icelandic glaciers": Quaternary Science Reviews, v. **18**(1): p. 13-41.

Measurements of Rhizocarpon section and Schmidt hammer R-values are reported from the proglacial geomorphic features on the forelands of the Icelandic glaciers of Kvíárjökull, Hólárjökull and Heinabergsjökull (Öræfi and south Vatnajökull), Sandfellsjökull and Öldufellsjökull (east Mýrdalsjökull), and Brúárjökull, Eyjabakkajökull and west Snæfell (north Vatnajökull). These data are used in reconstructions of patterns of glacier recession since the Little Ice Age maximum, and the geomophic signals of climatic *versus non-climatic events are discussed. Age control was obtained from various dated substrates by utilizing historical accounts, aerial photographs and grave stones. Three lichen growth rates are calculated: (a) 0.51 mm a−1 (corrected to 0.50 mm a−1) with a colonization lag time of < 16 yr for the arid forelands of north Vatnajökull; (b) 0.56 mm a−1 with a colonization lag time of 5 yr for the Icelandic southeast coast; and (c) 0.80 mm a−1 with a colonization lag time of 6.5 yr for the south Vatnajökull and east Mýrdalsjökull forelands. These compare favourably with a previously published growth rate of 0.44 mm a−1 for the arid north of Iceland. This regional coverage of data allows a comparison between annual precipitation totals and lichen growth rates and the construction of a growth rate prediction curve for Iceland. The success of the Schmidt hammer in differentiating moraines based upon age varied according to the geomorphological setting. Reasonable R-value/lichen size correlations were obtained on the east Mýrdalsjökull and Heinabergsjökull forelands where unrestricted glacier advance into lowlands allows for a higher degree of debris surface freshening by direct glacial processes. Weak correlations were obtained at Kvíárjökull, where the glacier was restricted by a precursor latero-frontal moraine loop and therefore the debris comprising the Little Ice Age recessional moraines was diluted with material of various ages being reworked by mass movement from the precursor moraine loop. Similar problems arise in areas affected by surging glaciers, such as Brúárjökull and Eyjabakkajökull. It appears that an accurate R-value age-prediction curve can not be constructed for a timescale of < 100 yr in Iceland.*

Jónsson, E. (2004) Í veröld jökla, sanda og vatna, *in* Björnsson, H., ed., Jöklaveröld, náttúra og mannlíf: Reykjavík, Skrudda, p. 11-86.

McKinzey, K.M., Orwin, J.F. and Bradwell, T. (2004) "Re-dating the moraines at Skálafellsjökull and Heinabergsjökull using different lichenometric methods: implications for the timing of the Icelandic Little Ice Age Maximum": Geografiske Annaler, v. **86A**: p. p.319-335.

Little Ice Age (LIA) moraines along the margins of Skálafellsjökull and Heinabergsjökull, two neighbouring outlet glaciers flowing from the Vatnajökull ice-cap, have been re-dated to test the reliability of different lichenometric approaches. During 2003, 12 000 lichens were measured on 40 moraine fragments at Skálafellsjökull and Heinabergsjökull to provide surface age proxies. The results are revealing. Depending on the chosen method of analysis, Skálafellsjökull either reached its LIA maximum in the early 19th century (population gradient) or the late 19th century (average of five largest lichens), whereas the LIA maximum of Heinabergsjökull occurred by the mid-19th century (population gradient) or late-19th century (average of 5 largest lichens). Discrepancies (c. 80 years for Skálafellsjökull and c. 40 years for Heinabergsjökull) suggest that the previously cited AD 1887 LIA maxima for both glaciers should be reassessed. Dates predicted by the lichen population gradient method appear to be the most appropriate, as mounting evidence from other geochronological reconstructions and sea-ice records throughout Iceland tends to support an earlier LIA glacier maximum (late 18th to mid-19th century) and probably reflects changes in the North Atlantic Oscillation. These revised chronologies shed further light on the precise timing of the Icelandic LIA glacier maximum, whilst improving our understanding of glacier-climate interactions in the North Atlantic.

McKinzey, K.M., Orwin, J.F., and Bradwell, T. (2005) "A revised chronology of key Vatnajökull outlet glaciers during the little ice age": Annals of Glaciology, v. **Vol. 42**(1): p. 171-179.

Glacier fluctuations from key Vatnajökull outlets have been redated using tephrochronology coupled with two lichenometric techniques to ascertain the timing of the Little Ice Age (LIA) maximum in southeast Iceland. An updated tephrochronology for southeast Iceland (both the number of tephra layers present and their geochemical signatures) indicates a LIA maximum for both glaciers between AD 1755 and 1873. Based on a population gradient approach, lichenometrically dated moraines along the margins of Skálafellsjökull and Heinabergsjökull narrow this window to the early to mid-19th century respectively. These revised chronologies, in addition to emerging evidence from elsewhere in Iceland, support a late 18th- to early 19th-century LIA glacier maximum. In contrast, the Norwegian LIA glacial maximum is strongly centred around AD 1750. This implies differing glaciological responses to secular shifts in the North Atlantic Oscillation. Such revisions to the Vatnajökull record are crucial, as accurately identifying the timing and delimiting the spatial extent of the Icelandic LIA glacier maximum will allow further light to be shed on glacier-climate interactions in the North Atlantic.

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Þórhallsdóttir, J.K. (2004) Flóðahætta á Mýrum í Austur-Skaftafellssýslu : orsakir, áhrif og varnaraðgerðir [**BSc thesis**]: Reykjavík, Háskóli Íslands.

4.1.35 Vatnsdalur

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Landform–sediment assemblages associated with two ice-dammed lakes, one active and one fossil, at Heinabergsjökull in southeast Iceland are described. The current ice-dammed lake (Vatnsdalur) is dominated by a large aggradational terrace, as well as an excellent suite of shorelines. The second fossil ice-dammed lake dates from the Neoglacial maximum of Heinabergsjökull (c. 1887) and drained during the late 1920s. This lake is associated with a suite of shorelines and ice-marginal glaciolacustrine fans. The sedimentology of one of these fans is described. Between 50 and 70% of the sediment succession is dominated by ice-rafted sediment, although rhythmites, matrix-rich gravels, sands and graded sand–silt couplets are also present. A range of intra-formational, soft-sediment deformation structures are present, consistent with liquefaction and deformation associated with loading, current shear, and iceberg

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Sigbjarnarson, G. (1997) "Frá myndun Hornafjarðar : afstaða láðs og lagar": Glettingur, v. **7** (3): p. 6-12; Myndir, kort, línurit

Sigmundsson, F., Pagli, C., Sturkell, E., Geirsson, H., Pinel, V., and Einarsson, P. (2005) Forecasting furure uplift and crustal response around Vatnajökull ice cap due to ice unloading. , *in* (ed.), G.V., ed., Second International Coastal Symposium Proceedings of the Second International Coastal Symposium at Höfn: Höfn.

Sjöberg, L.E., Pan, M., Asenjo, E., and Erlingsson, S. (2000) "Glacial rebound near Vatnajökull, Iceland, studied by GPS campaigns in 1992 and 1996": Journal of Geodynamics, v. **29**(1-2): p. 63-70.

Since about 1920 the Vatnajokull ice cap in Iceland has experienced a significant retreat, corresponding to a volume reduction of more than 180 km3. With two GPS campaigns in 1992 and 1996 along the southern border of the glacier preliminary results reveal land uplift rates of 1-6 mm/yr, after a one-parameter (bias) fit with recent earth rheology models. The best fit model suggests that the lithosphere in the area is about 30 km thick and the viscosity of the asthenosphere 5 x 1018 Pa s. The rms fit of uplift rate at all GPS sites is +/-1.4 mm/yr. As the GPS data alone cannot provide the absolute uplift rates, the one-parameter fit to the theoretical modelling implies that the absolute rates were estimated by the matching of the GPS data and model. The resulting uplift rate at station Hofn (1 mm/yr) is not consistent with two independent sources, and we therefore conclude that further GPS epoch and permanent GPS site data are needed to confirm the present geodynamic processes near Vatnajokull.

Viggósson, G., Sigurðarson, S., and Bruun, P. (1993) Stabilisation of the tidal entrance at Hornafjörður Iceland, POAC 93. The 12th International Conference on Port and Ocean Engineering under Arctic Conditions, Volume **2**: Conference Proceedings: Hamburg,

Hamburg Ship Model Basin (HSVA), Department for Ice and Environmental Technology, p. 681-690, ill., diags., maps.

Continuation of earlier work, described in proceedings of POAC'91, on improvement of shore stability. In addition, possible effects are discussed of further retreat, due to climatic warming, of outlet glacier emerging from Vatnajökull

Þórsdóttir, H. (2005) "Fjörðurinn yngri en áður var talið": Morgunblaðið156. tbl. 93. árg.(sunnudaginn 21. júní 2005): p. baksíða.

Viðtal við Pál Imsland og frétt Hrundar Þórsdóttur um niðurstöður fyrirlesturs á strandráðstefnu á Hornafirði

4.1.42 Skyndidalur

Jakobsson, S.P., and Friðleifsson, G.Ó. (1989) "Jarðbik í holufyllingum í Skyndidal, Lóni." Náttúrufræðingurinn, v. **59. árg.**(4. hefti): p. bls. 169-188.

N.N. (1985) "Jarðbik finnst á Lónsöræfum eystra": Týli, tímarit um náttúrufræði og náttúruvernd, v. **15**(1-2): p. 48.

4.1.43 Lambatungnajökull

Bradwell, T. (2004) "Annual moraines and summer temperatures at Lambatungnajökull, Iceland": Arctic, Antarctic and Alpine Researh, v. **36**: p. 502-508.

Bradwell, T., Dugmore, A.J., and Sugden, D.E. (2006) "The Little Ice Age glacier maximum in Iceland and the North Atlantic Oscillation: evidence from Lambatungnajökull, southeast Iceland": Boreas, v. **35**(1): p. 61-80.

This article examines the link between late Holocene fluctuations of Lambatungnajökull, an outlet glacier of the Vatnajökull ice cap in Iceland, and variations in climate. Geomorphological evidence is used to reconstruct the pattern of glacier fluctuations, while lichenometry and tephrostratigraphy are used to date glacial landforms deposited over the past ~400 years. Moraines dated using two different lichenometric techniques indicate that the most extensive period of glacier expansion occurred shortly before c. AD 1795, probably during the 1780s. Recession over the last 200 years was punctuated by re-advances in the 1810s, 1850s, 1870s, 1890s and c. 1920, 1930 and 1965. Lambatungnajökull receded more rapidly in the 1930s and 1940s than at any other time during the last 200 years. The rate and style of glacier retreat since 1930 compare well with other similar-sized, non-surging, glaciers in southeast Iceland, suggesting that the terminus fluctuations are climatically driven. Furthermore, the pattern of glacier fluctuations over the 20th century broadly reflects the temperature oscillations recorded at nearby meteorological stations. Much of the climatic variation experienced in southern Iceland, and the glacier fluctuations that result, can be explained by secular changes in the North Atlantic Oscillation (NAO). Advances of Lambatungnajökull generally occur during prolonged periods of negative NAO index.

The main implication of this work relates to the exact timing of the Little Ice Age in the Northeast Atlantic. Mounting evidence now suggests that the period between AD 1750 and 1800, rather than the late 19th century, represented the culmination of the Little Ice Age in Iceland.

Hoppe, G. (1953) "Nagra iakttagelser vid islandska joklar sommaren 1952": Ymer, v. **73**(4): p. 241-265.

— (2004) Svíar í rannsóknaferðum til Íslands fyrr og nú, *in* Björnsson, H., ed., Jöklaveröld, náttúra og mannlíf: Reykjavík, Skrudda, p. 265-318.

Jónsson, E. (2004) Í veröld jökla, sanda og vatna, *in* Björnsson, H., ed., Jöklaveröld, náttúra og mannlíf: Reykjavík, Skrudda, p. 11-86.

4.1.44 Axarfellsjökull

Engar heimildir fundust.

4.1.45 Vesturdalsjökull

Gústafsson, Þ.P. (2003) "Byrgið við Vesturdalsjökul": Glettingur, v. **13 (32. tölubl.)**(1): p. 42-46; Myndir, kort.

4.1.46 Vestrahorn

Blake, D.H., Elwell, R.W.D., Gibson, I.L., and Walker, G.P.L. (1965) "Some relationships resulting from the intimate association of acid and basic magma": Quarterly Journal of the Geological Society of London, v. **121**: p. 31-49.

Cargill, H.K., and others (1928) "The Major Intrusions of South-Eastern Iceland": The Quarterly Journal of the Geological Society of London, v. **84, part 3**: p. 505-539.

Mattson, S.R., Vogel, T.A., and Wilband, J.T. (1986) "Petrochemistry of the silicic-mafic complexes at Vesturhorn and Austurhorn, Iceland: evidence for zoned/stratified magma": Journal of Volcanology and Geothermal Research, v. **28**(3-4): p. 197-223.

Within the Austurhorn and Vesturhorn silicic intrusions of southeastern Iceland are composite complexes that consist of pillow-like bodies of mafic and intermediate rock entirely surrounded by silicic rock. The pillows with cuspate and chilled boundaries are interpreted to indicate a liquid-liquid relationship with a silicic magma. Some pillow-like bodies have a chilled and sharp cuspate boundary, whereas others have a distinct chemical and visible gradational contact with the silicic rock. The visible scale of mixing is of the same order of magnitude as the size of the pillows enclosed in the silicic rock (mm to meters).Two important types of chemical variation in the pillows are recognized. The first type of variation occurs from mafic pillow interiors to margins and *into the surrounding silicic rock. These variations are due to mechanical mixing between mafic magma and the silicic magma. The second type of chemical variation occurs between individual pillows. Large variations occur between pillows in P and Ti at nearly constant silica. These variations cannot have resulted from in situ simple magma mixing or crystal fractionation, and must have originated at depth below the present level of exposure. These compositions could have been derived from separate mafic (or intermediate) magma bodies or from a single zoned and/or stratified magma body. Because the Austurhorn, Vesturhorn, and Ardnamurchan composite complexes all exhibit similar variations in P and Ti and because these occurrences are separated in space and time, they are thought to have had similar processes occur during their evolution. The chemical variations are interpreted to have resulted from mafic magma that has underplated silicic magma and become zoned/stratified due to the effects of magma mixing and cooling-crystallization.*

Roobol, M.J. (1974) "The Geology of the Vesturhorn Intrusion, southeast Iceland": Geological Magazine, v. **111**(no. 4): p. 273-286.

Thomadsen, P., Tegner, C., Thorarinsson, S.B., Momme, P., Jakobsen, J.K., and Klausen, M.B. (2004) Icelandic magma chambers: constraints from layered gabbro of the Vesturhorn Igneous Centre, 14th Annual Goldschmidt Conference; Processes in Geochemistry. : Geochimica et Cosmochimica Acta: Copenhagen, p. 650.

Thomadsen, P.L., and Tegner, C. (2005) Rhythmic layering in the Vesturhorn Igneous Centre, SE Iceland, *in* Wilson, J.R., ed., Magma Chamber Processes XIII: Proceedings of a meeting held on September 30 at the Department of Earth Sciences: Aarhus University, Aarhus.

4.1.47 Eystrahorn

Blake, D.H. (1964) The volcanic geology of the Austurhorn area, south-eastern Iceland [**Ph.D. thesis**].

— (1966) "The Net-Veined complex of the Austurhorn Intrusion, southeastern Iceland": Journal of Geology, v. **74**(No. 6): p. 891-907.

Cargill, H.K., and others (1928) "The Major Intrusions of South-Eastern Iceland": The Quarterly Journal of the Geological Society of London, v. **84, part 3**: p. 505-539.

Mattson, S.R., Vogel, T.A., and Wilband, J.T. (1986) "Petrochemistry of the silicic-mafic complexes at Vesturhorn and Austurhorn, Iceland: evidence for zoned/stratified magma": Journal of Volcanology and Geothermal Research, v. **28**(3-4): p. 197-223.

Within the Austurhorn and Vesturhorn silicic intrusions of southeastern Iceland are composite complexes that consist of pillow-like bodies of mafic and intermediate rock entirely surrounded by silicic rock. The pillows with cuspate and chilled boundaries are *interpreted to indicate a liquid-liquid relationship with a silicic magma. Some pillow-like bodies have a chilled and sharp cuspate boundary, whereas others have a distinct chemical and visible gradational contact with the silicic rock. The visible scale of mixing is of the same order of magnitude as the size of the pillows enclosed in the silicic rock (mm to meters).Two important types of chemical variation in the pillows are recognized. The first type of variation occurs from mafic pillow interiors to margins and into the surrounding silicic rock. These variations are due to mechanical mixing between mafic magma and the silicic magma. The second type of chemical variation occurs between individual pillows. Large variations occur between pillows in P and Ti at nearly constant silica. These variations cannot have resulted from in situ simple magma mixing or crystal fractionation, and must have originated at depth below the present level of exposure. These compositions could have been derived from separate mafic (or intermediate) magma bodies or from a single zoned and/or stratified magma body. Because the Austurhorn, Vesturhorn, and Ardnamurchan composite complexes all exhibit similar variations in P and Ti and because these occurrences are separated in space and time, they are thought to have had similar processes occur during their evolution. The chemical variations are interpreted to have resulted from mafic magma that has underplated silicic magma and become zoned/stratified due to the effects of magma mixing and cooling-crystallization.*

Þorsteinsson, P. (1984) "Eystrahorn": Skaftfellingur v. **4**: p. 63-66.

Þórarinsson, S.B., Tegner, C., Thomadsen, P., Jakobsen, J.K., Momme, P., and Klausen, M.B. (2004) Icelandic magma chambers: petrology of the layered gabbro of the Austerhorn igneous Centre, S.E. Iceland *in* Holm, P.M., ed., Magma Chamber Processes XII: Proceedings of a meeting held on May 19 2004 at the Geological Institute: University of Copenhagen, p. 36.

— (2004) Icelandic magma chambers: petrology of the layered gabbro of the Austurhorn Igneous Centre, 14th Annual Goldschmidt Conference. Processes in Geochemistry: Geochimica et Cosmochimica Acta: Copenhagen, p. 660.

4.1.48 Lónsöræfi

Bjarnason, S. (2003) "Labbað milli Lóns og Nesja": Glettingur, v. **13 (34. tölubl.)**(3): p. 37-44; Myndir, kort, uppdr.

Björnsson, G. (1994) "Hvannavellir í Múladal : Grund í Víðidal": Múlaþing, v. **21**: p. 169-175.

Gunnarsson, S. (1994) "Skógur á Austurlandi milli Smjörvatnsheiðar og Lónsheiðar, frá 1755 til 1870": Glettingur v. **4**(1, nr. 41): p. 13-18.

Gústafsson, Þ.P. (2003) "Byrgið við Vesturdalsjökul": Glettingur, v. **13 (32. tölubl.)**(1): p. 42-46; Myndir, kort.

Indriðadóttir, D.B. (2000) "Frá Snæfelli yfir í Lón": Glettingur, v. **10** (3): p. 23.

Jakobsson, S.P., and Friðleifsson, G.Ó. (1989) "Jarðbik í holufyllingum í Skyndidal, Lóni." Náttúrufræðingurinn, v. **59. árg.**(4. hefti): p. bls. 169-188.

Jónsson, J. (1977) "Jarðhiti í Vandræðatungum": Náttúrufræðingurinn, v. **47**(2): p. 125-126.

Jónsson Stafafelli, S. (1994) "Sagnir um Eskifellshjónin Jón Markússon og Valgerði Ólafsdóttur": Skaftfellingur, v. **10**: p. 94-101.

Kristinsson, S. (1984) ""Mér þýðir ekki að kvíða" : þættir um byggð í Víðidal í Lónsöræfum og búskap á Bragðavöllum í Hamarsfirði": Múlaþing, v. **13**: p. 76-158.

Kristinsson, S., and Guðmundsson, E. (1993) "Frásagnir af Víðidalsfeðgum": Múlaþing, v. **20**: p. 192-197.

Magnússon, Þorvaldur Hjalti (1985) "Víðidalur í Lónsöræfum": Áfangar: tímarit um Ísland, v. **6**(2): p. 16-21.

N.N. (1985) "Jarðbik finnst á Lónsöræfum eystra": Týli, tímarit um náttúrufræði og náttúruvernd, v. **15**(1-2): p. 48.

Ólafsdóttir, G. (2003) Félagsleg þolmörk ferðamennsku : samanburður á viðhorfum ferðamanna í friðlandi að Fjallabaki og á Lónsöræfum [**Námsritgerð H.Í.**]: Reykjavík, Háskóli Íslands.

Sigurðsson, S. (2004),,Lífið er enn dásamlegt", *in* Björnsson, H., ed., Jöklaveröld, náttúra og mannlíf: Reykjavík, Skrudda, p. 319-390.

Stefánsson, H. (1968) "Æviþáttur Þorsteins Hinrikssonar og Ólafar Nikulásdóttur, Víðidal": Múlaþing, v. **3. h.**: p. 10-14.

Stefánsson Hlíð, B. (1996) "Þar skall hurð nærri hælum": Skaftfellingur, v. **11**: p. 61-65.

Thoroddsen, Þorvaldur (1908-1922) Öræfi og óbyggðir norðan jökla, *in* Thoroddsen, o., ed., Lýsing Íslands: Kaupmannahöfn, Hið íslenska bókmenntafélag, p. 1.b. s. 167-191.

Torfason, H. (1979) Investigation into the structure of South-Eastern Iceland [**Ph.D thesis**]: Liverpool, University of Liverpool.

4.1.49 Suðausturland, ekki skilgreint nánar

Albertsson, K.J., Norðdahl, H., and Guðbergsson, G.M. (1993) Iceland Summer Programme 1993, Geology and Geography of Iceland, Excursion Guide II South and Southeast Iceland: Reykjavík, Jarðfræðiskor Raunvísindadeildar Háskóla Íslands, 51 bls. p.

Anderson, F.W. (1949) "Geological Observations in South-eastern and Central Iceland": Transactions of the Royal Society of Edinburgh, v. **61, part 3**(No. 28): p. 779-791.

Björnsson, H. (1994) Rate of glacier erosion and subglacier topography under the southern part of Vatnajökull glacier, Iceland *in* Viggóson, G., ed., Proceedings of the Hornafjörður International Coastal Symposium: Höfn í Hornafirði, p. p. 317-318.

Blake, D.H. (1968) "Gravitational sorting of phenocrysts in some Icelandic intrusive sects": Geological Magazine, v. **105**(no. 2): p. 140-148.

Bradwell, T. (2001) "A new lichenometric dating curve for southeast Iceland": Geografiska Annaler v. **83 A**: p. 91-101.

This paper presents a new lichenometric dating curve for southeast Iceland. The temporal framework for the curve is based on reliably dated surfaces covering the last 270 years, making it the best constrained study of this nature conducted in Iceland. The growth of lichen species within Rhizocarpon Section Rhizocarpon is non-linear over time, with larger (older) thalli apparently growing more slowly. The linear 'growth' curves derived previously by former authors working in Iceland represent only part of a curve which has an overall exponential form. Reasons for the non-linearity of the new dating curve are probably physiological, although climatic change over the last three centuries cannot be ruled out. Use of linear 'growth' curves in Iceland is problematic over time-spans of more than c. 80 years. Pre-20th century moraines dated using a constant, linear relationship between lichen size and age are probably older than previously believed. Those moraines lichenometrically 'dated' to the second half of the 19th century in Iceland may actually pre-date this time by several decades (30–100 years), thus throwing doubt on the exact timing of maximum glaciation during the 'Little Ice Age'.

— (2004) "Lichenometric dating in southeast Iceland- the size-frequency approach." Geografiska Annaler v. **86 A**: p. 31-41.

The age of recent deposits can be determined using an intrinsic characteristic of the lichen 'population' growing on their surface. This paper presents a calibrated dating curve based on the gradient of the size-frequency distribution of yellow-green Rhizocarpon lichens. The dating potential of this new curve is tested on surfaces of known age in *southeast Iceland. This particular size—frequency technique is also compared with the more traditional largest-lichen approach. The results are very encouraging and suggest that the gradient can be used as an age indicator, at least on deposits formed within the last c. 150 years – and probably within the last c. 400 years – in the maritime subpolar climate of southeast Iceland. Using both lichenometric techniques, revised dates for moraines on two glacier forelands are presented which shed new light on the exact timing of the Little Ice Age glacier maximum in Iceland.*

Eiríksson, H.H. (1932) "Observations and measurements of some glaciers in Austur-Skaftafellssýsla: in the summer 1930": Societas Scientiarum Islandica v. **Rit 12**: 24 p.

Friðleifsson, G.Ó. (1995) Míósen jöklun á Suðausturlandi, *in* Hróarsson, B., Jónsson, D., and Jónsson, S.S., eds., Eyjar í eldhafi: safn greina um náttúrufræði; afmælisrit til heiðurs Jóni Jónssyni fil. Lic. Jarðfræðingi 85 ára þann 3. október 1995: Reykjavík, Gott mál, p. bls. 77-85.

Gale, N.H., Moorbath, S., Simons, J., and Walker, G.P.L. (1966) "K---Ar ages of acid intrusive rocks from Iceland": Earth and Planetary Science Letters, v. **1**(5): p. 284-288.

K---Ar ages of acid, intrusive rocks from plutonic centres in southeast and west Iceland fall in the range 1.5-10.0 m.y., i.e. Upper Miocene to Pleistocene. These ages contrast strongly with Lower Tertiary ages (ca. 50-60 m.y.) of the plutonic centres of northwest Scotland and east Greenland. The evidence that Iceland is geologically young is in line with current ideas on the history and structure of the North Atlantic region.

Gordon, J.E., and Sharp, M. (1983) "Lichenometry in dating recent glacial landforms and deposits, southeast Iceland": Boreas, v. **12**: p. p. 191-200.

Hafliðason, H. (1979) Laust set á landgrunninu suðaustan Íslands [**4. árs ritgerð**]: Reykjavík, Háskóli Íslands.

Hartsock, J.K. (1960) Submarine Topography and bottom sediments off the southeastern Coast of Iceland, Report of the 21. Session of the International Geological Congress, part 10, p. 7-15.

Hjartarson, Á., and Ingólfsson, Ó. (1988) "Preboreal glaciation of southeastern Iceland. " Jökull, v. **38**: p. pp.1-16.

Imsland, P. (1994) Twentieth Century Isostatic Behaviour of the Coastal Region in Southeast Iceland - Extended Abstract, *in* Viggósson, G., ed.: Proceedings of the Hornafjörður International Coastal Symposium: Höfn, Iceland, Útg. Hafnamálastofnun ríkisins, p. 513-518.

— (1995) Náttúrufarssaga Suðausturlands, yfirlit um landmyndun og landslagsmótun og áhrif náttúrufarsbreytinga liðinna alda á byggð og landnýtingarskilyrði í Austur-Skaftafelssýslu, p. Handritið er um 75 bls. með myndum.

Handrit, hluti - hugsað til útgáfu sem sjálfstæð bók fyrir opinn almennan markað og ætlað til kennslu og fræðslu um myndun, mótun og breytingar lands og landnýtingarskilyrða á svæðum þar sem hraði náttúrufarslegra ferla verður hraðari en almennt gengur og gerist vegna sérstæðra skilyrða bæði af innrænum og útrænum toga

Ives, J.D. (1994-1996) "Glacier and Climate Reconstruction in Southeast Iceland During the Last two Millennia: a Reconnaissance. " Jahrbuch der Geographischen Gesellschaft Bern, v. **Band 59/1994-1996**.

Jankovic, S. (1969) Mineral occurrences in Iceland (2)Progress report, Ljósritað fjölr. : Reykjavík, Rannsóknarráð ríkisins, p. 48 s. : kort, töflur.

— (1970) Frumleit að hagnýtum jarðefnum á Íslandi = Some of the mineral occurrences in Iceland, Rit 70-1: Reykjavík, Rannsóknarráð ríkisins, p. 125 s. : kort, uppdr., töflur.

— (1970) Reconnaissance prospection for base-metal mineralization in Southeastern Iceland, Fjölr.: Reykjavík, [Rannsóknarráð ríkisins] : Orkustofnun. Sameinuðu þjóðirnar, p. [2], 56 s. : teikn. .

Johnson, R.W. (1968) "Granophyre stock in Southeast Iceland and the distribution of epidote around it": Science in Iceland (Scientia Islandica). Anniversary volume, v. **1**: p. 55-59.

Jónsson, J. (1981) Jarðhiti og ölkeldur í Skaftafellsþingi. Yfirlit. , OS-81011/SH-D07, Orkustofnun. Jarðhitadeild. , p. 27, kort, töflur.

McKinzey, K.M., Ólafsdóttir, R., and Dugmore, A.J. (2005) "Perception, history and science coherence or disparity in the timing of the Little Ice Age maximum in southeast Iceland": Polar Record, v. **41**(4): p. 319-334.

In Iceland, studies that integrate local perceptions about the landscape with scientific evidence of change have been few. This article presents a case study from southeast Iceland that has two main objectives. Firstly, ethnographic data is used to explore the human dimension of the Little Ice Age through perceptions of landscape and climatic change and to describe the impacts that these changes had on life and livelihood. Secondly, the paper critically assesses the coherence of the scientific record regarding the Little Ice Age glacial maximum with evidence gained from the ethnographic survey and the local historical record. Although climatic deterioration from the seventeenth through nineteenth centuries ultimately affected farming viability, it was the interplay of climate with concomitant cultural and socio-economic factors that ensured effective strategies were emplaced to preserve life and livelihood in southeast Iceland. Furthermore, despite different trajectories of perception emanating from either the scientific or the local points of view, data from all sources are strongly coherent and *point to a Little Ice Age maximum during the late eighteenth to early nineteenth centuries. This study also illustrates that sensitive landscapes can 'store memories' through the cumulative accumulation of disturbances during periods of climatic variability, eventually reaching a critical threshold and inducing landscape instability, such as occurred during the nineteenth century.*

Norðdahl, H., and Einarsson, Þ. (1988) "Hörfun jökla og sjávarstöðubreytingar í ísaldarlok á Austfjörðum [English summary: Late Weichselian Deglaciation and Sea-level Changes in East and Southeast Iceland]": Náttúrufræðingurinn, v. **58**: p. 59-80.

Ottósson, J.G., and Baldursson, S. (2005) Náttúrufar og náttúruminjar sunnan Vatnajökuls - Yfirlit: Reykjavík, Náttúrufræðistofnun Íslands, p. 54.

Orwin, J.F., McKinzey, K.M., Stephens, M.A., and Dugmore, A.J. (submitted) "Mapping former ice margins using moraine lichen size distributions and the U2 statistic, southeast Iceland": Arctic, Antarctic and Alpine Researh.

Roobol, M.J. (1971) "Some relations between common acid-basic associations": Geological Magazine, v. **108**(no. 6): p. 525-531.

— (1972) "Size-graded igneous layering in an Icelandic Intrusion": Geological Magazine, v. **109**(no. 5): p. 393-404.

Sigurðsson, O. (2001) Jöklabreytingar á Islandi undanfarnar fjórar aldir, Vorráðstefna 2001: ágrið erinda og veggspjalda: Hótel Loftleiðum, Reykjavík, Jarðfræðifélag Íslands.

Thompson, A., and Jones, A. (1986) "Rates and causes of proglacial river terrace formation in southeast Iceland: an application of lichenometric dating techniques": Boreas v. **15**: p. p. 231-246.

Torfason, H. (1979) Investigation into the structure of South-Eastern Iceland [**Ph.D thesis**]: Liverpool, University of Liverpool.

Torfason, H. (1985) Geological Map of Southeast Iceland. Sheet 9. Bedrock Geology: Reykjavik, Icelandic Museum of Natural History and Iceland Geodetic Survey.

Tyrrell, G.W. (1949) "Petrography of Igneous Rocks from the Vatnajökull Region, Iceland, collected by Mr. F.W. Anderson": Transactions of the Royal Society of Edinburgh, v. **61, part 3**(No. 29): p. 793-801.

Ward, R.H., and others, a. (1978-79) South-east Iceland Expedition 1978, British Schools Exploring Society. Report, p. 1-38, illus., maps (1 folding).

4.1.50 Álftafjörður

Björnsson, G. (1994) "Hvannavellir í Múladal : Grund í Víðidal": Múlaþing, v. **21**: p. 169-175.

Blake, D.H. (1969) "Welded tuffs and the Mælifell caldera, Álftafjörður volcano, south-eastern Iceland": Geological Magazine, v. **106**(no. 6): p. 531-541.

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Guðmundsson, Á. (1983) "Form and dimensions of dykes in eastern Iceland": Tectonophysics, v. **95**(3-4): p. 295-307.

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Kárahnjúkavirkjun 470 MW [kort]
Virkjanir norðan Vatnajökuls [kort]
Áætlanir um virkjanir norðan Vatnajökuls í Jökulsá á Fjöllum, Jökulsá á Brú og Jökulsá í Fljótsdal [kort]

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Geological map and main features of strata sequence are presented except for postglacial vulcanism (to follow). Article describes effects of three central volcanoes. Table mountains represent glacial epochs and shield volcanoes interglacials. Article describes individual features and their rock types and locates active neovolcanic zone. In this magnetic polarity is normal, so age is less than 700,000 years

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4.1.54 Eyjabakkajökull, Eyjabakkar, Vesturöræfi

Björnsson, H. (1982) Niðurstöður íssjármælinga á Eyjabakkajökli: Reykjavík, Raunvísindastofnun Háskólans og Rafmagnsveitur ríkisins, p. 65.

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A series of seven groups of push-ridges ranging from 7 to 40 m in height, 50 to 280 m in length, and occupying a total width of more than 2 km, mark the marginal zone of the A.D. 1890 maximum of Eyjabakkajokull, an outlet glacier of the Vatnajokull ice cap, Iceland. The internal structure of one ridge complex comprises two distinct elements: a proglacial part which has been subject to compressional stresses, resulting in the development of imbricate thrust sheets; and a subglacial part which comprises low-angle normal fault structures. The two sub-systems appear to be linked via a floor thrust and to have evolved together as the glacier reached the limit of its rapid advance in A.D. 1890.

Evans, D.J.A., Archer, S., and Wilson, D.J.H. (1999) "A comparison of the lichenometric and Schmidt hammer dating techniques based on data from the proglacial areas of some Icelandic glaciers": Quaternary Science Reviews, v. **18**(1): p. 13-41.

Measurements of Rhizocarpon section and Schmidt hammer R-values are reported from the proglacial geomorphic features on the forelands of the Icelandic glaciers of Kvíárjökull, Hólárjökull and Heinabergsjökull (Öræfi and south Vatnajökull), Sandfellsjökull and Öldufellsjökull (east Mýrdalsjökull), and Brúárjökull, Eyjabakkajökull and west Snæfell (north Vatnajökull). These data are used in reconstructions of patterns of glacier recession since the Little Ice Age maximum, and the geomophic signals of climatic versus non-climatic events are discussed. Age control was obtained from various dated substrates by utilizing historical accounts, aerial photographs and grave stones. Three lichen growth rates are calculated: (a) 0.51 mm a−1 (corrected to 0.50 mm a−1) with a colonization lag time of < 16 yr for the arid forelands of north Vatnajökull; (b) 0.56 mm a−1 with a colonization lag time of 5 yr for the Icelandic southeast coast; and (c) 0.80 mm a−1 with a colonization lag time of 6.5 yr for the south Vatnajökull and east Mýrdalsjökull forelands. These compare favourably with a previously published growth rate of 0.44 mm a−1 for the arid north of Iceland. This regional coverage of data allows a comparison between annual precipitation totals and lichen growth rates and the construction of a growth rate prediction curve for Iceland. The success of the Schmidt hammer in differentiating moraines based upon age varied according to the geomorphological setting. Reasonable R-value/lichen size correlations were obtained on the east Mýrdalsjökull and Heinabergsjökull forelands where unrestricted glacier advance into lowlands allows for a higher degree of debris surface freshening by direct glacial processes. Weak correlations were obtained at Kvíárjökull, where the glacier was restricted by a precursor latero-frontal moraine loop and therefore the debris comprising the Little Ice Age recessional moraines was diluted with material of various ages being reworked by mass movement from the precursor moraine loop. Similar problems arise in areas affected by surging glaciers, such as Brúárjökull and Eyjabakkajökull. It appears that an accurate R-value age-prediction curve can not be constructed for a timescale of < 100 yr in Iceland.

Evans, D.J.A., Lemmen, D.S., and Rea, B.R. (1999) "Glacial landsystems of the southwest Laurentide Ice Sheet: modern Icelandic analogues": Journal of Quaternary Science, v. **14**(7): p. 673-691.

Landform assemblages and associated stratigraphy, sedimentology and structure are used in the reconstruction of palaeo-ice-sheet dynamics in Alberta, western Canada. Interpretations are based upon the modern analogues from four outlet glaciers at the margins of Vatnajökull and Mýrdalsjökull, Iceland. In the area between Lloydminster and Lac la Biche, central Alberta, an extensive landform assemblage of megaflutings, crevasse-squeeze ridges and thrust-block-moraine arcs document the former surging of part of the margin of the Laurentide Ice Sheet during later stages of recession. This and form assemblage, including numerous exposures of glacitectonised bedrock and Quaternary sediments, is comparable to the landsystem of the surging glaciers Eyjabakkajökull and Brúarjokull in Iceland. Near High River southern Alberta, the former existence of an ice lobe characterised by active recession is recorded by closely spaced, low-amplitude recessional push moraines that drape tunnel valleys. These are comparable in form and pattern to annual push moraines and fluted till surfaces produced by Breidamerkurjokull and Sandfellsjokull, Iceland, and also include

rimmed depressions produced by the escape of artesian water during ice-marginal pushing. This study provides interpretations of the regional glacial geomorphology of Alberta based upon comparisons of form and stratigraphy with modern glacial analogues, and provides an alternative to recent models which invoke large floods of subglacial meltwater to explain many of these same features. Implications for ice dynamics and regional till stratigraphies are discussed. Copyright (C) 1999 John Wiley & Sons, Ltd.

Eyþórsson, J. (1960) Vatnajökull: Reykjavík, Almenna bókafélagið, 44 s., [62] mbls. : teikn., ritsýni, uppdr.

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Investigation of origin of morainic ridges produced by surging glacier, undertaken at Eyjabakkajökull which drains north-eastern part of Vatnajökull

Sharp, M.J., and Dugmore, A. (1985) "Holocene glacier fluctuations in eastern Iceland. " Zeitschrift fuer Gletscherkunde und Glazialgeologie, v. **21**: p. 341-349.

Stratigraphic investigations at two outlet glaciers of Vatnajökull: Skálafellsjökull (non-surging) and Eyjabakkajökull (surging). Follows pattern of glacier fluctuations from Holocene to Little Ice Age.

Sigurðsson, O. (1998) "Eyjabakkajökull": Glettingur, v. **8**(2-3): p. 56-58.

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4.1.55 Snæfell

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Evans, D.J.A., Archer, S., and Wilson, D.J.H. (1999) "A comparison of the lichenometric and Schmidt hammer dating techniques based on data from the proglacial areas of some Icelandic glaciers": Quaternary Science Reviews, v. **18**(1): p. 13-41.

Measurements of Rhizocarpon section and Schmidt hammer R-values are reported from the proglacial geomorphic features on the forelands of the Icelandic glaciers of Kvíárjökull, Hólárjökull and Heinabergsjökull (Öræfi and south Vatnajökull), Sandfellsjökull and Öldufellsjökull (east Mýrdalsjökull), and Brúárjökull, Eyjabakkajökull and west Snæfell (north Vatnajökull). These data are used in reconstructions of patterns of glacier recession since the Little Ice Age maximum, and the geomophic signals of climatic versus non-climatic events are discussed. Age control was obtained from various dated substrates by utilizing historical accounts, aerial photographs and grave stones. Three lichen growth rates are calculated: (a) 0.51 mm a−1 (corrected to 0.50 mm a−1) with a colonization lag time of < 16 yr for the arid forelands of north Vatnajökull; (b) 0.56 mm a−1 with a colonization lag time of 5 yr for the Icelandic southeast coast; and (c) 0.80 mm a−1 with a colonization lag time of 6.5 yr for the south Vatnajökull and east Mýrdalsjökull forelands. These compare favourably with a previously published growth rate of 0.44 mm a−1 for the arid north of Iceland. This regional coverage of data allows a comparison between annual precipitation totals and lichen growth rates and the construction of a growth rate prediction curve for Iceland. The success of the Schmidt hammer in differentiating moraines based upon age varied according to the geomorphological setting. Reasonable R-value/lichen size correlations were obtained on the east Mýrdalsjökull and Heinabergsjökull forelands where unrestricted glacier advance into lowlands allows for a higher degree of debris surface freshening by direct glacial processes. Weak correlations were obtained at Kvíárjökull, where the glacier was restricted by a precursor latero-frontal moraine loop and therefore the debris comprising the Little Ice Age recessional moraines was diluted with material of various

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Geirsson, K. (1998) "Um friðlýsingu Snæfells og Vesturöræfa": Glettingur, v. **8**(2-3): p. 71-72.

Guðmundsson, A.T., and Sigurðsson, R.T. (1995) Jökulheimar : íslenskir jöklar: Seltjarnarnesi, Ormstunga, 82 s. : myndir, kort p.

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Guttormsson, H. (1998) "Við norðaustanverðan Vatnajökul": Glettingur, v. **8**(2-3): p. 9-21.

Hards, V.L., Kempton, P.D., Thompson, R.N., and Greenwood, P.B. (2000) "The magmatic evolution of the Snaefell volcanic centre; an example of volcanism during incipient rifting in Iceland": Journal of Volcanology and Geothermal Research, v. **99**(1-4): p. 97-121.

The Snaefell volcanic centre is situated in central-east Iceland, at the northern end of a short flank volcanic zone. Its products represent a typical suite of Icelandic volcanics and comprise a bimodal suite of alkalic lavas: a series from basaltic to mugearitic compositions and a small cluster of peralkaline rhyolites. Compositional variations across the whole series can be broadly explained by fractional crystallisation of a family of related parental/primary magmas in a magma chamber at mid-crustal (~13 km) levels, that has been subject to periodic replenishment and periodic tapping, with sufficient repose times for extreme differentiation. Interaction with the crust appears minimal, although some crustal input into the rhyolites is indicated by their isotopic characteristics. The Snaefell volcanics therefore represent largely new additions to the Icelandic crust.The apparent depth of the magma chamber appears significant and sets Snaefell apart from the axial rift zones at centres such as Krafla, where seismic studies (e.g. Brandsdottir, B., Menke, W., Einarsson, P., White, R.S., Staples, R.K., 1997. Faeroe-Iceland ridge experiment. 2. Crustal structure of Krafla central volcano. J. Geophys. Res. 102 (B4), 7867-7886) have detected the presence of magma bodies at depths of around 3 km beneath centres in the northern volcanic zone. Comparing Snaefell with volcanic centres in the propagating eastern volcanic zone suggests that, in terms of its stage of evolution, Snaefell is approximately equivalent to Torfajokull. Thus, the Oraefajokull-Snaefell volcanic zone may have represented a site of incipient rifting.

Hjartarson, Á. (2002) "Jöklar Snæfells": Glettingur v. **12**(3): p. 29-33; Myndir, kort.

Höskuldsson, A., and Imsland, P. (1998) "Geology of Snæfell, an intraplate volcano in Eastern Iceland": Glettingur, , v. **8**(2-3): p. 22-30.

Höskuldsson, Á., and Imsland, P. (1998) "Snæfell : eldfjall á gosbelti framtíðar": Glettingur v. **8**(2-3): p. 22-30.

Höskuldsson, Á., Óskarsson, N., and Imsland, P. (1996) Snæfell, ágrip af jarðfræði og kvikuþróun, Vorráðstefna 1996: ágrip erinda: Reykjavík, Jarðfræðifélag Íslands.

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Kjerúlf, P.J. (2001) "Í göngum á Vesturöræfum 1898 : úr skólaritgerð frá Eiðum 1901 ": Glettingur v. **11**(2-3): p. 80-82.

Pálsson, P., and Þórisson, S.G. (2001) "Vesturöræfi ": Glettingur, v. **11**(2-3): p. 16-25.

Skarphéðinsson, K.H. (1998) "Fuglar á Snæfellsöræfum": Glettingur, v. **8**(2-3): p. 51-55; Myndir, súlurit, tafla.

Snorrason, S.P. (2001) "Guðmundur Snorrason : fyrsti Snæfellsfarinn": Múlaþing v. **28**: p. 99-103.

Þorvarðardóttir, G. (2001) "Um friðlýsingu Snæfells og Vesturöræfa": Glettingur, v. **11**(2-3): p. 59-60.

Þórðardóttir, I.R. (2000) ""Ef maður heillast af fjalli" ... : höfundur segir frá kynnum sínum af Snæfelli, konungi íslenskra fjalla og rifjar upp minningar frá skálavörslu í Snæfellsskála": Glettingur, v. **10**(3): p. 30-33.

Þórisson, S.G. (1998) "Hreindýr á Snæfellsöræfum": Glettingur, v. **8**(2-3): p. 39-42; Myndir, tafla, uppdr. .

4.1.56 Kárahnjúkar, Hálslón, Kringilsárrani

Bjarnason, H. (1998) "Kárahnúkavirkjun : staða rannsókna og undirbúnings vegna áforma um virkjun Jökulsár á Brú": Glettingur, v. **8**(2-3): p. 75-78; Kort, uppdr.

Björnsson, H., Pálsson, F., Guðmundsson, S., and Eydal, G.P. (2001) Áhrif Hálslóns á Brúarjökul, RH-04-2001: Reykjavík, Raunvísindastofnun Háskólans, p. 26.

Gardarsson, S.M., and Eliasson, J. (2006) "Influence of climate warming on Hálslon reservoir sediment filling": Nordic Hydrology, v. **37**(3): p. 235-245.

Halslon reservoir is the main reservoir of the Kárahnjúkar hydropower project in the eastern highlands of Iceland. Studies for the environmental impact assessment for the hydropower project showed that sediment will fill the reservoir in about 500 years based on the present sediment transport rate. The main source of the sediment is the Brúarjökull outlet glacier which is a part of the Vatnajökull ice cap. Recent studies of the influence of climate warming on glaciers in Iceland show that they will decrease significantly and, in some cases, completely disappear during the next few hundred years. In this study, a glacier melt model for the Brúarjökull outlet glacier is constructed to predict how fast the glacier will retreat in response to accepted climate warming scenarios. The results from the glacier model are then used as input to a sediment transport mass balance model for the Hálslon reservoir, which predicts the influence of the retreat of the glacier on the sedimentation in the reservoir. The modeling shows that, instead of the reservoir being completely full of sediment in 500 years, the Halslon reservoir will at that time still have about 50-60% of its original volume as the sediment yield will decrease as a result of the decreasing glacier size.

Gardarsson, S.M., Jonsson, B., and Elíasson, J. (2005) Sediment model of Hálslon Reservoir filling taken into account Bráarjökull Glacier recede, EGU 2005, Volume **7**: Vienna.

Guttormsson, H. (1998) "Við norðaustanverðan Vatnajökul": Glettingur, v. **8**(2-3): p. 9-21.

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Harðardóttir, J., Jónsdóttir, H.E., and Geirsdóttir, Á. (2001) "Sethjallar sunnan Kárahnjúka": Glettingur, v. **11**(2-3): p. 37-40.

Höskuldsson, A. (2003) Túfflag á fyrirhuguðu lónstæði Hálslóns. Flikruberg eða Móberg við Lindur? , NÍ-03008: Reykjavík, Náttúrufræðistofnun.

Kaldal, I., and Víkingsson, S. (2000) Kárahnjúkavirkjun. Jarðgrunnskort af umhverfi Hálslóns, OS-2000/065, Orkustofnun, Rannsóknasvið.

— (2001) "Saga jökulhörfunar og forns jökullóns sunnan Kárahnjúka": Glettingur v. **11**(2-3): p. 31-36.

Lienhoop, N. (2001) "Mat á verndargildi náttúrunnar við Kárahnjúka": Glettingur v. **11**(2-3): p. 57-58.

Malmquist, H.J. (2001) "Vatnalíf á áhrifasvæði Kárahnjúkavirkjunar": Glettingur, v. **11**(2-3): p. 48-53, Myndir, línurit, skífurit, töflur.

Sæþórsdóttir, A.D. (1998) "Ferðamál og virkjanir á hálendinu norðan Vatnajökuls": Glettingur, v. **8**(2-3): p. 63-65.

Thoroddsen, o. (1908-1922) Öræfi og óbyggðir norðan jökla, *in* Thoroddsen, o., ed., Lýsing Íslands: Kaupmannahöfn, Hið íslenska bókmenntafélag, p. 1.b. s. 167-191.

Todtmann, E.M. (1951-52) "Im Gletscherrückzugsgebiet des Vatna Jökull auf Island, 1950 & 1951": Neues Jahrbuch für Geologie Und Palaeontologie, v. **Mh. 1951-11 & 1952-9**: p. 335-341 & 401-411; 2+2 fig.

Description of area and discussion of eskers and moraines

— (1952, 1957) Im Gletscherrückzugsgebiet des Vatna Jökull auf Island, 1951 ; Kringilsárrani, das Vorfeld des Brúarjökull, am Nordand des Vatnajökull 1955, Sérpr. úr Neues Jahrbuch für Geologie und Paläontologie. Monatshefte: Stuttgart, p. 401-411; 255-278, 2 mbl. : kort.

— (1955) "Übersicht über die Eisrandlagen in Kringilsárrani von 1890-1955": Jökull, v. **5**: p. 8-10.

— (1957) "Kringilsarrani, das Vorfeld des Bruarjökull am Nordrand des Vatnajökull": Neues Jahrbuch fur Geologie und Paläontologie. Monatshefte, v. **104**: p. 255-278.

4.1.57 Jökulsá á Fjöllum, Ásbyrgi

Alho, P. (2003) "Land cover characteristics in NE Iceland with special reference to jökulhlaup geomorphology": Geografiska Annaler Series a-Physical Geography, v. **85A**(3-4): p. 213-227.

Subglacial eruptions in Vatnajökull have accounted for several jökulhlaups (glacial outburst floods) in the Northern Volcanic Zone (NVZ). These events and aeolian processes have had a considerable impact on the landscape evolution of the area. Most of this area is occupied by barren land cover; the northern margin of the barren land cover is advancing northwards, burying vegetation under wind-blown sediment. This paper presents a land-cover classification based on a supervised Landsat TM image classification with pre-processing and extensive field observations. Four land cover categories were identified: (a) lava cover (34.8%); (b) barren sediment cover (39.0%); (c) vegetation (25.1%); and (d) water and snow (1.1%). The mapping of sand transport routes demonstrates that a major aeolian sand transportation pathway is situated in the western part of the study area. The sedimentary formation elongated towards the northeast is evidence of active and continuous aeolian sand transportation towards the

north. Interpretation of the satellite image suggests that four main areas are affected by jokulhlaups along the Jökulsa á Fjöllum: Ásbyrgi, Grímsstaðir, Herðubreið-Möðrudalur, and the Dyngjujökull sandur. In addition, jökulhlaup-related sediment cover (8%) in the study area, together with erosional features, are evidence of a severe and extensive jökulhlaup-induced process of land degradation.

Alho, P., Russell, A.J., Carrivick, J.L., and Kayhko, J. (2005) "Reconstruction of the largest Holocene jökulhlaup within Jökulsá á Fjöllum, NE Iceland": Quaternary Science Reviews, v. **24**(22): p. 2319-2334.

Glacial outburst floods (jökulhlaups) have a significant role for landscape evolution in NE Iceland. A number of jökulhlaups have routed from the northern margin of Vatnajökull during the Holocene. In this study, reconstruction of the largest Holocene jökulhlaup along Jökulsá á Fjöllum, NE Iceland was undertaken using the HEC-RAS hydraulic modelling and HEC-GeoRAS flood mapping techniques with a Digital Elevation Model (DEM) derived from ERS-InSAR data and field-based wash limit evidence. The largest jökulhlaup produced extensive erosional and depositional landforms across an inundated area of ~1390 km2 and is calculated to have had a peak discharge of 0.9x106 m3 s-1. Power per unit area within this jökulhlaup varied from 6 to 46,000 W m-2. Jökulhlaup hydraulics are related to geomorphogical evidence at three key sites: in Vaðalda, Upptyppingar and Möðrudalur sub-areas in order to explain the abrupt spatial variation of the flood characteristics on a regional scale and to relate erosional and depositional features to spatial variations in jökulhlaup hydraulics. These process-form relationships of the largest jökulhlaup along the Jökulsá á Fjöllum are compared with large outburst floods elsewhere. The largest Jökulsá á Fjöllum jökulhlaup had a factor of ~20 times smaller discharge and ~a factor of 20 times lower power per unit area than Altai palaeoflood--the largest known flood on the Earth.

Alho, P., Russell, A.J., J.L., C., and Käyhkö, J. (2005) "Large-scale impacts and characteristics of giant Holocene jökulhlaups within the Jökulsá á Fjöllum river, NE Iceland": Quaternary Science Reviews, v. **24**.

Glacial outburst floods (jökulhlaups) have a significant role for landscape evolution in NE Iceland. A number of jökulhlaups have routed from the northern margin of Vatnajökull during the Holocene. In this study, reconstruction of the largest Holocene jökulhlaup along Jökulsá á Fjöllum, NE Iceland was undertaken using the HEC-RAS hydraulic modelling and HEC-GeoRAS flood mapping techniques with a Digital Elevation Model (DEM) derived from ERS-InSAR data and field-based wash limit evidence. The largest jökulhlaup produced extensive erosional and depositional landforms across an inundated area of 1390 km2 and is calculated to have had a peak discharge of 0.9×106 m3 s−1. Power per unit area within this jökulhlaup varied from 6 to 46,000 W m−2. Jökulhlaup hydraulics are related to geomorphogical evidence at three key sites: in Vaðalda, Upptyppingar and Möðrudalur sub-areas in order to explain the abrupt spatial variation of the flood characteristics on a regional scale and to relate erosional and depositional features to spatial variations in jökulhlaup hydraulics. These process-form relationships of the largest jökulhlaup along the Jökulsá á Fjöllum are compared with large outburst floods elsewhere. The largest Jökulsá á Fjöllum jökulhlaup had a factor of 20 times smaller discharge and a factor of 20 times lower power per unit area than Altai palaeoflood—the largest known flood on the Earth.

Björnsson, H., and Einarsson, P. (1990) "Volcanoes beneath Vatnajökull, Iceland: Evidence from radio echo-sounding earthquakes and jökulhlaups": Jökull, v. **40**: p. 147-168.

Integration of knowledge of subglacial topography, earthquake activity and jökulhlaups has contributed to more precise locations of the volcanic systems beneath Vatnajökull. Bárðarbunga is the centre of a volcanic system which includes the fissure swarms of Veiðivötn to the SW and Dyngjuháls to the NE. The Grímsvötn volcano is the centre of a system that comprises the Laki fissure swarm in the SW and extends for an unknown distance to the NE of the volcano. Þórðarhyrna is probably a separate central volcano within this system. The Kverkfjöll system can be traced 10 km to the SW of the Kverkfjöll volcano. It appears to be separated from the Grímsvötn volcano. The Askja fissure swarm extends beneath Dyngjujökull and can possibly be traced to the Grímsvötn volcano. Hamarinn and the ridge striking eastward from Hamarinn (Loki Ridge) are central volcanoes which together with the Fögrufjöll fissure swarm form a volcanic system. No support can be found in the topographic data for the existence of a central volcano near Breiðabunga. Volcanic activity in historical times has mainly been limited to the Grímsvötn and Bárðarbunga systems. Major rifting events have affected large sections of these volcanic systems but both have been remarkably quiet for the past decades. A few volcanic events are presumed to have occurred on the Hamarinn - Loki system and on the Askja fissure swarm beneath Dyngjujökull, but no event is known with certainty on the Kverkfjöll system. The rivers Skeiðará and Súla have the most frequent eruption-related jökulhlaups. They receive meltwater from the Grímsvötn caldera and the area to the SW of it, including Þórðarhyrna. Núpsvötn, Djúpá and Hverfisfljót drain the southwestern part of the Grímsvötn system, an area bounded by Þórðarhyrna, Geirvörtur, Hágöngur and Pálsfjall. Skaftá drains the Loki Ridge and the area west of Grímsvötn. Jökulhlaups in Kaldakvísl, and ultimately Þjórsá, must originate in the Bárðarbunga or the Hamarinn - Loki systems, and the only possible source for volcanic jökulhlaups in Skjálfandafljót is the northern part of the Bárðarbunga system. Jökulsá á Fjöllum may drain meltwater from activity in all the volcanic systems in northern Vatnajökull: Bárðarbunga, the Askja fissure swarm and Kverkfjöll. This includes the voluminous, ice-filled calderas of Bárðarbunga and Kverkfjöll. Activity in the northern part of the Grímsvötn system may cause floods in Jökulsá á Fjöllum. Meltwater from volcanic activity on the SE flank of a ridge that strikes south from Kverkfjöll may drain to Jökulsá á Brú. Volcanic activity farther north on the E flanks of this ridge would cause floods in Kreppa.

Carrivick, J.L. (2004) Palaeohydraulics of a glacier outburst flood (jökulhlaup) from Kverkfjöll, Iceland, *in* Beylich, A.A., Sæmundsson, Decaulne, A., and Sandberg, O., eds., Sedimentary source-to-sink-fluxes in cold environments: Sauðárkrókur, Náttúrustofa Norðurlands vestra, p. 104.

— (2006) "Application of 2D hydrodynamic modelling to high-magnitude outburst floods: An example from Kverkfjoll, Iceland": Journal of Hydrology, v. **321**(1-4): p. 187-199.

High-magnitude outburst floods cause rapid landscape change and are a hazard to life, property and infrastructure. However, high-magnitude fluvial processes and mechanisms of erosion, transport and deposition are very poorly understood, and remain largely unquantified. This poor understanding is partly because of the inherent difficulty of directly measuring high-magnitude outburst floods, but also because of the limitations and assumptions of 1D models and other palaeohydrological methods, which reconstructions of high-magnitude floods have to date relied upon. This study therefore applies a 2D hydrodynamic model; SOBEK, to reconstructing a high-

magnitude outburst flood. This method offers the first calculations of high-magnitude fluvial flow characteristics within an anastomosing network of simultaneously inundated channels, including; sheet or unconfined flow, simultaneous channel and sheet flow, flow around islands, hydraulic jumps, multi-directional flow including backwater areas, hydraulic ponding and multiple points of flood initiation. 2D-modelling of outburst floods clearly has the potential to revolutionise understanding of high-magnitude spatial and temporal hydraulics and high-magnitude flow phenomena, geomorphological and sedimentological processes, and hence rapid fluvial landscape change. This potential for new understanding is because of the now wide availability of high-resolution DEM data for large and often inaccessible areas, and the availability of remotely-sensed data that can parameterise outburst flood sources, such as glacial lakes, for example. Additionally, hydraulic models and computing power are now sufficient to cope with large (5,000,000 grid cells) areas of inundation and large (100,000 m3 s-1) peak discharges.

— (2007 (in press)) "Modelling transient hydrodynamics and rapid landscape change due to a high-magnitude outburst flood: an example from Kverkfjöll volcano, Iceland": Annals of Glaciology, v. **45**.

— (Submitted) "Hydrodynamics and geomorphic work of jökulhlaups (glacial outburst floods) from Kverkfjöll volcano, Iceland": Hydrological Processes.

— (Submitted) Impacts and characteristics of jökulhlaups from Kverkfjöll, Iceland [**PhD thesis**], University of Keele.

Carrivick, J.L., Pringle, J.K., Russell, A.J., and Cassidy, N.J. (2007 (In press)) "Architecture and stratigraphy of high-magnitude outburst flood sedimentation within a bedrock valley system": Journal of Environmental and Engineering Geophysics.

Jökulhlaups and lahars are both types of high-magnitude outburst flood that commonly comprise a glacial meltwater and volcaniclastic sediment mix, and have discharges that are typically several orders of magnitude greater than perennial flows. Both types thus constitute a serious threat to life, property and infrastructure but are too powerful and too short-lived for direct measurements of flow characteristics to be made. Consequently a variety of indirect methods have been used to reconstruct flow properties, processes and mechanisms. Unfortunately, a lack of observations of sedimentary architecture, geometry and stratigraphic relationships, are hampering our ability to discriminate fluvial magnitude-frequency regimes and styles of deposition, particularly within rapidly-varied flows. This paper therefore uses Ground Penetrating Radar (GPR) to obtain quantitative data on subsurface sedimentary character of high-magnitude outburst flood sediments, including geometry, architecture and stratigraphy, from a bedrock-valley system in north-central Iceland. Basement pillow lava and subaerial lava flows are distinguished based upon a chaotic, and hummocky signature, and thickness, lack of coherent internal structure, and upper rough surface as evidenced by concentration of hyperbole point sources, respectively. Unconsolidated sedimentary units are interpreted due to the presence of coherent internal structures of a horizontal and sub horizontal nature. Deposition produced spatially diverse sediments due to rapidly-varied flow conditions. Observations include prograding and backfilling architecture, intercalated slope material and fluvial

sediments, and multiphase deposition of sediments. Specifically, outburst flood sediments were initially deposited by traction load of coarse-grained material on prograding bedforms, and subsequently by drop-out from suspension of finer-grained material. The latter phase produces laterally extensive tabular sedimentary architectures that in-fill pre-existing topography and mask the complexity of bedrock forms beneath. Existing qualitative concepts of high-magnitude fluvial deposition within a topographically confined bedrock channel are therefore now refined with quantitative data on sediment architecture and thus flow regimes.

Carrivick, J.L., Russell, A.J., and Tweed, F.S. (2004) "Geomorphological evidence for jökulhlaups from Kverkfjöll volcano, Iceland": Geomorphology v. **63**: p. 81-102.

Jökulhlaups (glacial outburst floods) are known to have drained along the Jökulsá á Fjöllum river in Iceland during the Holocene. However, little is known about their number, age, source, and flow characteristics. This paper provides detailed geomorphological evidence for jökulhlaups that have routed from the Kverkfjöll ice margin and hence into the Jökulsá á Fjöllum. Erosional evidence of jökulhlaups from Kverkfjöll includes gorges, cataracts, spillways, subaerial lava steps, and valley-wide scoured surfaces. Depositional evidence includes wash limits, boulder bars, cataract-fill mounds, terraces, slackwater deposits, and outwash fans. Some of these landforms have been documented previously in association with jökulhlaups. However, subaerial lava surfaces that have been scoured of the upper clinker, gorges within pillow–hyaloclastite ridges, gorges between pillow–hyaloclastite ridges and subaerial lava flows, subaerial lava lobe steps, cataract-fill mounds, and boulder run-ups are previously undocumented in the literature. These landforms may therefore be diagnostic of jökulhlaups within an active volcanic rifting landscape. The nature and spatial distribution of these landforms and their stratigraphic association with other landforms suggest that there have been at least two jökulhlaups through Kverkfjallarani. The Biskupsfell eruption occurred between these two jo¨kulhlaups. Kverkfjallarani jökulhlaups were very strongly influenced by topography, geology, and interevent processes that together determined the quantity and nature of sediment availability. Such controls have resulted in jökulhlaups that were probably fluidal, turbulent, and supercritical over large areas of the anastomosing channel bed. Kverkfjallarani jökulhlaups would have had highly variable hydraulic properties, both spatially and temporally. The knowledge of flow characteristics that can be gained from jökulhlaup impacts has implications for recognising jökulhlaups in the rock record and for hazard analysis and mitigation within similar landscapes and upon other glaciated volcanoes.

— (2004) Glacier outburst floods (jökulhlaups) from Kverkfjöll, Iceland:flood routeways, flow characteristics and sedimentary impacts, *in* Beylich, A.A., Sæmundsson, Decaulne, A., and Sandberg, O., eds., Sedimentary source-to-sink-fluxes in cold environments: Sauðárkrókur, Náttúrustofa Norðurlands vestra, p. 104.

Carrivick, J.L., Russell, A.J., Tweed, F.S., and Twigg, D. (2004) "Palaeohydrology and sedimentary impacts of jokulhlaups from Kverkfjoll, Iceland": Sedimentary Geology, v. **172**(1-2): p. 19-40.

Jökulhlaups (glacial outburst floods) occur frequently within Iceland and within most glaciated regions of the world. The largest jökulhlaups known to have occurred within Iceland drained from the northern margin of the Vatnajökull and along the Jökulsá á Fjöllum *during the Holocene. However, little is known about the number, age and flow characteristics of the Jökulsá á Fjöllum jökulhlaups. One source of meltwater into the Jökulsá á Fjöllum is Kverkfjöll, a glaciated stratovolcano. This paper provides detailed sedimentological evidence demonstrating that jökulhlaups have routed through Kverkfjallarani and hence from Kverkfjöll. Sedimentological evidence of jökulhlaups includes valley-fill deposits and slack water deposits. Lithofacies, which are indicative of high-magnitude fluvial sedimentation, show that these deposits cannot be the result of nonjökulhlaup processes. The situation and nature of the sediments permit palaeoflow reconstructions. Fine-grained deposits within slack water deposits mark a break in jökulhlaup deposition and suggest that at least three jökulhlaups have drained through Hraundalur, the predominant valley within Kverkfjallarani. Evidence of lava overrunning `wet' jokulhlaup deposits indicates that jökulhlaups occurred in close association with volcanic eruptions in the Biskupsfell fissure. The largest jökulhlaup was initially hyperconcentrated and subsequently became more fluid. Slope-area reconstructions indicate that the largest jökulhlaup had a probable average peak discharge of 45,000-50,000 m3 s-1; however, the peak discharge attenuated by 25-30% in just 25 km. These observations quantify the number, rheology, hydraulics and chronology of jokulhlaups from Kverkfjöll and hence within the Jökulsá á Fjöllum. This study presents a model of jökulhlaup impacts and characteristics from glaciated volcanoes and/or within volcanic rifting zones.*

Carrivick, J.L., and Twigg, D.R.T. (2004) "Jökulhlaup-influenced Topography and Geomorphology at Kverkfjöll, Iceland": Journal of Maps p. 17-27.

High magnitude jökulhlaups (glacial outburst floods) are known to have drained along the Jökulsá á Fjöllum river from the northern margin of Vatnajökull, Iceland during the Holocene. However, little is known of the number, age, source and flow characteristics of these jökulhlaups. Ongoing research therefore seeks to quantitatively analyse jökulhlaups from Kverkfjöll, which is a discrete source of meltwater into the Jökulsá á Fjöllum. To this end a high-resolution digital elevation model was produced and extensive geomorphological mapping and sedimentary analyswere accomplished in the field.The digital elevation model was produced by processing digitally scanned aerial photographs with the ERDAS Imagine Orthobase software. Processing incorporated twenty-nine ground control points, which were surveyed with a differential global positioning system. Ground control points allow photographic distortion to be remove and the elevation model to be located on the Earth's surface. A DEM with 10m horizontal resolution was resampled from a 5m horizontal resolution extraction. The DEM has sub-metre vertical accuracy. The DEM is substantially more detailed than presently available topographic maps an is therefore of interest for a whole range of recreational and scientific purposes. This research has identified geomorphological surfaces that distinguish at least three jökulhlaups from Kverkfjöll during the Holocene. These jökulhlaups routed into the Jökulsá á Fjöllum. Ongoing research has also sought to examine flow characteristics of jökulhlaups through Kverkfjallarani and to compare calculations of spatial and temporal hydraulics to maps of geomorphological and sedimentological jökulhlaup products.

Cassidy, N.J., Russell, A.J., Pringle, J.K., and Carrivick, J.L. (2004) GPR-Derived Architecture of Large-Scale Icelandic Jökulhlaup Deposits, North-East Iceland, Tenth International Conference on Ground Penetrating Radar: Delft, The Netherlands, .

Jökulhlaups (glacial outburst floods) occur frequently throughout Iceland and across most of the glaciated regions of the world. The largest of these jökulhlaups are known to have

occurred along the northern margin of the Vatnajökull Icecap and drained down the Jökulsá á Fjöllum river during the Holocene. Unfortunately, little is known about the number, frequency, age and flow characteristics of the Jökulsá á Fjöllum jökulhlaups and the relationship between their deposit architectures and the underlying volcanic lavas. During the summer of 2003, a total of over 20 km of GPR data was collected from a variety of jökulhlaup outwash sediments across the Jökulsá á Fjöllum flood plain. GPR results and corresponding facies interpretations are presented for the outwash deposits at two locations: Kverkfjöll, (approximately 20 Km from the jökulhlaup source) and Möðrudalur (approximately 100 Km downstream from the glacial margin). By combining the GPR data with ground surveying, photogrammetry and detailed sedimentary outcrop evidence, this study adds new perspectives to the sedimentary analysis of high-magnitude jökulhlaup events and their large-scale bars and bedforms. The results indicate that sedimentary architectures are controlled by the topographic nature of the underling lavas and the flow conditions in each region. By analysing the GPR derived facies in detail, it is also possible to identify different phases of jökulhlaup deposition. This information is vital for the assessment of jökulhlaup magnitudes, frequencies, and pathways and can be used for the prediction of future jökulhlaup impacts.

Egilsson, K. (1996) Áhrif Norðlingaöldumiðlunar á fuglalíf í Þjórsárverum, NÍ-97018: Reykjavík, Náttúrufræðistofnun Íslands; Unnið fyrir Landsvirkjun, p. 62 s. : kort, kortabl. br., töflur ; 30 sm + 3 laus kort br. (30x21 (2) ; 41x21 sm) (í vasa).

Kárahnjúkavirkjun 470 MW [kort]
Virkjanir norðan Vatnajökuls [kort]
Áætlanir um virkjanir norðan Vatnajökuls í Jökulsá á Fjöllum, Jökulsá á Brú og Jökulsá í Fljótsdal [kort]

Einarsson, T. (1976) "Tilgáta um orsök hamfarahlaupsins í Jökulsá á Fjöllum og um jarðvísindalega þýðingu þessa mikla hlaups": Jökull, v. **26**: p. 61-64.

Elíasson, S. (1974) "Eldsumbrot í Jökulsárgljúfrum": Náttúrufræðingurinn, v. **44**(1): p. 52-70.

— (1976) "Flóð í Jökulsá á Fjöllum og ný vötn í Kelduhverfi": Týli, tímarit um náttúrufræði og náttúruvernd, v. **6**(1): p. 35-38.

— (1978) "Molar um Jökulsárhlaup og Ásbyrgi": Náttúrufræðingurinn, v. **47**(3-4): p. 160-177.

— (1980) "Jarðsaga Jökulsárgljúfra": Lesörk Náttúruverndarráðs, v. **6**.

Guðmundsson, M.T. (2004) Viðauki E. Jarðfræðileg einkenni og sérstaða Vatnajökuls og svæðisins norðan hans: Ódáðahrauns með vatnasviði Jökulsár á Fjöllum, Þjóðgarður norðan Vatnajökuls, Umhverfisráðuneytið, p. 125-135.

— (2006) Jarðfræðileg einkenni og sérstaða Vatnajökuls og gosbeltisins norðan hans: Ódáðahraun og vatnasvið Jökulsár á Fjöllum, Viðauki A í: Vatnajökulsþjóðgarður. Skýrsla ráðgjafnefndar Umhverfisráðuneytisins, Umhverfisráðuneytið, p. 31-40.

Ísaksson, S.P. (1985) "Stórhlaup í Jökulsá á Fjöllum á fyrri hluta 18. aldar": Náttúrufræðingurinn, v. **54**(3-4): p. 165-191.

Kirkbride, M.P., Dugmore, A.J., and Brazier, V. (2006) "Radiocarbon dating of mid-Holocene megaflood deposits in the Jökulsá á Fjöllum, north Iceland": The Holocene, v. **16**(4): p. 605 - 609.

Two megafloods in the canyon of the Jökulsá á Fjöllum, the major northern routeway for glaciovolcanic floods from Vatnajökull, have been closely dated by 14C AMS dates from Betula macrofossils within peat immediately below beds of flood-deposited sand. Ages of c. 4415 and c. 4065 yr BP (5020 and 4610 cal. yr BP) are consistent with the presence of the Hekla 4 tephra (c. 3830 yr BP) resting on the upper surface of the younger flood sand. These sediments are correlated across the Jökulsá a Fjöllum canyon with the upper flood sands in a stack recording around 16 flood events. Deposits on both sides of the canyon were trimmed by the last megaflood after the Hekla 3 tephra fall at c. 2900 yr BP, and the highest Holocene flood stages were at the culmination of a series peaking at c. 3500 yr BP. These floods have wider palaeoclimatic significance because they require the formation of large subglacial reservoirs below Vatnajökull. Therefore, the dated floods indicate that a large composite ice cap covered volcanoes in the southeastern highlands through the early and middle Holocene, and that flood routeways largely switched to the south after c. 3500 yr BP.

Knudsen, Ó., and Russell, A.J. (2002) Jökulhlaup deposits at Ásbyrgi, northern Iceland: sedimentology and implications or flow type. Proceedings of a symposium held July 2000 at Reykjavik, Iceland, *in* Snorrason, A., Finsdottir, H.P., and Moss, M.E., eds., The Extremes of the Extremes: An International Symposium on Extraordinary Floods: IAHS Publication Number 271: , p. 107-112.

Most research into the impact of Icelandic jökulhlaups has concentrated on large relatively unconfined outwash plains in the south of Iceland. By contrast, here is only a limited picture of the magnitude, rheology, geomorphic impact and sedimentology of floods draining to the north from Vatnajökull glacier. This paper presents sedimentary evidence of jökulhlaup deposits at Ásbyrgi. The sedimentary succession consists of large-scale sandy trough cross-bedded units capped by a boulder-rich unit. These deposits are interpreted as the product of a hyperconcentrated flow. The location of the pit and the boulder surface suggests these flows emanated from the present river course of the Jökulsá á Fjöllum. The last period of jökulhlaup activity within the Jökulsá á Fjöllum was in the early-mid eighteenth century when a series of jökulhlaups inundated the lowlands north of Ásbyrgi. The fact that the historical floods within the Jökulsá á Fjöllum were hyperconcentrated suggests that these floods may have had a subglacial volcanic origin.

Kristmannsdottir, H., Bjornsson, A., Palsson, S., and Sveinbjornsdottir, A.E. (1999) "The impact of the 1996 subglacial volcanic eruption in Vatnajökull on the river Jökulsá á Fjöllum, North Iceland": Journal of Volcanology and Geothermal Research, v. **92**(3-4): p. 359-372.

A subglacial volcanic eruption took place in October 1996 beneath the Vatnajökull glacier, Iceland. The volcanic fissure erupted for some 14 days and it extended between two known subglacial central volcanoes. Most of the melt water drained to the south into the Grimsvötn caldera from where it escaped a month later during a major jökulhlaup (extreme flood) into the glacial rivers flowing to the south from Vatnajökull. At the start of the eruption, the northernmost part of the volcanic fissure extended across the water divide beneath the glacier and into the river basin of Jökulsá á Fjöllum, flowing to the north. A few days later, signs of melt water from the volcanic site were detected in the glacial river Jökulsá á Fjöllum. Distinct changes in the chemical composition of the water were observed. Both discharge and turbidity of the river were somewhat higher than normal for the season, but there was no extreme flood (jökulhlaup). Total dissolved solids (TDS) and conductivity of the river water, as well as bicarbonate, were found to be higher than previously observed. Traces of sulphide and mercury were detected, which are never recorded at normal conditions. The stable isotope ratios, [delta]D and [delta]18O, the 14C apparent age and the [delta]13C value were also found to be anomalous. In a few weeks the chemistry was back to normal. The chemical changes were most likely caused by a direct flow of melt water from the northernmost part of the main volcanic fissure or from small cauldrons created at the rim of the Bárdarbunga caldera. The flow of melt water to the north from the volcanic centre ebbed soon after or even just before the volcanic eruption in Vatnajökull ended. This experience shows clearly that simultaneous monitoring of chemical changes and flow rate in glacial rivers can deliver valuable data for following subglacial volcanic activity in space and time and may be used to give warning before a major catastrophic flood. Chemical study of glacial rivers can also be used to find out if a jökulhlaup is connected with a simultaneous volcanic eruption or not.

Russell, A., Knudsen, O., Tweed, F., Marren, P.M., Rice, J.W., Roberts, M., Waitt, R.B., and Rushmer, L. (2001) Giant jökulhlaup from the northern margin of Vatnajökull ice cap, Vorráðstefna 2001: ágrip erinda og veggspjalda: Hótel Loftleiðum, Reykjavík, Jarðfræðifélag Íslands.

Russell, A.J., Kayhkö, J., Tweed, F.S., Alho, P., Carrivick, J.L., Marren, P.M., Cassidy, N.J., Rushmer, E.L., Mountney, N.P., and Pringle, J. (2004) Jökulhlaups impacts within the Jökulsá á Fjöllum system, NE Iceland: implications for sediment transfer, *in* Beylich, A.A., Sæmundsson, Decaulne, A., and Sandberg, O., eds., Sedimentary source-to-sink-fluxes in cold environments: Sauðárkrókur, Náttúrustofa Norðurlands vestra, p. 104.

Sigurgeirsson (frá Helluvaði), J. (1996) "Kláfurinn á Jökulsá á Fjöllum": Glettingur, v. **6**(3): p. 40-41.

Sæmundsson, K. (1973) "Straumrákaðar klappir í kringum Ásbyrgi": Náttúrufræðingurinn, v. **43**: p. 52-60.

Sæþórsdóttir, A.D. (1997-1998) "Ferðamennska og virkjanir á hálendinu norðan Vatnajökuls": Landabréfið, v. **14-15**(1): p. 25-29.

— (1998) Áhrif virkjana norðan Vatnajökuls á ferðamennsku: Reykjavík, Iðnaðar- og viðskiptaráðuneytið : Landsvirkjun, p. 118 s. : myndir, kort, línurit, töflur ; 30 sm.

Tómasson, H. (1973) "Hamfarahlaup í Jökulsá á Fjöllum": Náttúrufræðingurinn, v. **43**(1-2): p. 12-34.

Van Vliet-Lanoe, B., Van Cauwenberge, A.-S., Bourgeois, O., Dauteuil, O., and Schneider, J.-L. (2001) "A candidate for the Last Interglacial record in northern Iceland: the Sydra formation. Stratigraphy and sedimentology": Comptes Rendus de l'Academie des Sciences - Series IIA - Earth and Planetary Science, v. **332**(9): p. 577-584.

The Sydra Formation is a widespread interglacial complex in the North Volcanic Zone, Iceland, from the sector of the Askja volcano down to Öxarfjördur at the north coast. It probably corresponds to OIS 5e, 5d and 5c. Subsequently, the region was covered by the Weichselian ice cap. It is significant as well for the understanding of the OIS 6 deglaciation and its relations to volcanism as also for the erosional budget of the Saalian, warm based and Weichselian, cold based, glaciations. A topographic bulge linked with a rapid glacio-isostatic rebound, downstream of the Jökulsá á Fjöllum river, is responsible for the development of the Sydra lacustrine deposits. An early abrupt event (Sy2), the Sydra ash probably corresponds to ash zone B as on the northern Iceland shelf and possibly an abrupt cooling. It presents no similarity with the Fossvogur formation in the Reykjavik district. The meaning of the formation is significant in term of rift activity and of palaeoclimate for OIS5.

Þórarinsson, S. (1950) "Jökulhlaup og eldgos á jökulvatnasvæði Jökulsár á Fjöllum": Náttúrufræðingurinn, v. **20**(3): p. 113-133.

— (1950) "Leiðrétting við "Jökulhlaup og eldgos..." 20. árg. bls. 113-133": Náttúrufræðingurinn, v. **20**(4): p. 191.

4.1.58 Brúárjökull

Björnsson, H., and Aðalgeirsdóttir, G. (1995) Veður á Brúarjökli og samanburður þess við leysingu á jökli og veður utan hans, RH-24-95: Reykjavík, Raunvísindastofnun Háskólans, p. 35.

Björnsson, H., and Eydal, G.P. (1999) Jökulhlaup í Kverká og Kreppu frá jaðarlónum við Brúarjökul, Science Institute of the University of Iceland, p. 5.

Björnsson, H., Guðmundsson, S., Pálsson, F., and Haraldsson, H.H. (2003) Energy balance and degree-day models of summer ablation on ice caps in Iceland, Vorráðstefna Jarðfræðifélags Íslands: Reykjavík.

Björnsson, H., Pálsson, F., Guðmundsson, S., and Eydal, G.P. (2001) Áhrif Hálslóns á Brúarjökul, RH-04-2001: Reykjavík, Raunvísindastofnun Háskólans, p. 26.

Daniel, B. (1953) Ferð á Brúarjökul; Pálmi Hannesson íslenzkaði, *in* Hannesson, P., and Eyþórsson, J., eds., Hrakningar og heiðarvegir, Volume **3.b**: Akureyri, Norðri, p. 110-119

Evans, D.J.A., Archer, S., and Wilson, D.J.H. (1999) "A comparison of the lichenometric and Schmidt hammer dating techniques based on data from the proglacial areas of some Icelandic glaciers": Quaternary Science Reviews, v. **18**(1): p. 13-41.

Measurements of Rhizocarpon section and Schmidt hammer R-values are reported from the proglacial geomorphic features on the forelands of the Icelandic glaciers of Kvíárjökull, Hólárjökull and Heinabergsjökull (Öræfi and south Vatnajökull), Sandfellsjökull and Öldufellsjökull (east Mýrdalsjökull), and Brúárjökull, Eyjabakkajökull and west Snæfell (north Vatnajökull). These data are used in reconstructions of patterns of glacier recession since the Little Ice Age maximum, and the geomophic signals of climatic versus non-climatic events are discussed. Age control was obtained from various dated substrates by utilizing historical accounts, aerial photographs and grave stones. Three lichen growth rates are calculated: (a) 0.51 mm a−1 (corrected to 0.50 mm a−1) with a colonization lag time of < 16 yr for the arid forelands of north Vatnajökull; (b) 0.56 mm a−1 with a colonization lag time of 5 yr for the Icelandic southeast coast; and (c) 0.80 mm a−1 with a colonization lag time of 6.5 yr for the south Vatnajökull and east Mýrdalsjökull forelands. These compare favourably with a previously published growth rate of 0.44 mm a−1 for the arid north of Iceland. This regional coverage of data allows a comparison between annual precipitation totals and lichen growth rates and the construction of a growth rate prediction curve for Iceland. The success of the Schmidt hammer in differentiating moraines based upon age varied according to the geomorphological setting. Reasonable R-value/lichen size correlations were obtained on the east Mýrdalsjökull and Heinabergsjökull forelands where unrestricted glacier advance into lowlands allows for a higher degree of debris surface freshening by direct glacial processes. Weak correlations were obtained at Kvíárjökull, where the glacier was restricted by a precursor latero-frontal moraine loop and therefore the debris comprising the Little Ice Age recessional moraines was diluted with material of various ages being reworked by mass movement from the precursor moraine loop. Similar problems arise in areas affected by surging glaciers, such as Brúárjökull and Eyjabakkajökull. It appears that an accurate R-value age-prediction curve can not be constructed for a timescale of < 100 yr in Iceland.

Evans, D.J.A., Lemmen, D.S., and Rea, B.R. (1999) "Glacial landsystems of the southwest Laurentide Ice Sheet: modern Icelandic analogues": Journal of Quaternary Science, v. **14**(7): p. 673-691.

Landform assemblages and associated stratigraphy, sedimentology and structure are used in the reconstruction of palaeo-ice-sheet dynamics in Alberta, western Canada. Interpretations are based upon the modern analogues from four outlet glaciers at the margins of Vatnajökull and Mýrdalsjökull, Iceland. In the area between Lloydminster and Lac la Biche, central Alberta, an extensive landform assemblage of megaflutings,

crevasse-squeeze ridges and thrust-block-moraine arcs document the former surging of part of the margin of the Laurentide Ice Sheet during later stages of recession. This and form assemblage, including numerous exposures of glacitectonised bedrock and Quaternary sediments, is comparable to the landsystem of the surging glaciers Eyjabakkajökull and Brúarjokull in Iceland. Near High River southern Alberta, the former existence of an ice lobe characterised by active recession is recorded by closely spaced, low-amplitude recessional push moraines that drape tunnel valleys. These are comparable in form and pattern to annual push moraines and fluted till surfaces produced by Breidamerkurjokull and Sandfellsjokull, Iceland, and also include rimmed depressions produced by the escape of artesian water during ice-marginal pushing. This study provides interpretations of the regional glacial geomorphology of Alberta based upon comparisons of form and stratigraphy with modern glacial analogues, and provides an alternative to recent models which invoke large floods of subglacial meltwater to explain many of these same features. Implications for ice dynamics and regional till stratigraphies are discussed.

Eyþórsson, J. (1960) Vatnajökull: Reykjavík, Almenna bókafélagið, 44 s., [62] mbls. : teikn., ritsýni, uppdr. p.

— (1963) "Brúarjökull hlaupinn (A sudden advance of Brúarjökull) ": Jökull, v. **13**: p. 19-21.

— (1964) "Brúarjökulsleiðangur 1964 (An expedition to Brúarjökull 1964) ": Jökull, v. **14**: p. 104-107.

Gardarsson, S.M., and Eliasson, J. (2006) "Influence of climate warming on Hálslon reservoir sediment filling": Nordic Hydrology, v. **37**(3): p. 235-245.

Halslon reservoir is the main reservoir of the Kárahnjúkar hydropower project in the eastern highlands of Iceland. Studies for the environmental impact assessment for the hydropower project showed that sediment will fill the reservoir in about 500 years based on the present sediment transport rate. The main source of the sediment is the Brúarjökull outlet glacier which is a part of the Vatnajökull ice cap. Recent studies of the influence of climate warming on glaciers in Iceland show that they will decrease significantly and, in some cases, completely disappear during the next few hundred years. In this study, a glacier melt model for the Brúarjökull outlet glacier is constructed to predict how fast the glacier will retreat in response to accepted climate warming scenarios. The results from the glacier model are then used as input to a sediment transport mass balance model for the Hálslon reservoir, which predicts the influence of the retreat of the glacier on the sedimentation in the reservoir. The modeling shows that, instead of the reservoir being completely full of sediment in 500 years, the Halslon reservoir will at that time still have about 50-60% of its original volume as the sediment yield will decrease as a result of the decreasing glacier size.

Gardarsson, S.M., Jonsson, B., and Elíasson, J. (2005) Sediment model of Hálslon Reservoir filling taken into account Brúarjökull Glacier recede, EGU 2005, Volume **7**: Vienna.

Guðmundsson, A.T. (1986) "Mat á búskap og afrennsli Tungnaárjökuls og Brúarjökuls í Vatnajökli": Jökull, v. **36**: p. 75-82.

Guðmundsson, M.T., Högnadóttir, and Björnsson, H. (1996) Brúarjökull - framhlaupið 1963-1964 og áhrif þess á rennsli Jökulsár á Brú, RH-11-96: Reykjavík, Raunvísindastofnun Háskólans.

Guðmundsson, S., Björnsson, H., Pálsson, F., and Haraldsson, H. (2005) Energy balance calculations of Brúarjökull during the August 2004 floods in Jökla, N-Vatnajökull, Iceland, RH-03-2005: Reykjavík, Raunvísindastofnun Háskólans.

Vatnajökull ice cap (Fig. 1) is located in the North Atlantic Ocean close to the maritime southeastern coast of Iceland; the summers are mild, the annual precipitation extensive and the mass turnover high. The north facing Brúarjökull (1550 km2), the largest outlet of Vatnajökull (Fig. 1), is flat and with an elevation range of 600 to 1550 m a.s.l. over 45 km. In years of zero mass balance the equilibrium line is close to 1200 m and the accumulation zone is about 60% of the total glacier area. The main river draining Brúarjökull is Jökla with a glaciated water drainage basin of 1250 km2 (Fig. 1). One to three automatic weather stations, providing both the short- and long wave radiation balance, the transfer of turbulent heat fluxes, and the total energy supplied for melting, have been operated during the ablation season at Brúarjökull since 1996 (Figs. 1 and 2). Since 1992 annual summer and winter balance observations have been conducted at 15 sparse locations spread over the outlet glacier (Fig. 1). Records of temperature and precipitation near Vatnajökull, and discharge of the river Jökla (at Brú á Jökuldal, 40 km from the glacier margin, 20 km north of Kárahnjúkar), are available for the periods of the glaciological observations (Fig. 1). Large floods were observed in the river Jökla right after intensive precipitation 1 to 3 August 2004, and during an exceptionally warm and sunny period 9 to 14 August 2004. The three main objects of this work were to i) obtain energy budget maps (EBMs) of Brúarjökull over the summer 2004, ii) compare the glacier runoff as estimated with the EBMs to the August 2004 floods in Jökla and iii) use the EBMs to evaluate the results of calculating the runoff with three distinct regression models that use only temperature observation outside the glacier as an input. The EBMs allow us to relate the computed runoff to observed weather parameters, winter balance and surface characteristics and to see how the runoff compares to the measured riverdischarge.

Guðmundsson, S., Björnsson, H., Pálsson, F., and Haraldsson, H.H. (2005) "Energy balance of Brúarjökull and circumstances leading to the August 2004 floods in the river Jökla, N-Vatnajökull": Jökull, v. **55**: p. 121-138.

— (2005) Energy balance of Brúarjökull during the period of August 2004 floods in Jökla, CWE meeting: Reykjavík.

— (2006) Energy balance of Brúarjökull and circumstances leading to the August 2004 floods in the river Jökla, N-Vatnajökull, Raunvísindaþing.

Guttormsson, H. (1998) "Við norðaustanverðan Vatnajökul": Glettingur, v. **8**(2-3): p. 9-21.

Hall, D.K., Williams, R.S., and Sigurðsson, O. (1995) "Glaciological observations of Brúarjökull, Iceland, using synthetic aperture radar and thematic mapper satellite data": Annals of Glaciology, v. **21**: p. 271-276.

Hannesson, P. (1953) Á Brúaröræfum, *in* Hannesson, P., and Eyþórsson, J., eds., Hrakningar og heiðarvegir, Volume **3.b**: Akureyri, Norðri, p. 18-64.

Hoppe, G. (1995) "Brúarjökull": Glettingur, v. **5**(2): p. 38-41.

Kaldal, I., and Víkingsson, S. (2001) "Saga jökulhörfunar og forns jökullóns sunnan Kárahnjúka": Glettingur v. **11**(2-3): p. 31-36.

Kaldal, I., Víkingsson, S., and Sigurðsson, O. (2001) "Framhlaup Brúarjökuls á sögulegum tíma": Glettingur v. **11** (2-3): p. 26-30.

Kjaer, K.H., Larsen, E., van der Meer, J., Ingólfsson, Ó., Kruger, J., Benediktsson, I. Ö., Knudsen, C.G., and Schomacker, A. (2006) "Subglacial decoupling at the sediment/bedrock interface: a new mechanism for rapid flowing ice": Quaternary Science Reviews, v. **25**(21-22): p. 2704-2712.

On millennial or even centennial time scales, the activity of rapid flowing ice can affect climate variability and global sea level through release of meltwater into the ocean and positive feedback loops to the climate system. At the surge-type glacier Brúarjökull, an outlet of the Vatnajökull ice cap, eastern Iceland, extremely rapid ice flow was sustained by overpressurized water causing decoupling beneath a thick sediment sequence that was coupled to the glacier. This newly discovered mechanism has far reaching consequences for our understanding of fast-flowing ice and its integration with sediment discharge and meltwater release.

Kjerúlf, P.J. (2001) "Í göngum á Vesturöræfum 1898 : úr skólaritgerð frá Eiðum 1901 ": Glettingur v. **11**(2-3): p. 80-82.

Kjerúlf, Þ. (1962) "Vatnajökull hlaupinn (Brúarjökull 1980)": Jökull, v. **12**: p. 47-48.

Knudsen, O. (1995) "Concertina eskers, Brúarjökull, Iceland: An indicator of surge-type glacier behaviour": Quaternary Science Reviews, v. **14**(5): p. 487-493.

Brúarjökull is a surging outlet lobe of Vatnajökull in SE Iceland. Geological evidence indicates that during quiescent phases, water drainage takes place in ice-walled and ice-roofed channels. As the glacier retreats, the courses of these channels are represented by eskers. Eskers which were englacial prior to surges become deformed during a surge. The deformation of eskers reflects strong longitudinal compression of the ice in the terminal zone. The wavelength of one of the compressed eskers indicates that ice in a 4 km wide margin was compressed by 50% of its original length. Compressed, or concertina eskers, date from the 1963-1964 and the 1890 surges of Brúarjökull. They *have not been found from the 1810 surge, indicating that they may not survive if overrun by subsequent surges.*

Knudsen, O., and Marren, P.M. (2002) "Sedimentation in a volcanically dammed valley, Brúarjökull, northeast Iceland": Quaternary Science Reviews, v. **21**(14-15): p. 1677-1692.

Sedimentation in upper Jokuldalur, northeast Iceland reveals a complex deglaciation history for the area. Subglacial eruption of an en-echelon ridge of pillow lavas and tuffs dammed the valley. The retreat of Brúarjökull to within the volcanic dam allowed a proglacial lake to form. Extensive retreat between surges of Brúarjökull may have resulted in the lake infilling and draining several times. The present infill reflects progressive glacier retreat, punctuated by stillstands and deposition of discrete wedges of coarse grained, ice-contact subaqueous fans. The valley infilled with sediment to within 10 m of the uppermost shoreline before progressive lowering of the outlet drained the lake. Breaching of the volcanic dam has since led to the incision of up to 85 m of sediment, deep into the underlying bedrock to create a spectacular gorge. This study documents how proglacial sedimentation can be controlled by glacier surge behaviour and the pattern of quiescent phase retreat.

Larsen, G., Gudmundsson, M.T., and Björnsson, H. (2000) Tephrostratigraphy of ablation areas of the Vatnajökull ice cap, Tungnaárjökull and Brúarjökull glaciers. Iceland 2000, Modern Processes and Past Environments: Keele, England, Keele University.

Magnússon, E., Pálsson, F., and Björnsson, H. (2004) Yfirborð Brúar- og Eyjabakkajökuls og vatnasvið Jökulsár á Brú, Kreppu, Kverkár og Jökulsár á Fljótsdal 1946-2000, RH-10-2004: Reykjavík, Jarðvísindastofnun Háskólans, p. 32.

Nelson, A.E., Willis, I.C., and Cofaigh, C.Ó. (2005) "Till genesis and glacier motion inferred from sedimentological evidence associated with the surge-type glacier, Brúarjökull, Iceland": Annals of Glaciology, v. **42**(1): p. 14-22.

A study employing macro- and micro-sedimentological techniques was conducted at three sites with recently deglaciated sediments in the proglacial area of Brúarjökull, a surge-type outlet glacier of the Vatnajökull ice cap, Iceland. Tills at these sites were likely deposited and deformed during the 1963/64 surge. At the height of the last surge, these sediments were beneath 90-120 m of ice, and associated basal shear stresses would have been 24-32 kPa. Tills associated with the surge at these sites formed by a combination of subglacial sediment deformation and lodgement and are thus regarded as 'hybrid tills'. The tills show evidence of both ductile and brittle deformation. Discontinuous clay lenses within the tills, indicating local ice-bed decoupling and sliding, imply that subglacial water pressures were spatially and temporally variable during the surge. The thickness of the subglacial deforming-till layer was 50-90 cm.

Rist, S. (1990) Ár og vötn í einstökum landshlutum: Austurland, *in* Rist, S., ed., Vatns er þörf: Reykjavík, Menningarsjóður, p. 141-148.

— (1990) Vatns er þörf: Reykjavík, Menningarsjóður, 248 s. : myndir, kort, línurit, töflur, uppdr. p.

Schomacker, A., Kruger, J., and Kjaer, K.H. (2006) "Ice-cored drumlins at the surge-type glacier Brúarjökull, Iceland: a transitional-state landform": Journal of Quaternary Science, v. **21**(1): p. 85-93.

This paper presents data on a glacial landform that, to Our knowledge, has not previously been described in the literature: the ice-cored drumlin. The study area is the forefield of the surge-type glacier Bruarjokull at the northeastern margin of the Vatnajokull ice cap, Fast Iceland. Based on sedimentological field investigations and aerial photograph interpretation, a qualitative model for the formation of ice-cored drumlins is proposed. The drumlin core consists of stagnant glacier ice from a previous advance and bubbly ice formed by snowdrifts, which were incorporated during the most recent advance-the 1963-64 surge. This advance deposited a mantle of basal till and streamlined the ice-cored moraines. Till deformation and deposition on the drumlin ice-core is facilitated by a substratum of low-permeability ice-cored moraines.

Todtmann, E.M. (1951-52) "Im Gletscherrückzugsgebiet des Vatna Jökull auf Island, 1950 & 1951": Neues Jahrbuch für Geologie Und Palaeontologie, v. **Mh. 1951-11 & 1952-9**: p. 335-341 & 401-411; 2+2 fig.

Description of area and discussion of eskers and moraines

— (1952, 1957) Im Gletscherrückzugsgebiet des Vatna Jökull auf Island, 1951 ; Kringilsárrani, das Vorfeld des Brúarjökull, am Nordand des Vatnajökull 1955, Sérpr. úr Neues Jahrbuch für Geologie und Paläontologie. Monatshefte: Stuttgart, p. 401-411; 255-278, 2 mbl. : kort.

— (1955) "Übersicht über die Eisrandlagen in Kringilsárrani von 1890-1955": Jökull, v. **5**: p. 8-10.

— (1957) "Am östlichen Rand des Brúarjökull, Nordrand des Vatnajökull (Island)": Neues Jb. Geol. Paläontol., v. **Monatsh. 316-327**.

— (1957) "Kringilsarrani, das Vorfeld des Bruarjökull am Nordrand des Vatnajökull": Neues Jahrbuch fur Geologie und Paläontologie. Monatshefte, v. **104**: p. 255-278.

Williams, R.S., Hall, D.K., and Benson, C.S. (1991) "Analysis of Glacier Facies Using Satellite Techniques": Journal of Glaciology, v. **37**(125): p. 120-128.

The different snow and ice types on a glacier may be subdivided according to the glacier-facies concept. The surficial expression of some facies may be detected at the end of the balance year by the use of visible and near-infrared image data from the Landsat multispectral scanner (MSS) and thematic mapper (TM) sensors. Ice and snow can be distinguished by reflectivity differences in individual or ratioed TM bands on Bruarjokull, an outlet glacier on the northern margin of the Vatnajökull ice cap, Iceland. The Landsat scene shows the upper limit of wet snow on 24 August 1986. Landsat-

derived reflectance is lowest for exposed ice and increases markedly at the transient snow line. Above the slush zone is a gradual increase in near-infrared reflectance as a result of decreasing grain-size of the snow, which characterizes drier snow. Landsat data are useful in measuring the areal extent of the ice facies, the slush zone within the wet-snow facies (combined wetsnow, percolation and dry-snow facies), and the respective positions of the transient snow line and the slush limit. In addition, fresh snowfall and/or airborne contaminants, such as soot and tephra, can limit the utility of Landsat data for delineation of the glacier facies in some cases.

Þórarinsson, S. (1964) "On the age of the terminal moraines of Brúarjökull and Hálsajökull": Jökull, v. **14**: p. 67-75.

— (1969) "Glacier surges in Iceland, with special reference to surges of Brúarjökli": Canadian Journal of Earth Sciences, v. **6**(no. 4): p. 875-882.

4.1.59 Dyngjujökull

Aðalgeirsdóttir, G., Björnsson, H., Pálsson, F., and Magnússon, E. (2005) "Analyses of a surging outlet glacier of Vatnajökull ice cap, Iceland." Annals of Glaciology, v. **Vol. 42**(1): p. 23-28.

Many of the large outlet glaciers of Vatnajökull ice cap, Iceland, have a history of regular surges. The mass transport during surges can be up to 25% of the total ice flux. This is a considerable amount that affects the whole ice cap, the location of the ice divides, the flow field and the size and shape of the ice cap. Data from the surging outlet Dyngjujökull, on the northern side of Vatnajökull, which surged during the period 1998-2000, are presented: surface elevation changes, displacement and total mass tr ansport. The total gain in ice volume in the receiving area, due to the surge, is considerably smaller than the loss in the reservoir area. The difference is mainly due to enhanced melting rates on the larger surface area of the crevassed glacier surface, and increased turbulent fluxes above the surface, but also due to increased frictional melting at the bed during the surge. A two-dimensional vertically integrated numerical flow model, of standard shallow-ice approximation type, is used to show that a modeled glacier that is similar in size to Dyngjujökull and subject to the same mass balance has three times higher velocities than the measured velocity during the quiescent phase. Adding surges in the numerical model, by periodically increasing the sliding velocity, causes the glacier to retreat and oscillate around a smaller state when subject to the same mass-balance regime. Lowering the equilibrium line by 50 m lets the modeled surging glacier oscillate around a size similar to that of the present glacier, indicating that surging is an efficient long-term ablation mechanism.

Alho, P. (2003) "Land cover characteristics in NE Iceland with special reference to jökulhlaup geomorphology": Geografiska Annaler Series a-Physical Geography, v. **85A**(3-4): p. 213-227.

Subglacial eruptions in Vatnajökull have accounted for several jökulhlaups (glacial outburst floods) in the Northern Volcanic Zone (NVZ). These events and aeolian processes have had a considerable impact on the landscape evolution of the area. Most of this area is occupied by barren land cover; the northern margin of the barren land cover is *advancing northwards, burying vegetation under wind-blown sediment. This paper presents a land-cover classification based on a supervised Landsat TM image classification with pre-processing and extensive field observations. Four land cover categories were identified: (a) lava cover (34.8%); (b) barren sediment cover (39.0%); (c) vegetation (25.1%); and (d) water and snow (1.1%). The mapping of sand transport routes demonstrates that a major aeolian sand transportation pathway is situated in the western part of the study area. The sedimentary formation elongated towards the northeast is evidence of active and continuous aeolian sand transportation towards the north. Interpretation of the satellite image suggests that four main areas are affected by jokulhlaups along the Jökulsa á Fjöllum: Ásbyrgi, Grímsstaðir, Herðubreið-Möðrudalur, and the Dyngjujökull sandur. In addition, jökulhlaup-related sediment cover (8%) in the study area, together with erosional features, are evidence of a severe and extensive jökulhlaup-induced process of land degradation.*

Björnsson, H., and Einarsson, P. (1990) "Volcanoes beneath Vatnajökull, Iceland: Evidence from radio echo-sounding earthquakes and jökulhlaups": Jökull, v. **40**: p. 147-168.

Integration of knowledge of subglacial topography, earthquake activity and jökulhlaups has contributed to more precise locations of the volcanic systems beneath Vatnajökull. Bárðarbunga is the centre of a volcanic system which includes the fissure swarms of Veiðivötn to the SW and Dyngjuháls to the NE. The Grímsvötn volcano is the centre of a system that comprises the Laki fissure swarm in the SW and extends for an unknown distance to the NE of the volcano. Þórðarhyrna is probably a separate central volcano within this system. The Kverkfjöll system can be traced 10 km to the SW of the Kverkfjöll volcano. It appears to be separated from the Grímsvötn volcano. The Askja fissure swarm extends beneath Dyngjujökull and can possibly be traced to the Grímsvötn volcano. Hamarinn and the ridge striking eastward from Hamarinn (Loki Ridge) are central volcanoes which together with the Fögrufjöll fissure swarm form a volcanic system. No support can be found in the topographic data for the existence of a central volcano near Breiðabunga. Volcanic activity in historical times has mainly been limited to the Grímsvötn and Bárðarbunga systems. Major rifting events have affected large sections of these volcanic systems but both have been remarkably quiet for the past decades. A few volcanic events are presumed to have occurred on the Hamarinn - Loki system and on the Askja fissure swarm beneath Dyngjujökull, but no event is known with certainty on the Kverkfjöll system. The rivers Skeiðará and Súla have the most frequent eruption-related jökulhlaups. They receive meltwater from the Grímsvötn caldera and the area to the SW of it, including Þórðarhyrna. Núpsvötn, Djúpá and Hverfisfljót drain the southwestern part of the Grímsvötn system, an area bounded by Þórðarhyrna, Geirvörtur, Hágöngur and Pálsfjall. Skaftá drains the Loki Ridge and the area west of Grímsvötn. Jökulhlaups in Kaldakvísl, and ultimately Þjórsá, must originate in the Bárðarbunga or the Hamarinn - Loki systems, and the only possible source for volcanic jökulhlaups in Skjálfandafljót is the northern part of the Bárðarbunga system. Jökulsá á Fjöllum may drain meltwater from activity in all the volcanic systems in northern Vatnajökull: Bárðarbunga, the Askja fissure swarm and Kverkfjöll. This includes the voluminous, ice-filled calderas of Bárðarbunga and Kverkfjöll. Activity in the northern part of the Grímsvötn system may cause floods in Jökulsá á Fjöllum. Meltwater from volcanic activity on the SE flank of a ridge that strikes south from Kverkfjöll may drain to Jökulsá á Brú. Volcanic activity farther north on the E flanks of this ridge would cause floods in Kreppa.

Björnsson, H., Guðmundsson, S., Pálsson, F., and Haraldsson, H.H. (2003) Energy balance and degree-day models of summer ablation on ice caps in Iceland, Vorráðstefna Jarðfræðifélags Íslands: Reykjavík.

Björnsson, H., Pálsson, F., Guðmundsson, M.T., and Haraldsson, H.H. (1998) "Mass balance of western and northern Vatnajökull, Iceland, 1991-1995. " Jökull, v. **45**: p. 35-58.

During the period from 1991 to 1995, glacier mass balance has been monitored on the western and northern outlets of Vatnajökull (8100 km2; Fig. 1) which altogether comprise about half of the total area of the ice cap (4000 km2) and extend from an elevation of 2000 m down to 600 m. In the central areas of the ice cap, the winter balance has typically been about 2.5 m of water equivalent but the summer balance has varied from +0.5 to -0.5 m, and hence the net mass balance has varied from 2 to 3 m. At the glacier termini of 700-800 m elevation, the summer balance was typically about -5 m, and the winter balance 1.5 m on the western outlets and 0.5 m on the northern ones. The mean specific winter balance of the glaciers was fairly constant over this period but the summer balance, and hence the annual net balance, decreased year by year. The specific annual net balance was positive for all the northern outlets in the first three years due to cold spells and snowfall during the summers but slightly negative for the western ones in the third year. In the last year (1994-95) the mass balance was in general negative but close to zero for one outlet (Dyngjujökull, Fig. 2). For a year of zero net balance, the equilibrium line is estimated to be about 1100 m for the southwestern outlets but 1200-1300 m for the northwestern and northern outlets; the accumulation area is typically about 60% of the total glacier area and the specific runoff, corresponding to the summer balance, about 60 l s-1 km-2 averaged over the entire glacier and the whole year. During the years of the most positive mass balance this contribution from the summer balance dropped down to 30l s-1 km-2. Precipitation on the glaciers during summer may add 10-20 l s-1 km-2 to the specific discharge.

Björnsson, H., Pálsson, F., and Guðmundsson, S. (2001) The response of Arctic Ice Masses to Climate change (ICEMASS). SIUI, Final report. European Commission, Framework IV, Environmental and Climate Research Programme (DG XII), contract ENV4-CT97-0490, RH-10-2001: Reykjavík, Raunvísindastofnun Háskólans, p. 19.

During the years 1998-2000, the Science Institute, University of Iceland carried out measurements of the ice cap Vatnajökull (8200 km2) to quantify the mass balance components and their spatial and temporal variability. Meteorological observations were collected for the calibration of models of the energy and mass balance of Vatnajökull, and to calculate the energy balance components responsible for melting during the summer months. Further, we evaluated the impact of the volcanic eruptions in October 1996 and December 1998 mass balance of the ice cap; both direct melting and the effect of reduced albedo on the radiation balance. We also evaluated the effect of the recent surges in Vatnajökull on the downglacier mass transport. The winter balance is to a large extent determined by orographic effects, decreasing with increasing distance from the southern coast of Iceland. The summer balance decreases also along this transect due to decreasing albedo in the ablation areas. In the year 1997-98, the average winter balance for the entire ice cap was about 1.14 m of water equivalent, the summer balance –2.08 m and the net balance –0.93 m. The accumulation area comprised 44 % of the total area of the ice cap. In the year 1998-99, the average winter balance was only about 1.36 m, the summer balance – 1.83 m and the net balance –0.47 m. The accumulation area comprised about 54 % of the total area of the ice cap. In the year 1999-2000, the average winter balance was only

about 1.46 m, the summer balance –2.31 m and the net balance –0.85 m. The accumulation area comprised about 48 % of the total area of the ice cap. A rise in the equilibrium line by 100 m due to a climate change would reduce the net balance of Vatnajökull by about 0.75 m of water equivalent per year. In the ablation area radiation provides typically two-thirds of the melt energy and turbulent exchange one-third during the summer period May-August, and turbulent fluxes about one-third. In the accumulation area turbulent exchange becomes less significant. Spatial and temporal variations of the radiation balance are due to increasing solar radiation with elevation (due to low-lying clouds) and decreasing albedo towards the western part of the ice cap. Surface albedo varies enormously in space and time and values as low as 0.1 are found in places where volcanic ash layers melt out. Katabatic flow shapes the microclimate of the glacier except during the passage of intense storms. Two main factors determine the distribution of turbulent heat flux components: higher temperatures on the western and southern slopes of the ice cap than the northern parts, and the increasing strength of catabatic winds downglacier. The total loss of the ice cap's volume in 1997-2000 was 18.5 km3, which is about 0.5 % of its volume. During the period 1991-2000 the mass balance has been negative by 16 km3. In addition to this, the volume of ice melted by the volcanic eruption in October 1996 was 4 km3. The loss of the surface net balance during the year 1996-1997 was 8 km3, the total loss of the ice cap was 12 km3. The volcanic eruption in December 1998 melted only about 0.1 km3. The volcanic ash of the eruption in 1996 lowered the albedo by 20% in large areas and increased the annual ablation of Vatnajökull for one year by 10-15%. During the surge of Dyngjujökull (1100 km2) in 1999-2000 a mass of 13 km3 was transported downglacier from the accumulation area to the ablation area of that glacier outlet. During surges in Vatnajökull 1995-2000 altogether 23 km3 of ice were transported downglacier from the accumulation area. The summer ablation of the surging glacier outlets increases by 30 % during the first summer after a surge anddeclines gradually with time until the next surge takes place.

Eyþórsson, J. (1960) Vatnajökull: Reykjavík, Almenna bókafélagið, 44 s., [62] mbls. : teikn., ritsýni, uppdr. p.

Fischer, A., Rott, H., and Bjornsson, H. (2003) "Observation of recent surges of Vatnajokull, Iceland, by means of ERS SAR interferometry": Annals of Glaciology, v. **37**: p. 69-76.

Recent surges of two outlet glaciers of the Vatnajökull ice cap, Iceland, were observed using European Remote-sensing Satellite (ERS) synthetic aperture radar (SAR) tandem interferograms from 12 different dates between December 1995 and January 2000. ERS SAR interferometry provided new information on the temporal and spatial variations in surface velocity during surges, after fieldwork became impossible. The area affected by the surge and therefore by increased basal sliding was delineated. The migration of flow divides on the ice cap during a surge was described. At Sylgjujokull, a western outlet glacier covering an area of 175 km(2), the fully developed surge and its abating phase were studied. Over a period of > 2 years after December 1995, the ice motion decreased steadily, with initially the highest velocities and subsequently the most pronounced decrease in velocity at the glacier terminus. The surge of Dyngjujökull, a northern outlet glacier covering an area of 1040 km(2), reached its maximum in 1999/2000. Slow acceleration over an area of about 200 km(2) was first observed between March 1996 and January 1997. The interferogram from January 1999 shows a well-developed surge area, covering 210 km(2). This area more than doubled by January 2000, with maximum velocities reaching > 7 m d(-1).

Between January 1997 and January 2000, the flow divide between Dyngju- and Skeiðarárjökull shifted 16 km to the south. The investigations indicate that a surge cycle on these glaciers spans several years, with slowly increasing motion over an extended area in the beginning, and more pronounced velocity changes during the active surge phase lasting 1-2 years.

Pálsson, F., Magnússon, E., and Björnsson, H. (2002) The surge of Dyngjujökull 1997-2000. Mass transport, ice flow velocities, and effects on mass balance and runoff, RH-01-2002: Reykjavík, Raunvísindastofnun Háskólans, p. 23.

Guðmundsson, A.T. (1986) "Eldgos á Dyngjuhálsi á 18. öld": Náttúrufræðingurinn, v. **56**(1. hefti).

Sigvaldason, G.E. (2002) "Volcanic and tectonic processes coinciding with glaciation and crustal rebound: an early Holocene rhyolitic eruption in the Dyngjufjöll volcanic centre and the formation of the Askja caldera, north Iceland": Bulletin of Volcanology v. **64**: p. 192-205.

A pronounced volcanic production maximum on the rift zones through Iceland coincided with rapid crustal rebound during and after glacier melting at the Pleistocene/Holocene boundary. At peak glaciation, ice thickness over central Iceland may have reached 1,500–2,000 m, causing 400–500-m depression of the crust. Rapid climatic improvement caused glacier melting and removal of the ice load within about 1,000 years. Low mantle viscosity resulted in rapid crustal rebound which was completed in about 1,000 years, with an average rate of uplift on the order of nearly half a metre per year over central Iceland. High volcanic production rate is documented by tephrachronological dating and volume estimates of several large-volume monogenetic lava shields and polygenetic volcanic centres along the plate boundary. A Plinian rhyolitic eruption, dated at about 10 ka within the Askja caldera in the Dyngjufjöll volcanic centre, left a pumice deposit which serves as a marker horizon during this remarkable, high-intensity period in the history of the volcano. At the time of the eruption, glaciers had retreated from the coastal areas of the country but the central, elevated parts were covered with a thinning glacier. The Plinian eruption (1–2 km3 dense rock equivalent) was triggered by pressure release caused by glacier melting and volatile supersaturation. Distal deposits of rhyolitic pumice are found in soil sections in coastal areas of eastern and northern Iceland where the pumice occurs between tephra layers from other sources which have been dated by independent methods. A few proximal deposits are preserved within the Dyngjufjöll centre. These provide age constraints on major tectonic and volcanic events during the period of crustal rebound, before and after complete glacier removal. The rhyolitic pumice is sandwiched between thick layers of phreatomagmatic basaltic tephra formed in an open melt-water lake. Sharp contacts between the deposits suggest quick succession of events, but lack of mixing between magmas indicates separate vent locations. The vent location for the 10-ka Plinian eruption has been obliterated by later events but available evidence, supported by a gravity survey, suggests its location in the central part of the Dyngjufjöll volcano. The eruption formed a subsidence structure, presently seen as an embayment in the hyaloclastite mountain block in the southern part of the Askja caldera where a second Plinian eruption occurred in 1875 A.D. The Plinian 10-ka eruption occurred while thinning glaciers were still present over central Iceland, but the Askja caldera formed after lavas started to flow over ice-free surfaces. The morphology of the caldera faults suggests non-simultaneous movement, and the tectonics are not easily compatible with conventional caldera models. A model is

proposed involving uplift of tectonically well-defined crustal blocks to the north and west of the Askja caldera, combined with downsagging caused by voluminous outpouring of basaltic lava. The southern and eastern borders of the caldera are remnants of a subsidence following the 10-ka Plinian eruption, partly reactivated by the 1875 A.D. Plinian eruption. The model provides a satisfactory explanation for the enigmatic Öskjuop pass, and it is in agreement with a gravity survey of the Dyngjufjöll centre. The uplift coincided with rapid crustal rebound which was amplified by crustal deformation (doming) of the volcanic centre caused by high magmatic pressure in the plumbing system of the volcano. This is supported by emission of very large lava flows produced in the first millennia of the Holocene.

Sigvaldason, G.E., Annertz, K., and Nilsson, M. (1992) "Effect of glacier loading/deloading on volcanism: postglacial volcanic production rate of the Dyngjufjöll area, central Iceland": Bulletin of Volcanology, v. **54**(5): p. 385-392.

Tephrochronological dating of postglacial volcanism in the Dyngjufjöll volcanic complex, a major spreading center in the Icelandic Rift Zone, indicates a high production rate in the millennia following deglaciation as compared to the present low productivity. The visible and implied evidence indicates that lava production in the period 10 000–4500 bp was at least 20 to 30 times higher than that in the period after 2900 bp but the results are biased towards lower values for lava volumes during the earlier age periods since multiple lava layers are buried beneath younger flows. The higher production rate during the earlier period coincides with the disappearance of glaciers of the last glaciation. Decreasing lithostatic pressure as the glacier melts and vigorous crustal movements caused by rapid isostatic rebound may trigger intense volcanism until a new pressure equilibrium has been established.

4.1.60 Köldukvíslarjökull

Björnsson, H. (1983) Niðurstöður íssjármælinga á Köldukvíslarjökli, RH-83-03: Reykjavík, Raunvísindastofnun Háskólans og Landsvirkjun, p. 55.

Björnsson, H., Guðmundsson, S., Pálsson, F., and Haraldsson, H.H. (2003) Energy balance and degree-day models of summer ablation on ice caps in Iceland, Vorráðstefna Jarðfræðifélags Íslands: Reykjavík.

Freysteinsson, S. (1972) "Jökulhlaup í Köldukvísl": Jökull, v. **22**: p. 83-88.

Guðmundsson, S., Björnsson, H., Haraldsson, H., and Pálsson (2000) Veðurathuganir og jökulleysing á Vatnajökli sumarið 1999, RH-16-00: Reykjavík, Raunvísindastofnun Háskólans.

Sumarið 1999 var haldið áfram rekstri sjálfvirkra veðurstöðva á Vatnajökli, sem hófst 1994 í þeim tilgangi að tengja sumarleysingu á jöklinum og veðurþætti. Alls voru settar upp sex stöðvar: í 1205 m hæð á Brúarjökli, 1100 m á Köldukvíslarjökli, 1725 m á Grímsfjalli , þrjár á Tungnaárjökli í 755 m, 1100 m og 1440 m. Að auki var veðurgögnum safnað í 725 m í Jökulheimum. Fimm af stöðvunum mynduðu línu sem náði frá 725 m í Jökulheimum, yfir Tungnaárjökul og upp í 1725 m á Grímsfjalli.

Stöðvarnar sex á Vatnajökli mældu allar hita, raka, vind og alla geislunarþætti. Í Jökulheimum var ekki mæld stuttbylgjugeislun. Í þessari skýrslu er greint fr niðurstöðum gagnasöfnunar um veðurþætti í 2 m hæð en í annarri skýrslu mun greint frá útreikninga á orkuþáttum sem bárust að yfirborði jökulsins. Mælitæki voru sett upp af starfsmönnum Landsvirkjunar og Raunvísindastofnunar en úrvinnsla fór fram við Raunvísindastofnun. Verkefnið var að hluta styrkt af Evrópusambandinu, fjórða árið í röð.

Guðmundsson, S., Björnsson, H., Haraldsson, H., and Pálsson, F. (1999) Veðurathuganir og jökulleysing á Vatnajökli sumarið 1998, RH-13-99: Reykjavík, Raunvísindastofnun Háskólans.

Sumarið 1998 var haldið áfram rekstri sjálfvirkra veðurstöðva á Vatnajökli, sem hófst 1994 í þeim tilgangi að tengja sumarleysingu á jöklinum og veðurþætti. Alls voru settar upp fimm stöðvar: á Brúarjökli, Dyngjujökli, Köldukvíslarjökli og tvær á Tungnaárjökli. Allar stöðvarnar mæla nú sömu veðurþætti: hita, raka, vind og alla geislunarþætti. Önnur stöðin á Tungnaárjökli bilaði hins vegar svo að gögn fengust aðeins frá fjórum stöðvum. Í þessari skýrslu er greint frá niðurstöðum gagnasöfnunar um veðurþætti í 2 m hæð en í annarri skýrslu mun greint frá útreikninga á orkuþáttum sem bárust að yfirborði jökulsins. Mælitæki voru sett upp af starfsmönnum Landsvirkjunar og Raunvísindastofnunar en úrvinnsla fór fram við Raunvísindastofnun. Verkefnið var að hluta styrkt af Evrópusambandinu, þriðja árið í röð.

— (2001) Veðurathuganir og jökulleysing á Vatnajökli sumarið 2000, RH-17-2001: Reykjavík, Raunvísindastofnun Háskólans.

Sumarið 2000 var haldið áfram rekstri sjálfvirkra veðurstöðva á Vatnajökli, sem hófst 1994 í þeim tilgangi að tengja sumarleysingu á jöklinum og veðurþætti. Alls voru settar upp sex stöðvar: í 1205 m hæð á Brúarjökli, 1100 m á Köldukvíslarjökli, 1725 m á Grímsfjalli , þrjár á Tungnaárjökli í 755 m, 1235 m og 1440 m. Að auki var veðurgögnum safnað í 725 m í Jökulheimum. Eins og sumarið 1999 mynduðu fimm af stöðvunum línu sem náði frá 725 m í Jökulheimum, yfir Tungnaárjökul og upp í 1725 m á Grímsfjalli. Stöðvarnar sex á Vatnajökli mældu allar hita, raka, vind og alla geislunarþætti. Í Jökulheimum var ekki mæld langbylgjugeislun. Í þessari skýrslu er greint frá niðurstöðum gagnasöfnunar um veðurþætti í 2 m hæð en í annarri skýrslu mun greint frá útreikninga á orkuþáttum sem bárust að yfirborði jökulsins. Mælitæki voru sett upp af starfsmönnum Landsvirkjunar og Raunvísindastofnunar en úrvinnsla fór fram við Raunvísindastofnun. Verkefnið var að hluta styrkt af Evrópusambandinu, fimmta árið í röð.

Hróarsson, B. (1992) Geysers and hot springs in Iceland: Reykjavík, Mál og menning, 158 s. : myndir, kort

Hróarsson, B., and Jónsson, S.S. (1991) Hverir á Íslandi: Reykjavík Mál og menning, 160 s. : myndir, kort, uppdr.

4.1.61 Tungn(a)árjökull, Tungn(a)á

Andrzejewski, L. (2002) "The impact of surges on the ice-marginal landsystem of Tungnaárjökull, Iceland": Sedimentary Geology, v. **149**(1-3): p. 59-72.

Geomorphological mapping of the Tungnaárjökull marginal zone based on the analysis of aerial and satellite photographs and field research were used as the basis for determining its morphogenesis. The differentiation of glacial and glaciofluvial forms, their association, and their mode of formation allowed five different domains of the Tungnaárjökull marginal zone to be distinguished. They record the distinct mechanism of glaciation and deglaciation of the glacier forefield, which is the result of the morphostructure of the volcanic substrate and the dynamics of the glacier snout. Structural and textural investigation of end moraine deposits and some proximal parts of the sandar allowed numerous glaciotectonic structures to be identified. Subglacial activity is conditioned by the local morphostructure of the substrate and transforms flat or undulated moraine surfaces and results in their drumlinisation. Reconstruction of the character of individual advances of Tungnaárjökull, from the end of the 19th century using geomorphological and sedimentological evidence within the ice marginal zone, suggest that they are consistent with surge-type advances. The configuration, dynamics and location of glacial streams in the marginal zone of Tungnaárjökull are conditioned by the Late Pleistocene volcanic relief. Where the arrangement of volcanic ridges is parallel to the glacier margin, its dynamics were restricted, creating groups of linear ice-contact forms. Where volcanic ridges were arranged perpendicularly to the glacier snout, conditions were suitable for the development of thrust end moraines and the formation of vast outwash plains.

Björnsson, H. (1970) "Hugleiðingar um jöklarannsóknir á Íslandi": Jökull, v. **20**: p. 15-26.

This paper gives a short outline of some aspects of glaciology with the main emphasis on topics related to meteorology and hydrology. A descriptive summary of the basic theory and modern measurement techniques is given along with suggestions for new research projects in Iceland. Following topics are discussed: The main links in the relation between glacier variations and climate, the mass balance, the energy budget, glacier response, kinematic waves, diffusion of kinematic waves, response time and lag time of a glacier. The value of measurements of glacier variations in Iceland is discussed in light of these topics. Furher, a description is given of glacier flow and glacier surges. Crystallographic problems are briefly mentioned. The paper concludes with a proposal for investigations on Tungnaárjökull.

— (1981) Niðurstöður íssjármælinga á Tungnárjökli og Sylgjujökli: Reykjavík, Raunvísindastofnun Háskólans og Landsvirkjun, p. 50.

Freysteinsson, S. (1968) "Tungnárjökull": Jökull, v. **18**: p. 371-388.

— (1984) "Tungnárjökull - langskurðarmæling 1959-1979 (Tungnárjökull Profile Surveys 1959-1979)": Jökull, v. **34**: p. 131-139.

Gudmundsson, G.H., Adalgeirsdottir, G., and Bjornsson, H. (2003) "Observational verification of predicted increase in bedrock-to-surface amplitude transfer during a glacier surge": Annals of Glaciology, v. **36**: p. 91-96.

The amplitude ratio between surface and bedrock topography has been predicted to depend strongly on the ratio of deformational velocity to mean basal sliding velocity. Observations made prior to and during a surge of Tungnaarjokull, Vatnajokull ice cap, Iceland, allow this prediction to be tested. During the surge, the ratio of internal deformational velocity and basal sliding (slip ratio) changed from about unity to a few hundred. The amplitude ratio changed from about 0.1 to about 0.7. This increase in amplitude ratio is in good overall agreement with predictions based on an analytical perturbation analysis for a linearly viscous medium which includes the effects of horizontal deviatoric stresses on glacier flow. An increase in amplitude ratio of this magnitude is not predicted by a similarly linearized analysis that employs the commonly used shallow-ice approximation. The strong increase in transfer amplitude observed in the surge of Tungnaarjokull is a clear illustration of the effects of horizontal stress transmission on glacier flow reported here for the first time.

Guðmundsson, A.T. (1986) "Mat á búskap og afrennsli Tungnaárjökuls og Brúarjökuls í Vatnajökli": Jökull, v. **36**: p. 75-82.

Guðmundsson, M.T., and Björnsson, H. (1992) Tungnaárjökull. I. Framhlaupið 1945-1946, RH-92-17: Reykjavík, Raunvísindastofnun Háskólans, p. 27.

— (1992) Tungnaárjökull. II. Breytingar á stærð, ísskriði og afrennsli eftir 1946, RH-92-19: Reykjavík, Raunvísindastofnun Háskólans, p. 39.

Guðmundsson, S., Björnsson, H., Haraldsson, H., and Pálsson, F. (1999) Veðurathuganir og jökulleysing á Vatnajökli sumarið 1998, RH-13-99: Reykjavík, Raunvísindastofnun Háskólans.

Sumarið 1998 var haldið áfram rekstri sjálfvirkra veðurstöðva á Vatnajökli, sem hófst 1994 í þeim tilgangi að tengja sumarleysingu á jöklinum og veðurþætti. Alls voru settar upp fimm stöðvar: á Brúarjökli, Dyngjujökli, Köldukvíslarjökli og tvær á Tungnaárjökli. Allar stöðvarnar mæla nú sömu veðurþætti: hita, raka, vind og alla geislunarþætti. Önnur stöðin á Tungnaárjökli bilaði hins vegar svo að gögn fengust aðeins frá fjórum stöðvum. Í þessari skýrslu er greint frá niðurstöðum gagnasöfnunar um veðurþætti í 2 m hæð en í annarri skýrslu mun greint frá útreikninga á orkuþáttum sem bárust að yfirborði jökulsins. Mælitæki voru sett upp af starfsmönnum Landsvirkjunar og Raunvísindastofnunar en úrvinnsla fór fram við Raunvísindastofnun. Verkefnið var að hluta styrkt af Evrópusambandinu, þriðja árið í röð.

Guðmundsson, S., Björnsson, H., Haraldsson, H., and Pálsson (2000) Veðurathuganir og jökulleysing á Vatnajökli sumarið 1999, RH-16-00: Reykjavík, Raunvísindastofnun Háskólans.

Sumarið 1999 var haldið áfram rekstri sjálfvirkra veðurstöðva á Vatnajökli, sem hófst 1994 í þeim tilgangi að tengja sumarleysingu á jöklinum og veðurþætti. Alls voru settar upp sex stöðvar: í 1205 m hæð á Brúarjökli, 1100 m á Köldukvíslarjökli, 1725 m á Grímsfjalli , þrjár á Tungnaárjökli í 755 m, 1100 m og 1440 m. Að auki var veðurgögnum safnað í 725 m í Jökulheimum. Fimm af stöðvunum mynduðu línu sem náði frá 725 m í Jökulheimum, yfir Tungnaárjökul og upp í 1725 m á Grímsfjalli. Stöðvarnar sex á Vatnajökli mældu allar hita, raka, vind og alla geislunarþætti. Í

Jökulheimum var ekki mæld stuttbylgjugeislun. Í þessari skýrslu er greint fr niðurstöðum gagnasöfnunar um veðurþætti í 2 m hæð en í annarri skýrslu mun greint frá útreikninga á orkuþáttum sem bárust að yfirborði jökulsins. Mælitæki voru sett upp af starfsmönnum Landsvirkjunar og Raunvísindastofnunar en úrvinnsla fór fram við Raunvísindastofnun. Verkefnið var að hluta styrkt af Evrópusambandinu, fjórða árið í röð.

— (2001) Veðurathuganir og jökulleysing á Vatnajökli sumarið 2000, RH-17-2001: Reykjavík, Raunvísindastofnun Háskólans.

Sumarið 2000 var haldið áfram rekstri sjálfvirkra veðurstöðva á Vatnajökli, sem hófst 1994 í þeim tilgangi að tengja sumarleysingu á jöklinum og veðurþætti. Alls voru settar upp sex stöðvar: í 1205 m hæð á Brúarjökli, 1100 m á Köldukvíslarjökli, 1725 m á Grímsfjalli , þrjár á Tungnaárjökli í 755 m, 1235 m og 1440 m. Að auki var veðurgögnum safnað í 725 m í Jökulheimum. Eins og sumarið 1999 mynduðu fimm af stöðvunum línu sem náði frá 725 m í Jökulheimum, yfir Tungnaárjökul og upp í 1725 m á Grímsfjalli. Stöðvarnar sex á Vatnajökli mældu allar hita, raka, vind og alla geislunarþætti. Í Jökulheimum var ekki mæld langbylgjugeislun. Í þessari skýrslu er greint frá niðurstöðum gagnasöfnunar um veðurþætti í 2 m hæð en í annarri skýrslu mun greint frá útreikninga á orkuþáttum sem bárust að yfirborði jökulsins. Mælitæki voru sett upp af starfsmönnum Landsvirkjunar og Raunvísindastofnunar en úrvinnsla fór fram við Raunvísindastofnun. Verkefnið var að hluta styrkt af Evrópusambandinu, fimmta árið í röð.

— (2002) Veðurathuganir og jökulleysing á Vatnajökli og Langjökli sumarið 2001, RH-17-2002: Reykjavík, Raunvísindastofnun Háskólans.

Sumarið 2001 var haldið áfram rekstri sjálfvirkra veðurstöðva á Vatnajökli, sem hófst 1994 í þeim tilgangi að tengja sumarleysingu á jöklinum og veðurþætti. Stöðvarnar lágu á sniði upp vesturhluta jökulsins upp á Grímsfjall (1724 m) og niður norðausturhluta hans; tvær á Tungnaárjökli í 1100 m og 1445 m hæð og þrjár á Brúarjökli í 860 m, 1210 m og 1525 m hæð. Að auki var veðurgögnum safnað í 725 m hæð í Jökulheimum og 656 m við Kárahnjúka. Stöðvarnar á jöklinum mældu hita, raka, vind og alla geislunarþætti. Í Jökulheimum var ekki mæld langbylgjugeislun og engir geislunarþættir við Kárahnjúka. Á Langjökli voru reknar tvær veðurstöðvar. Stöðvarnar lágu á sniði eftir Hagafellsjökli vestari, í 490 m og 1060 m hæð. Að auki var hitagögnum safnað í 474 m hæð norðan við Skjaldbreið og í 299 m hæð á Söðulhólum. Í þessari skýrslu er greint frá niðurstöðum gagnasöfnunar um veðurþætti í 2 m hæð en í annarri skýrslu mun greint frá útreikningum á orkuþáttum sem bárust að yfirborði jöklanna. Mælitæki voru sett upp af starfsmönnum Landsvirkjunar og Raunvísindastofnunar en úrvinnsla fór fram við Raunvísindastofnun. Verkefnið var að hluta styrkt af Evrópusambandinu, sjötta árið í röð.

Kaldal, I., and Víkingsson, S. (2001) Umhverfi og orkuöflun - jöklalandslag. Síðujökull, Skaftárjökull, Tungnaárjökull og Sylgjujökull. Stöðuyfirlit í apríl 2001, IK-0001, Orkustofnun, Rannsóknasvið. Greinargerð.

Larsen, G., Gudmundsson, M.T., and Björnsson, H. (2000) Tephrostratigraphy of ablation areas of the Vatnajökull ice cap, Tungnaárjökull and Brúarjökull glaciers. Iceland 2000, Modern Processes and Past Environments: Keele, England, Keele University.

Larsen, G., Guðmundsson, M.T., and Björnsson, H. (1996) Gjóskulög í Tungnaárjökli: gossaga, aldur íss og dvalartími gjósku í jökli, Vorráðstefna 1996: "Eldgos í Vatnajökli 1996", ágrip erinda og veggspjalda: Reykjavík, Jarðfræðafélag Íslands, p. 33-35.

Molewski, P. (2005) REKONSTRUKCJA PROCESÓW GLACJALNYCH W WYBRANYCH STREFACH MARGINALNYCH LODOWCÓW ISLANDII - FORMY I OSADY. Reconstruction of glacial processes in the chosen marginal zones of the Icelandic glaciers - forms and deposits: Torun, Instytut Geografii UMK; Stowarzyszenie Geomorfologów Polskich, p. 148.

Pálsson, S. (1959) "Skýrsla um mælingar á Tungnárjökli": Jökull, v. **9**: p. 19-21.

Rist, S. (1965) "Tungnárjökull": Jökull, v. **15**: p. 135-138.

Sigurðsson, O. (1994) "Tungnaárjökull veltur fram": Jökull, v. **44**: p. 1-2.

Sumarliðason, P. (1965) "Vatnshæðarmælingar í Tungná við Félaga sumarið 1965 (Oscillations of river Tungnaá at Jökulheimar in summer 1965). " Jökull, v. **15**: p. 144-147.

Vilmundardóttir, E.G. (1977) Tungnárhraun, Jarðfræðiskýrsla, OS-ROD 7702, Orkustofnun, p. 156.

Vilmundardóttir, E.G., Snorrason, S.P., Larsen, G., and Aðalsteinsson, B. (1999) Bergrunnskort Tungnaárjökull 1913 I, 1:50.000. Unnið í Landfræðilegu upplýsingakerfi (ArcInfo), Landmælingar Íslands, Orkustofnun og Landsvirkjun.

4.1.62 Sylgjujökull

Björnsson, H. (1981) Niðurstöður íssjármælinga á Tungnárjökli og Sylgjujökli: Reykjavík, Raunvísindastofnun Háskólans og Landsvirkjun, p. 50.

Dowdeswell, J.A. (1982) "Supraglacial Re-Sedimentation from Melt-Water Streams on to Snow Overlying Glacier Ice, Sylgjujokull, West Vatnajokull, Iceland": Journal of Glaciology, v. **28**(99): p. 365-375.

Fischer, A., Rott, H., and Björnsson, H. (2003) "Observation of recent surges of Vatnajokull, Iceland, by means of ERS SAR interferometry": Annals of Glaciology, v. **37**: p. 69-76.

Recent surges of two outlet glaciers of the Vatnajökull ice cap, Iceland, were observed using European Remote-sensing Satellite (ERS) synthetic aperture radar (SAR) tandem interferograms from 12 different dates between December 1995 and January 2000. ERS SAR interferometry provided new information on the temporal and spatial variations in surface velocity during surges, after fieldwork became impossible. The area affected by the surge and therefore by increased basal sliding was delineated. The migration of flow divides on the ice cap during a surge was described. At Sylgjujökull, a western outlet glacier covering an area of 175 km(2), the fully developed surge and its abating phase were studied. Over a period of > 2 years after December 1995, the ice motion decreased steadily, with initially the highest velocities and subsequently the most pronounced decrease in velocity at the glacier terminus. The surge of Dyngjujökull, a northern outlet glacier covering an area of 1040 km(2), reached its maximum in 1999/2000. Slow acceleration over an area of about 200 km(2) was first observed between March 1996 and January 1997. The interferogram from January 1999 shows a well-developed surge area, covering 210 km(2). This area more than doubled by January 2000, with maximum velocities reaching > 7 m d(-1). Between January 1997 and January 2000, the flow divide between Dyngju- and Skeiðarárjökull shifted 16 km to the south. The investigations indicate that a surge cycle on these glaciers spans several years, with slowly increasing motion over an extended area in the beginning, and more pronounced velocity changes during the active surge phase lasting 1-2 years.

Kaldal, I., and Víkingsson, S. (2001) Umhverfi og orkuöflun - jöklalandslag. Síðujökull, Skaftárjökull, Tungnaárjökull og Sylgjujökull. Stöðuyfirlit í apríl 2001, IK-0001, Orkustofnun, Rannsóknasvið. Greinargerð.

4.1.63 Skaftaárjökull, Skaftárkatlar, Skaftá

Björnsson, H. (1977) "The cause of jökulhlaups in the Skaftá river (Skaftárhlaup og orsakir þeirra). " Jökull, v. **27**: p. 71-78.

— (2002) "Subglacial lakes and jökulhlaups in Iceland": Global and planetary change, v. **35**: p. 255-271.

Active volcanoes and hydrothermal systems underlie ice caps in Iceland. Glacier–volcano interactions produce meltwater that either drains toward the glacier margin or accumulates in subglacial lakes. Accumulated meltwater drains periodically in jökulhlaups from the subglacial lakes and occasionally during volcanic eruptions. The release of meltwater from glacial lakes can take place in two different mechanisms. Drainage can begin at pressures lower than the ice overburden in conduits that expand slowly due to melting of the ice walls by frictional and sensible heat in the water. Alternatively, the lake level rises until the ice dam is lifted and water pressure in excess of the ice overburden opens the waterways; the glacier is lifted along the flowpath to make space for the water. In this case, discharge rises faster than can be accommodated by melting of the conduits. Normally jökulhlaups do not lead to glacier surges but eruptions in ice-capped stratovolcanoes have caused rapid and extensive glacier sliding. Jökulhlaups from subglacial lakes may transport on the order of 107 tons of sediment per event but during violent volcanic eruptions, the sediment load has been 108 tons.

Björnsson, H., Pálsson, F., and Guðmundsson, M.T. (1994) Mat á áhrifum framhlaups Síðujökuls 1993-1994 á afrennsli jökulhlaups frá Skaftárkötlum til Hverfisfljóts, RH-95-19: Reykjavík, Raunvísindastofnun Háskólans, p. 10.

Björnsson, H., Rott, H., Guðmundsson, S., Fischer, A., Siegel, A., and Guðmundsson, M.T. (2001) "Glacier-volcano interactions deduced by SAR interferometry": Journal of Glaciology, v. **47**(156): p. 58-70.

Glacier-surface displacements produced by geothermal and volcanic activity beneath Vatnajokull ice cap in Iceland are described by field surveys of the surface topography combined with interferograms acquired from repeat-pass synthetic aperture radar images. A simple ice-flow model serves well to confirm the basic interpretation of the observations. The observations cover the period October 1996-January 1999 and comprise: (a) the ice-flow field during the infilling of the depressions created by the subglacial Gjalp eruption of October 1996, (b) the extent and displacement of the floating ice cover of the subglacier lakes of Grimsvotn and the Skafta cauldrons, (c) surface displacements above the subglacier pathways of the jokulhlaups from the Gjalp eruption site and the Grimsvotn lake, (d) detection of areas of increased basal sliding due to lubrication by water, and (e) detection of spots of temporal displacement that may be related to altering subglacial volcanic activity. At the depression created by the Gjalp eruption, the maximum surface displacement rate away from the radar decreased from 27 cm d(-1) to 2 cm d(-1) over the period January 1997-January 1999. The observed vertical displacement of the ice cover of Grimsvotn changed from an uplift rate of 50 cm d(-1) to sinking of 48 cm d(-1), and for Skafta cauldrons from 2 cm d(-1) to 25 cm d(-1).

Brandsdóttir, B. (1984) "Seismic activity in Vatnajökull in 1900-1982 with special reference to Skeiðarárhlaups, Skaftárhlaups and Vatnajökull eruptions (Jarðskjálftar í Vatnajökli 1900-1982, tengsl þeirra við Skeiðarárhlaup, Skaftárhlaup og eldgos í jöklinum)": Jökull, v. **34**: p. 141-150.

Gíslason, S.R., Eiríksdóttir, E.S., Sigfússon, B., Elefsen, S.Ó., and Harðardóttir, J. (2004) Efnasamsetning og rennsli skaftár; í septemberhlaupi 2002, sumarrennsli 2003 og í septemberhlaupi 2003 RH-07-2004 Raunvísindastofnun Háskólans, p. 21 pp.

Gíslason, S.R., Ingvarsson, G.B., Eiríksdóttir, E.S., Sigfússon, B., Elefsen, S.Ó., Harðardóttir, J., Kristinsson, B., and Þorláksdóttir, S.B. (2005) Efnasamsetning og rennsli straumvatna á slóðum Skaftár 2002 til 2004, RH-12-2005, Raunvísindastofnun Háskólans, p. 54 pp.

Guðmundsson, A.T. (1992) "Framhlaup Síðujökuls 1934 og Skaftárjökuls 1945": Náttúrufræðingurinn, v. **61**(2): p. 143-144.

Guðmundsson, M.T., and Högnadottir, Þórdís (2007) "Volcanic systems and calderas in the Vatnajökull region, central Iceland: Constraints on crustal structure from gravity data": Journal of Geodynamics, v. **43**(1): p. 153-169.

A Bouguer anomaly map is presented of southern central Iceland, including the western part of Vatnajökull and adjacent areas. A complete Bouguer reduction for both ice surface and bedrock topography is carried out for the glaciated regions. Parts of the volcanic systems of Vonarskarð-Hágöngur, Barðarbunga-Veiðivötn, Grimsvötn-Laki, and to a lesser extent Kverkfjöll, show up as distinct features on the gravity map. The large central volcanoes with calderas: Vonarskarð, Barðarbunga, Kverkfjöll and Grimsvötn, are associated with 15-20 mGal gravity highs caused by high density bodies in the uppermost 5 km of the crust. Each of these bodies is thought to be composed of several hundred km3 of gabbros that have probably accumulated over the lifetime of the volcano. The Skaftarkatlar subglacial geothermal areas are not associated with major anomalous bodies in the upper crust. The central volcanoes of Vonarskarð and Hagöngur belong to the same volcanic system; this also applies to Barðarbunga and Hamarinn, and Grimsvötn and Þórðarhyrna. None of the smaller of the two volcanoes sharing a system (Hagöngur, Hamarinn and Þórðarhyrna) is associated with distinct gravity anomalies and clear caldera structures have not been identified. However, ridges in the gravity field extend between each pair of central volcanoes, indicating that they are connected by dense dyke swarms. This suggests that when two central volcanoes share the same system, one becomes the main pathway for magma, forming a long-lived crustal magma chamber, a caldera and large volume basic intrusive bodies in the upper crust. Short residence times of magma in the crust beneath these centres favour essentially basaltic volcanism. In the case of the second, auxillary central volcano, magma supply is limited and occurs only sporadically. This setting may lead to longer residence times of magma in the smaller central volcanoes, favouring evolution of the magma and occasional eruption of rhyolites. The eastern margin of the Eastern Volcanic Zone is marked by a NE-SW lineation in the gravity field, probably caused by accumulation of low density, subglacially erupted volcanics within the volcanic zone. This lineation lies 5-10 km to the east of Grimsvötn.

Hardardóttir, J., Snorrason, Á., Zóphaníasson, S., and Pálsson, S. (2004) Sediment discharge in jökulhlaups in Skaftá river, South Iceland, *in* Beylich, A.A., Sæmundsson, Decaulne, A., and Sandberg, O., eds., Sedimentary source-to-sink-fluxes in cold environments: Sauðárkrókur, Náttúrustofa Norðurlands vestra, p. 104.

Jóhannesson, T., Knudsen, Ó., and Ástvaldsson, L. (1985) "Mæling á hitastigi hlaupvatns við jökuljaðar nálægt hámarki Skaftárhlaups sumarið 1984": Jökull, v. **35**: p. 110.

Kaldal, I. (2002) Skaftá, athugun á áfoki. Útbreiðsla Skaftárhlaupsins 1995, OS-2002/022, Orkustofnun, Rannsóknasvið

Kaldal, I., and Vilmundardóttir, E.G. (2000) Athugun á áfoki við Skaftá og Hverfisfljót. Stöðuyfirlit í mars 2000, OS-2000/029, Orkustofnun, Rannsóknasvið.

Kaldal, I., and Víkingsson, S. (2001) Umhverfi og orkuöflun - jöklalandslag. Síðujökull, Skaftárjökull, Tungnaárjökull og Sylgjujökull. Stöðuyfirlit í apríl 2001, IK-0001, Orkustofnun, Rannsóknasvið. Greinargerð.

N.N. (1979) "Hlaup í Skaftá": Týli, tímarit um náttúrufræði og náttúruvernd, v. **9**(2): p. 57-58.

Old, G.H., Lawler, D.M., and Snorrason, A. (2005) "Discharge and suspended sediment dynamics during two jökulhlaups in the Skaftá river, Iceland": Earth Surface Processes and Landforms, v. **30**(11): p. 1441-1460.

This paper investigates the dynamics and significance of discharge and suspended sediment transport (SST) during two jökulhlaups (glacier outburst floods) in the Skaftá River, south Iceland. Jökulhlaups occur frequently in many glacial environments and are highly significant in the gemorphological evolution of river basins and coastal environments. However, direct high-resolution monitoring of jökulhlaups has rarely been accomplished and hardly ever at more than one station in a downstream sequence. Here we present detailed data on jökulhlaup discharge and water quality from an intensive monitoring and sampling programme at two sites in summer 1997 when two jökulhlaups occurred. Evidence is discussed that supports the origin of both jökulhlaups being subglacial reservoirs, produced over several months by subglacial geothermal activity. At the downstream site, Asa-Eldvatn, the larger jökulhlaup (1) had a peak discharge of 572 m(3) s(-1) and a peak suspended sediment flux of 4650 kg s(-1)(channel-edge value) or 4530 kg s(-1) (cross-sectional). These values compare to the non-jökulhlaup flow of 120 m(3) s(-1) and suspended sediment flux of 190 kg s(-1)(channel-edge) or 301 kg s(-1) (cross-sectional). Significantly, the jökulhlaups transported 18(.)8 per cent of the annual runoff and 53 per cent of the annual suspended sediment transport in 6(.)6 per cent of the year. Furthermore, water chemistry, suspended sediment and seismic data suggest that volcanic activity and geothermal boiling (possibly including steam explosions) may have occurred during Jökulhlaup 1. The research illustrates the value of integrating high-resolution, multi-point field monitoring of meteorological, hydrological, hydrochemical, geomorphological and seismological data for understanding the dynamics, significance and downstream translation of jökulhlaups.

Skúlason, J., Kaldal, I., and Víkingsson, S. (2002) Hólmsár og Skaftárvirkjanir. Athugun á lausum jarðlögum 2002, Rarik, Landsvirkjun.

— (2003) Hólmsár og Skaftárvirkjanir. Athugun á lausum jarðlögum austan Skaftár 2003, Rarik, Landsvirkjun.

Sævarsdóttir, R.H. (2002) Grunnvatn og vatnajarðfræði Skaftársvæðisins [**MSc thesis**]: Reykjavík, Háskóli Íslands

Þórarinsson, S., and Rist, S. (1955) "Skaftárhlaup í september 1955 (Summary)": Jökull v. **5**: p. 37-40.

4.1.64 Síðujökull

Björnsson, H., Pálsson, F., and Guðmundsson, M.T. (1994) Mat á áhrifum framhlaups Síðujökuls 1993-1994 á afrennsli jökulhlaups frá Skaftárkötlum til Hverfisfljóts, RH-95-19: Reykjavík, Raunvísindastofnun Háskólans, p. 10.

Friðgeirsson, Á., and Stefánsson, P. (1994) "Dances with glaciers": Iceland Review, v. **32**(2): p. 34-39, ill., diag., map.

Account of surge of Síðujökull, glacial tongue of Vatnajökull,which advanced 1200\g m in a few weeks at start of 1994

Guðmundsson, A.T. (1992) "Framhlaup Síðujökuls 1934 og Skaftárjökuls 1945": Náttúrufræðingurinn, v. **61**(2): p. 143-144.

— (1994) "Sjónarspilið á Síðujökli": Náttúrufræðingurinn, v. **64**(2): p. 161-163.

Jaksch, K. (1970) "Beobachtungen in den Gletschervorfeldern des Sólheima- und Síðujökull im Sommer 1970": Jökull, v. **20**: p. 47-49.

— (1984) "Das Gletschervorfeld des Vatnajökull am Oberlauf der Djúpá, Süd-Island (Jaðar Vatnajökuls við upptök Djúpár)." Jökull, v. **34**: p. 97-103.

Kaldal, I., and Víkingsson, S. (2001) Umhverfi og orkuöflun - jöklalandslag. Síðujökull, Skaftárjökull, Tungnaárjökull og Sylgjujökull. Stöðuyfirlit í apríl 2001, IK-0001, Orkustofnun, Rannsóknasvið. Greinargerð.

Sigurðsson, O. (1993) "Síðujökull á flugferð": Jökull, v. **43**: p. 72.

4.1.65 Laki, Lakagígar, Skaftáreldar

Björnsson, H., and Einarsson, P. (1990) "Volcanoes beneath Vatnajökull, Iceland: Evidence from radio echo-sounding earthquakes and jökulhlaups": Jökull, v. **40**: p. 147-168.

Integration of knowledge of subglacial topography, earthquake activity and jökulhlaups has contributed to more precise locations of the volcanic systems beneath Vatnajökull. Bárðarbunga is the centre of a volcanic system which includes the fissure swarms of Veiðivötn to the SW and Dyngjuháls to the NE. The Grímsvötn volcano is the centre of a system that comprises the Laki fissure swarm in the SW and extends for an unknown distance to the NE of the volcano. Þórðarhyrna is probably a separate central volcano within this system. The Kverkfjöll system can be traced 10 km to the SW of the Kverkfjöll volcano. It appears to be separated from the Grímsvötn volcano.

The Askja fissure swarm extends beneath Dyngjujökull and can possibly be traced to the Grímsvötn volcano. Hamarinn and the ridge striking eastward from Hamarinn (Loki Ridge) are central volcanoes which together with the Fögrufjöll fissure swarm form a volcanic system. No support can be found in the topographic data for the existence of a central volcano near Breiðabunga. Volcanic activity in historical times has mainly been limited to the Grímsvötn and Bárðarbunga systems. Major rifting events have affected large sections of these volcanic systems but both have been remarkably quiet for the past decades. A few volcanic events are presumed to have occurred on the Hamarinn - Loki system and on the Askja fissure swarm beneath Dyngjujökull, but no event is known with certainty on the Kverkfjöll system. The rivers Skeiðará and Súla have the most frequent eruption-related jökulhlaups. They receive meltwater from the Grímsvötn caldera and the area to the SW of it, including Þórðarhyrna. Núpsvötn, Djúpá and Hverfisfljót drain the southwestern part of the Grímsvötn system, an area bounded by Þórðarhyrna, Geirvörtur, Hágöngur and Pálsfjall. Skaftá drains the Loki Ridge and the area west of Grímsvötn. Jökulhlaups in Kaldakvísl, and ultimately Þjórsá, must originate in the Bárðarbunga or the Hamarinn - Loki systems, and the only possible source for volcanic jökulhlaups in Skjálfandafljót is the northern part of the Bárðarbunga system. Jökulsá á Fjöllum may drain meltwater from activity in all the volcanic systems in northern Vatnajökull: Bárðarbunga, the Askja fissure swarm and Kverkfjöll. This includes the voluminous, ice-filled calderas of Bárðarbunga and Kverkfjöll. Activity in the northern part of the Grímsvötn system may cause floods in Jökulsá á Fjöllum. Meltwater from volcanic activity on the SE flank of a ridge that strikes south from Kverkfjöll may drain to Jökulsá á Brú. Volcanic activity farther north on the E flanks of this ridge would cause floods in Kreppa.

Grönvold, K. (1984) Bergfræði Skaftáreldahrauns, *in* Gunnlaugsson, G.Á., ed., Skaftáreldar 1783-1784: Reykjavík, Mál og menning, p. 49-107.

Grönvold, K., and Jóhannesson, H. (1984) "Eruption of Grímsvötn 1983; course of events and chemical studies of tephra (Grímsvatnagosið 1983, atburðarás og efnagreining á gjósku)": Jökull, v. **34**: p. 1-11.

A short eruption took place in the Grímsvötn volcano in May - June 1983. The eruption most probably started on May 28th. Activity was last observed on June 1st and by June 5th it was certainly over.

The Grímsvötn volcano is situated within the western part of the Vatnajökull ice cap. It is almost totally ice covered and the caldera lake is covered by an ice chelf about 200 metres thick. The eruption site is within the caldera near the southern rim and a lake, about 500 m in diameter, formed in the ice shelf with a small island in the middle. The eruption was subaquatic and intermittent ash explosions were observed in the lake. Usually these were about 50-100 m high and a steam column rose up to about 5000 m height a. s. l.

Three small ash fans formed on the surrounding ice sheet; two by explosions, one to the south early in the eruption and another to the east most likely on June 1st; the third to the north within the caldera was most likely caused mainly by an avalanche from the overhanging caldera wall into the lake.

The glass phase of the ash was analyzed in a number of samples and found to be evolved basalt with a uniform chemical composition but minor variations are indicated. Samples from the 1934, 1922 and 1903 Grímsvötn eruptions were analyzed for comparison and show very similar chemical composition as the 1983 ash. This composition is also very similar to that of the glass phase of the eruption of the Laki craters 1783-84.

The Grímsvötn volcano is also the site of a major geothermal system, stimated at 5000 MW. The heat source of this system is assumed to be magmatic intrusions, most likely with the same compostion as the ash. It appears unlikely that the heat extraction takes place in the same parts of the magmatic system as the evolution of the basalt.

Guðmundsson, A.T. (1986) Íslandseldar : eldvirkni á Íslandi í 10.000 ár Reykjavík, Vaka-Helgafell, 168 s. : myndir, teikn., kort, línurit, töflur p.

Guðmundsson, M.T., and Högnadottir, Þ. (2007) "Volcanic systems and calderas in the Vatnajökull region, central Iceland: Constraints on crustal structure from gravity data": Journal of Geodynamics, v. **43**(1): p. 153-169.

A Bouguer anomaly map is presented of southern central Iceland, including the western part of Vatnajökull and adjacent areas. A complete Bouguer reduction for both ice surface and bedrock topography is carried out for the glaciated regions. Parts of the volcanic systems of Vonarskarð-Hágöngur, Barðarbunga-Veiðivötn, Grimsvötn-Laki, and to a lesser extent Kverkfjöll, show up as distinct features on the gravity map. The large central volcanoes with calderas: Vonarskarð, Barðarbunga, Kverkfjöll and Grimsvötn, are associated with 15-20 mGal gravity highs caused by high density bodies in the uppermost 5 km of the crust. Each of these bodies is thought to be composed of several hundred km3 of gabbros that have probably accumulated over the lifetime of the volcano. The Skaftarkatlar subglacial geothermal areas are not associated with major anomalous bodies in the upper crust. The central volcanoes of Vonarskarð and Hagöngur belong to the same volcanic system; this also applies to Barðarbunga and Hamarinn, and Grimsvötn and Þórðarhyrna. None of the smaller of the two volcanoes sharing a system (Hagöngur, Hamarinn and Þórðarhyrna) is associated with distinct gravity anomalies and clear caldera structures have not been identified. However, ridges in the gravity field extend between each pair of central volcanoes, indicating that they are connected by dense dyke swarms. This suggests that when two central volcanoes share the same system, one becomes the main pathway for magma, forming a long-lived crustal magma chamber, a caldera and large volume basic intrusive bodies in the upper crust. Short residence times of magma in the crust beneath these centres favour essentially basaltic volcanism. In the case of the second, auxillary central volcano, magma supply is limited and occurs only sporadically. This setting may lead to longer residence times of magma in the smaller central volcanoes, favouring evolution of the magma and occasional eruption of rhyolites. The eastern margin of the Eastern Volcanic Zone is marked by a NE-SW lineation in the gravity field, probably caused by accumulation of low density, subglacially erupted volcanics within the volcanic zone. This lineation lies 5-10 km to the east of Grimsvötn.

Gunnlaugsson, G.Á. (1984) Skaftáreldar 1783-1784. Safnrit eftir ýmsa höfunda: Reykjavík, Mál og Menning.

Jónsson, J. (1983) Um fjöll og heiðar, Vestur-Skaftafellssýsla. Árbók Ferðafélags Íslands: Reykjavík.

Larsen, G. (1999) The Lakagígar crater row; Katla volcanic system and Eldgjá fissure; Hekla, *in* Arnórsson, S., and Gíslason, S.R., eds., The Fifth International Symposium on the Geochemistry of the Earths Surface Field Guide: Iceland, p. 27-28, 38-40, 51-53.

— (2005) "Explosive volcanism in Iceland: Three examples of hydromagmatic basaltic eruptions on long volcanic fissures within the past 1200 years": Geophysical Research Abstracts, v. **7**(10158).

Larsen, G., and Þórðarson, Þ. (1984) Gjóskan frá Skaftáreldum 1783. Útlit og helstu einkenni, *in* Gunnlaugsson, G.Á., ed., Skaftáreldar: Reykjavík, Mál og Menning, p. 59-66.

Óskarsson, N., Larsen, G., and Grönvold, K. (1984) Móðan frá Skaftáreldum, *in* Gunnlaugsson, G.A., and al, e., eds., Skaftáreldar: Reykjavík, Mál og Menning, p. 67-79.

Sigmarsson, O., Grönvold, K., Þórðarson, o., and Condomines, M. (1991) "Extreme magma homogenity in the 1783-1784 Lakagígar eruption: origin of a large volume of evolved basalt in Iceland": Geophysical Research Letters, v. **18**(12): p. 2229-2232.

Sveinsdóttir, E.L. (1982) Lakagígar og Skaftáreldahraun : kortlagning [**4.árs ritgerð**]: Reykjavík, Háskóli Íslands.

Theodórsson, T. (1983) Áhrif Skaftárelda 1783-1784 á byggð og mannfjölda í Vestur-Skaftafellssýslu austan Mýrdalssands [**4. árs ritgerð**]: Reykjavík, Háskóli Íslands.

van Swinden, S.P. (2001) "Observations on the cloud (dry fog) which appeared in June 1783": Jökull, v. **50** p. 73-80.

Þórarinsson, S. (1969) "The Lakagigar Eruption of 1783": Bulletin of Volcanology, v. **33**: p. 910-929

Þórðarson, Þ. (1990) Skaftáreldar 1783-1785. Gjóskan og framvinda gossins: Reykjavík, Háskóli Íslands.

— (2003) "The 1783-1785 A.D. Laki-Grímsvötn eruptions I: A critical look at the contemporary chronicles": Jökull, v. **53**: p. 1-10.

Þórðarson, Þ., Larsen, G., and Steinthorsson, S. (1992) Eruption dynamics of the 1783 Laki eruption, S-Iceland, *in* Geirsdóttir, Á., Norðdahl, H., and Helgadóttir, G., eds., 20th Nordic Geological Winter Meeting: Abstracts: Reykjavík, p. 168.

Þórðarson, Þ., Larsen, G., Steinþórsson, S., and Self, S. (2003) "The 1783-1785 A.D. Laki-Grímsvötn eruptions II: Appraisal based on contemporary accounts": Jökull, v. **53**: p. 11-48.

Þórðarson, T., Miller, D.J., Larsen, G., Self, S., and Sigurðsson, H. (2001) "New estimates of sulfur degassing and atmospheric mass-loading by the 934 AD Eldgjá eruption, Iceland": Journal of Volcanology and Geothermal Research, v. **108**(1-4): p. 33-54.

The 934 AD Eldgjá basaltic flood lava eruption in southern Iceland is the largest on Earth in the last millennium. The Eldgjá fissures produced 19.6 km^3 of transitional basalt in a prolonged eruption that featured at least eight distinct episodes and may have lasted for 3-8 years. The atmospheric SO_2 mass loading by Eldgjá is determined by new measurements of pre-eruption and residual sulfur contents in the products from all phases of the eruption. A pre-eruption sulfur content of ~2150 ppm indicates that the magma carried 232 Mt of SO_2 to the surface, where vent and lava flow degassing released 219 Mt into the atmosphere. This value corresponds to a potential H_2SO_4-aerosol yield of ~450 Mt, increasing previous H_2SO_4-aerosol mass estimates by a factor of 2.6-4.5. Approximately 79% of the original sulfur mass was released at the vents, indicating ~185 Mt SO_2 were discharged into the atmosphere above the Eldgjá fissures and carried aloft by the eruption columns to upper tropospheric and lower stratospheric altitudes (~15 km). Consequently, only ~35 Mt SO_2 escaped from the lava into the lower troposphere. These estimates of the SO_2 mass loading from Eldgjá make it the greatest known volcanic pollutant of recent history, exceeding that of 1783 AD Laki and 1815 AD Tambora eruptions by factors of 1.8 and 2.0-2.8, respectively. However, the intensity of climatic effects deduced by the Eldgjá event are not thought to have surpassed that of Laki or Tambora because the eruption was prolonged and subsequently the sulfur emissions were drawn out over several years. The lack of detailed historic records for this period make estimates of the effects of long term but significant release of SO_2 (30-70 Mt/yr) on the atmosphere uncertain.

Þórðarson, Þ., and Self, S. (1993) "The Laki (Skaftár Fires) and Grímsvötn eruptions in 1783-1785": Bulletin of Volcanology, v. **55**(4): p. 233-263.

Þórðarson, Þ., and Self, S. (2001) "Real-time observations of the Laki sulfuric aerosol cloud in Europe during 1783 as documented by Professor S. P. van Swinden at Franeker, Holland." Jökull v. **50**: p. 65-72.

Þórðarson, Þ., Self, S., Larsen, G., and Steinþórsson, S. (1987) "Eruption Sequence of the Skaftár fires 1783-1785, Iceland": EOS, Transactions, American Geophysical Union, v. **68**(44, supplement): p. 1550.

Þórdarson, Self, S., Óskarsson, N., and Hulsebosch, T. (1996) "Sulfur, chlorine, and fluorine degassing and atmospheric loading by the 1783-1784 AD Laki (Skaftár Fires) eruption in Iceland": Bulletin of Volcanology, v. **58**: p. 205-225.

The 1783-1784 Laki tholeiitic basalt fissure eruption in Iceland was one of the greatest atmospheric pollution events of the past 250 years, with widespread effects in the northern hemisphere. The degassing history and volatile budget of this event are determined by measurements of pre-eruption and residual contents of sulfur, chlorine, and fluorine in the products of all phases of the eruption. In fissure eruptions such as Laki, degassing occurs in two stages: by explosive activity or lava fountaining at the vents, and from the lava as it flows away from the vents. Using the measured sulfur concentrations in glass inclusions in phenocrysts and in groundmass glasses of quenched eruption products, we calculate that the total accumulative atmospheric mass loading of sulfur dioxide was 122 Mt over a period of 8 months. This volatile release is sufficient to have generated ~250 Mt of H2SO4 aerosols, an amount which agrees with an independent estimate of the Laki aerosol yield based on atmospheric turbidity measurements. Most of this volatile mass (~60 wt.%) was released during the first 1.5 months of activity. The measured chlorine and fluorine concentrations in the samples indicate that the atmospheric loading of hydrochloric acid and hydrofluoric acid was ~7.0 and 15.0 Mt, respectively. Furthermore, ~75% of the volatile mass dissolved by the Laki magma was released at the vents and carried by eruption columns to altitudes between 6 and 13 km. The high degree of degassing at the vents is attributed to development of a separated two-phase flow in the upper magma conduit, and implies that high-discharge basaltic eruptions such as Laki are able to loft huge quantities of gas to altitudes where the resulting aerosols can reside for months or even 1-2 years. The atmospheric volatile contribution due to subsequent degassing of the Laki lava flow is only 18 wt.% of the total dissolved in the magma, and these emissions were confined to the lowest regions of the troposphere and therefore important only over Iceland. This study indicates that determination of the amount of sulfur degassed from the Laki magma batch by measurements of sulfur in the volcanic products (the petrologic method) yields a result which is sufficient to account for the mass of aerosols estimated by other methods.

4.1.66 Veiðivötn

Aðalsteinsson, H. (1987) "Veiðivötn. The Veiðivötn lakes": Náttúrufraeðingurinn, v. **57. árg.**(4. hefti): p. 185-204, ill., diags., tables, maps.

Detailed description of these lakes west of Vatnajökull, Iceland, including formation, discharge and biology

Björnsson, H., and Einarsson, P. (1990) "Volcanoes beneath Vatnajökull, Iceland: Evidence from radio echo-sounding earthquakes and jökulhlaups": Jökull, v. **40**: p. 147-168.

Integration of knowledge of subglacial topography, earthquake activity and jökulhlaups has contributed to more precise locations of the volcanic systems beneath Vatnajökull. Bárðarbunga is the centre of a volcanic system which includes the fissure swarms of Veiðivötn to the SW and Dyngjuháls to the NE. The Grímsvötn volcano is the centre of a system that comprises the Laki fissure swarm in the SW and extends for an unknown distance to the NE of the volcano. Þórðarhyrna is probably a separate central volcano within this system. The Kverkfjöll system can be traced 10 km to the SW of the Kverkfjöll volcano. It appears to be separated from the Grímsvötn volcano. The Askja fissure swarm extends beneath Dyngjujökull and can possibly be traced to

the Grímsvötn volcano. Hamarinn and the ridge striking eastward from Hamarinn (Loki Ridge) are central volcanoes which together with the Fögrufjöll fissure swarm form a volcanic system. No support can be found in the topographic data for the existence of a central volcano near Breiðabunga. Volcanic activity in historical times has mainly been limited to the Grímsvötn and Bárðarbunga systems. Major rifting events have affected large sections of these volcanic systems but both have been remarkably quiet for the past decades. A few volcanic events are presumed to have occurred on the Hamarinn - Loki system and on the Askja fissure swarm beneath Dyngjujökull, but no event is known with certainty on the Kverkfjöll system. The rivers Skeiðará and Súla have the most frequent eruption-related jökulhlaups. They receive meltwater from the Grímsvötn caldera and the area to the SW of it, including Þórðarhyrna. Núpsvötn, Djúpá and Hverfisfljót drain the southwestern part of the Grímsvötn system, an area bounded by Þórðarhyrna, Geirvörtur, Hágöngur and Pálsfjall. Skaftá drains the Loki Ridge and the area west of Grímsvötn. Jökulhlaups in Kaldakvísl, and ultimately Þjórsá, must originate in the Bárðarbunga or the Hamarinn - Loki systems, and the only possible source for volcanic jökulhlaups in Skjálfandafljót is the northern part of the Bárðarbunga system. Jökulsá á Fjöllum may drain meltwater from activity in all the volcanic systems in northern Vatnajökull: Bárðarbunga, the Askja fissure swarm and Kverkfjöll. This includes the voluminous, ice-filled calderas of Bárðarbunga and Kverkfjöll. Activity in the northern part of the Grímsvötn system may cause floods in Jökulsá á Fjöllum. Meltwater from volcanic activity on the SE flank of a ridge that strikes south from Kverkfjöll may drain to Jökulsá á Brú. Volcanic activity farther north on the E flanks of this ridge would cause floods in Kreppa.

Blake, S. (1984) "Magma mixing and hybridization processes at the alkalic, silicic, Torfajökull central volcano triggered by tholeiitic Veiðivötn fissuring, south Iceland": Journal of Volcanology and Geothermal Research, v. **22**(1-2): p. 1-31.

Around 19°W64°N19, in the Eastern Volcanic Zone of south Iceland, the southwestern extremity of the tholeiitic Veiðivötn fissure swarm abuts the northern periphery of the mildly alkaline silicic central volcano Torfajökull. Effusive mixed-magma eruptions in this area have been initiated by crustal rifting associated with lateral injection of tholeiitic magma into the rhyolitic Torfajökull chamber. Mixed rocks, in which cm- to dm-sized mafic inclusions constitute ~ 10% of the rhyolite lava are distinguished from hybrid rocks which are thorough mixtures having an homogeneous fabric.Mapping of the Domadalshraun lava (0.05-0.1 km3) reveals the early eruption of hybrid spatter and lava followed by less thoroughly blended mixed lava. Geochemical study discloses the participation of three end-members. Plagioclase-phyric tholeiite containing ~ 10-20% pl + cpx + o1 precipitated at ~ 1140-1160[deg]C is typical of the Veiðivötn component. The Torfajökull rhyolite contains ~ 10% crystals, dominantly anorthoclase and oligoclase, and is found to be compositionally zoned. Early-late trends include SiO2: 71.6-70.1%, A.I.: 1.07-0.86, Sr: 61-86 ppm and result from feldspar fractionation. The third end-member is a transitional alkali basaltic andesite ([identical to] hawaiite) belonging to the mafic magma suite associated with Torfajökull. This intermediate magma resided at depth within the stratified Torfajökull chamber and contains xenocrystic feldspars which have settled out of the differentiating rhyolite. The calculated positions in tholeiite-rhyolite-basaltic andesite composition space of eight hybrid rocks show that hybridization was not a random process. No rhyolite/transitional alkali hybrids are present. The only two tholeiite/transitional alkali hybrids are both 0.45/0.55 blends of these two end-members. No rhyolite-bearing hybrid contains more than 20% transitional alkali magma. It is proposed that rhyolite/tholeiite hybrids are most likely to be generated where a shallow tholeiitic

fissure has been laterally intruded into and above the roof of the rhyolitic chamber. Near the top of the fissure, tholeiite containing excess water may have been sufficiently vesicular for its bulk density to equal that of the rhyolitic magma. Calculations identify this critical depth as 0.75-1 km-coincident with calculated quenching pressures of small vesicular tholeiitic clots in the mixed lavas (assuming 1 wt.% water). Dense tholeiite at deeper levels in the dyke collapses into the chamber and is replaced by buoyantly rising rhyolite. Hybridization ensues where the rhyolite and vesicular tholeiite come together in the fissure. These and other relative-density controlled processes account for the selective nature of the hybridization process and the order in which hybrid and mixed magmas were erupted.The late 15th century Laugahraun and Sudurnamshraun flows at Landmannalaugar reveal participation of only tholeiitic and rhyolitic end-members. Hybrids are poorly represented and it is hypothesized that this is due to the deep ([greater-than or equivalent to] 1 km) intrusion of undersaturated tholeiite, which leads to the generation of mixed rather than hybrid magmas.These and other tholeiite/rhyolite mixed-magma eruptions in the area were triggered by lateral flow of tholeiite from the Veidivotn system, initiated by the overfilling of the Veiðivötn magma chamber, 40 km to the NE, in the style recognized at Krafla and elsewhere in Iceland. Future concern over any renewed activity in Veiðivötn should not, therefore, prohibit consideration of rhyolitic or mixed-magma eruptions being induced in the Torfaöokull region.

Guðmundsson, A.T. (1986) Íslandseldar : eldvirkni á Íslandi í 10.000 ár Reykjavík, Vaka-Helgafell, 168 s. : myndir, teikn., kort, línurit, töflur p.

Guðmundsson, A.T., and (1996) Volcanoes in Iceland : 10.000 years of volcanic history: Reykjavík, Vaka-Helgafell, 136 s. : myndir, teikn., kort, töflur p.

Guðmundsson, M.T., and Högnadottir, Þ. (2007) "Volcanic systems and calderas in the Vatnajökull region, central Iceland: Constraints on crustal structure from gravity data": Journal of Geodynamics, v. **43**(1): p. 153-169.

A Bouguer anomaly map is presented of southern central Iceland, including the western part of Vatnajökull and adjacent areas. A complete Bouguer reduction for both ice surface and bedrock topography is carried out for the glaciated regions. Parts of the volcanic systems of Vonarskarð-Hágöngur, Barðarbunga-Veiðivötn, Grimsvötn-Laki, and to a lesser extent Kverkfjöll, show up as distinct features on the gravity map. The large central volcanoes with calderas: Vonarskarð, Barðarbunga, Kverkfjöll and Grimsvötn, are associated with 15-20 mGal gravity highs caused by high density bodies in the uppermost 5 km of the crust. Each of these bodies is thought to be composed of several hundred km3 of gabbros that have probably accumulated over the lifetime of the volcano. The Skaftarkatlar subglacial geothermal areas are not associated with major anomalous bodies in the upper crust. The central volcanoes of Vonarskarð and Hagöngur belong to the same volcanic system; this also applies to Barðarbunga and Hamarinn, and Grimsvötn and Þórðarhyrna. None of the smaller of the two volcanoes sharing a system (Hagöngur, Hamarinn and Þórðarhyrna) is associated with distinct gravity anomalies and clear caldera structures have not been identified. However, ridges in the gravity field extend between each pair of central volcanoes, indicating that they are connected by dense dyke swarms. This suggests that when two central volcanoes share the same system, one becomes the main pathway for magma, forming a long-lived crustal magma chamber, a caldera and large volume basic

intrusive bodies in the upper crust. Short residence times of magma in the crust beneath these centres favour essentially basaltic volcanism. In the case of the second, auxillary central volcano, magma supply is limited and occurs only sporadically. This setting may lead to longer residence times of magma in the smaller central volcanoes, favouring evolution of the magma and occasional eruption of rhyolites. The eastern margin of the Eastern Volcanic Zone is marked by a NE-SW lineation in the gravity field, probably caused by accumulation of low density, subglacially erupted volcanics within the volcanic zone. This lineation lies 5-10 km to the east of Grimsvötn.

Kaldal, I., Vilmundardóttir, E.G., and Larsen, G. (1988) Jarðgrunnskort Sigalda-Veiðivötn, 3340 J, 1:50.000: Reykjavík, Orkustofnun, Vatnsorkudeild, og Landsvirkjun.

Larsen, G. (1982) Volcanic history and prediction: The Veidivötn area, southern Iceland, IAVCEI-IAGC Scientific Assembly: Reykjavík, p. 118.

— (1984) "Recent volcanic history of the Veidivötn fissure swarm, southern Iceland-an approach to volcanic risk assessment": Journal of volcanology and geothermal research, v. **22**(1-2): p. 33-58.

The recent volcanic history of the southwestern part of the Veiðivötn fissure swarm, southern Iceland, provides a basis for assessment of volcanic risk in an area of large hydropower potential. Local tephrastratigraphy and regional tephrochronology provide relative and absolute dating of individual eruptions as well as information on the volume and distribution of the products formed in each eruption.

Three large eruptions took place in this area in 1480 A.D., 900 A.D. and 150 A.D., respectively. Each eruption produced approx. 1 km3 (DRE) of basaltic, and minor amounts of silicic lava and tephra on fissures up to 42 km long. No evidence is found of smaller eruptions during this period. The estimated eruption frequency, one eruption every 600–800 years, implies that this part of the Veidivötn fissure swarm is inactive for long periods between relatively large volcanic events.

A change in the mode of eruption from effusive to explosive took place during this period. The hazards posed by this area include far-reaching lava flows, widespread heavy tephra fall with thicknesses in excess of 2 m at distances of 10 km, and damming of a large glacial river with the consequent formation of unstable lakes.

A volcano-tectonic model, which explains the observed eruption frequency and provides a basis for a long-term monitoring program, is proposed. Eruptions on the Veidivötn fissure swarm are interpreted as corollaries of rifting episodes initiated in the Bárdarbunga central volcano. Volcano-tectonic episodes affect the fissure swarm at an average interval of 100 years. Minor episodes are limited to the central volcano and adjacents parts of the fissure swarm. During the less frequent major episodes, rifting and volcanic activity extends to the extreme southwestern part of the fissure swarm.

Seismic monitoring of the Bárdarbunga central volcano could provide an early warning of renewed activity on the Veidivötn fissure swarm. A major rifting episode resulting in eruption on its southwestern part can be expected during the next 100 to 300 years.

— (1984) Recent volcanic history of the Veiðivötn fissure swarm, Southern Iceland. A basis for volcanic risk assessment, NVI Research Report 8403, Nordic Volcanological Center, p. 46.

— (1987) The Dike of the 1480 A.D. Veidivötn Eruption, S-Iceland, IAVCEI-IUGG XiX General Assembly: Abstracts V2: Vancouver, Canada, p. 396.

— (1988) Veiðivötn og Veiðivatnagos á 15 öld, Árbók Ferðafélags Íslands 1988, p. 149-163.

— (2005) "Explosive volcanism in Iceland: Three examples of hydromagmatic basaltic eruptions on long volcanic fissures within the past 1200 years": Geophysical Research Abstracts, v. **7**(10158).

Larsen, G., and Dugmore, A. (2001) Unstable tephra dammed lakes in the Veiðivötn volcanic area, Iceland, Earth System Processes: Abstracts: Edinburgh, p. 44.

Mörk, M.B.E. (1982) Magma mixing in the post-glacial Veiðivötn fissure eruption, South-East Iceland, NVI Research Report 8205, Nordic Volcanological Center.

Vilmundardóttir, E.G., and Larsen, G. (1986) Productivity Pattern of the Veidivötn Fissure Swarm, South Iceland, in Postglacial Time, 17e Nordiska Geologmötet: Abstracts: Helsingfors, Finland, p. 214.

Vilmundardóttir, E.G., Snorrason, S.P., Larsen, G., and Guðmundsson, Á. (1988) Berggrunnskort Sigalda-Veiðivötn, 3340 B, 1:50.000: Reykjavík, Orkustofnun, Vatnsorkudeild, og Landsvirkjun.

4.1.67 Eldgjá

Jónsson, G. (1984) "Hugleiðingar um eldgos í Skaftafellssýslu": Náttúrufræðingurinn, v. **54**(3.-4.h.): p. 155-158.

Larsen, G. (1979) "Um aldur Eldgjárhrauna": Náttúrufræðingurinn, v. **49**: p. 1-26.

— (1990) The 10th century Eldgjá-Katla eruption; its products and consequences, 19. Nordiske Geologiske Vintermöte. Geonytt 1/90: Stavanger, Norge, p. 71-72.

— (1993) "Tephra layer from the 10th century Eldgjá fissure eruption, South Iceland": EOS, Transactions, American Geophysical Union, v. **74**(43, supplement): p. 132.

— (1994) Gjóskulagatímatal og leiðarlög frá Eldgjárgosi og Vatnaöldugosi, RH-25-94: Reykjavik, Science Institute, p. 20.

— (1999) The Lakagígar crater row; Katla volcanic system and Eldgjá fissure; Hekla, *in* Arnórsson, S., and Gíslason, S.R., eds., The Fifth International Symposium on the Geochemistry of the Earths Surface Field Guide: Iceland, p. 27-28, 38-40, 51-53.

— (2005) "Explosive volcanism in Iceland: Three examples of hydromagmatic basaltic eruptions on long volcanic fissures within the past 1200 years": Geophysical Research Abstracts, v. **7**(10158).

Larsen, G., Thordarson, T., and Miller, J.D. (2004) Nature, style and magnitude of explosive activity in the 934-40 Eldgjá flood lava eruption in S-Iceland, IAVCEI General Assembly: Abstracts: Pucon, Chile.

Miller, D.J., Thordarson, T., and Larsen, G. (1996) "Sulphur degassing and nature of eruptive activity during the 935 AD Eldgjá eruption, S-Iceland": EOS, Transactions, American Geophysical Union, v. **77 (supplement)**.

Miller, J. (1989) The 10th century eruption of Eldgjá, Southern Iceland, NVI Research Report 8903, Nordic Volcanological Center.

Zielinski, G.A., Germani, M.S., Larsen, G., Baillie, M.G.L., Whitlow, S., Twickler, M.S., and Taylor, K. (1995) "Evidence of the Eldgjá (Iceland) eruption in the GISP2 Greenland ice core: relationship to eruption processes and climatic conditions in the tenth century": Holocene, v. **5**(2): p. 129-140.

Þórdarson, Þ., Miller, D.J., Larsen, G., Self, S., and Sigurðsson, H. (2001) "New estimates of sulfur degassing and atmospheric mass-loading by the 934 AD Eldgjá eruption, Iceland": Journal of Volcanology and Geothermal Research, v. **108**(1-4): p. 33-54.

The 934 AD Eldgjá basaltic flood lava eruption in southern Iceland is the largest on Earth in the last millennium. The Eldgjá fissures produced 19.6 km3 of transitional basalt in a prolonged eruption that featured at least eight distinct episodes and may have lasted for 3-8 years. The atmospheric SO_2 mass loading by Eldgjá is determined by new measurements of pre-eruption and residual sulfur contents in the products from all phases of the eruption. A pre-eruption sulfur content of ~2150 ppm indicates that the magma carried 232 Mt of SO_2 to the surface, where vent and lava flow degassing released 219 Mt into the atmosphere. This value corresponds to a potential H_2SO_4-aerosol yield of ~450 Mt, increasing previous H_2SO_4-aerosol mass estimates by a factor of 2.6-4.5. Approximately 79% of the original sulfur mass was released at the vents, indicating ~185 Mt SO_2 were discharged into the atmosphere above the Eldgjá fissures and carried aloft by the eruption columns to upper tropospheric and lower

stratospheric altitudes (~15 km). Consequently, only ~35 Mt SO2 escaped from the lava into the lower troposphere. These estimates of the SO2 mass loading from Eldgjá make it the greatest known volcanic pollutant of recent history, exceeding that of 1783 AD Laki and 1815 AD Tambora eruptions by factors of 1.8 and 2.0-2.8, respectively. However, the intensity of climatic effects deduced by the Eldgja event are not thought to have surpassed that of Laki or Tambora because the eruption was prolonged and subsequently the sulfur emissions were drawn out over several years. The lack of detailed historic records for this period make estimates of the effects of long term but significant release of SO2 (30-70 Mt/yr) on the atmosphere uncertain.

4.1.68 Grænalón, Núpsstaðarskógur

Arason, H. (1957) Hlaup úr Grænalóni í Fljótshverfi 1898 *in* Hannesson, P., and Eyþórsson, J., eds., Hrakningar og heiðarvegir Volume **4.b.**: Akureyri, Norðri, p. 189-191

Björnsson, H., and Pálsson, F. (1989) "Rúmmál Grænalóns og breytingar á stærð og tíðni jökulhlaup": Jökull, v. **39**: p. 90-95.

Eiríksson, J., and others (1994) Roadlog : Nordic geological excursion in Iceland : quaternary geology - glaciology Reykjavík, myndir, kort, línurit p.

Eyþórsson, J. (1950) "Hlaupið úr Grænalóni í september 1949": Náttúrufræðingurinn, v. **20**(3.h.): p. 141-142.

Hróarsson, B. (1988) "Núpsstaðarskógur": Áfangar: tímarit um Ísland, v. **9**(1): p. 6-19.

Jóhannesson, H. (1982) "Fróðleiksmolar um Grænalón og nágrenni": Náttúrufræðingurinn, v. **52**(1.-4.h.): p. 86-101.

Kjaran, B. (1964) Bærinn í skjóli Lómagnúps, Auðnustundir: Reykjavík, Bókfellsútgáfan, p. 351 s., [8] mbl., [16] mbls. : teikn.

Inniheldur:
Gos í Öskju
Náttúran talar
Þeir, sem landið erfa
Skáld litanna
Í afture ldingu
Tveir Reykvíkingar
Gróður á gömlum akri
Litli víxlarinn af Skaga
Eyðibyggðir
Konungur fuglanna og þegnar hans
Vörn og sókn

Óla, Á. (1949) Í Nup(s)staðarskógum, *in* Óla, Á., ed., Blárra tinda blessað land: Reykjavík, Bókfellsútgáfan, p. 271-280.

Rist, S. (1951) "Grænalón": Náttúrufræðingurinn, v. **21. árg.**(4. hefti): p. 184-186.

— (1990) Vatns er þörf: Reykjavík, Menningarsjóður, 248 s. : myndir, kort, línurit, töflur, uppdr. p.

Roberts, M.J., Pálsson, F., Gudmundsson, M.T., Björnsson, H., and Tweed, F.S. (2005) "Ice-water interactions during floods from Grænalón glacier-dammed lake, Iceland": Annals of Glaciology, v. **40**(1): p. 133-138.

This paper explores changing ice–water interactions during jökulhlaups from Grænalón, a 5 × 108 m3 subaerial lake dammed by Skeiðarárjökull, Iceland. Unstable drainage of Graenalón since the early 20th century has resulted in 45 jökulhlaups whose hydrologic character has varied enormously. Geomorphic observations and geophysical measurements from the inlet and outlet zones of the subglacial floodwater tract constrained the hydromechanical factors governing ice–water interactions at Grænalón. To date, three distinct drainage regimes have occurred in response to the changing surface elevation of Grænalón. Shifts from one drainage regime to another involved pronounced changes in jökulhlaup magnitude, timing and cyclicity. Present hydraulic conditions for lake drainage differ from the classical view of a pressure-coupled lake draining directly beneath an ice dam. Instead, lowamplitude drawdown occurs at regular, frequent intervals when hydrostatic pressure in a shallow, rock–ice trench enables water to flow beneath a sagging ice barrier. Floodwater exits Skeiðarárjökull in a supercooled state due to rapid hydraulic displacement from an overdeepened subglacial basin.

Þórarinsson, S. (1969) Afleiðingar jöklabreytinga á Íslandi ef tímabil hafísára fer í hönd, Hafísinn: Reykjavík, A.B., p. 364-388; Kort, línurit.

4.1.69 Lómagnúpur

Jóhannesson, H. (1983) "Skalf þá og nötraði bærinn ": Náttúrufræðingurinn, v. **53**(1.-2.h.): p. 1-4.

Jónsson, J. (1974) "Sprungurnar í Lómagnúpi og fleira": Náttúrufræðingurinn, v. **44**(1.h.): p. 41-44.

— (1976) Berghlaupið úr Lómagnúp, *in* Jónsson, Ó., ed., Berghlaup: Akureyri, Ræktunarfélag Norðurlands, p. 587-591.

4.1.70 Vestur-Skaftafellssýsla (ekki skilgreint nánar)

Baldursson, S., Jakobsson, S.P., Magnússon, S.H., and Guðjónsson, G. (2006) Náttúrufar og náttúruminjar suðvestan Vatnajökuls: Reykjavík, Náttúrufræðistofnun Íslands, p. 38.

Bruun, D. (1903) "Gennem afsides egne paa Island : iagttagelser foretagne paa rejser i Skaftafellssyslerne 1899 og 1902": Tidsskrift for landøkonomi: p. 417-534.

Einarsson, E.H. (1972) "Af náttúrurannsóknum í Vestur-Skaftafellssýslu 1972": Týli, tímarit um náttúrufræði og náttúruvernd, v. **3**(2): p. 67.

Jónsson, J. (1977) "Jökulgarðar í Vestur-Skaftafellssýslu": Týli, tímarit um náttúrufræði og náttúruvernd, v. **7**(2): p. 37-40.

Magnússon, H., Jónsson, J., and Þórarinsson, S. (1983) Vestur-Skaftafellssýsla austan Skaftár og Kúðafljóts. Árbók Ferðafélag Íslands 1983: Reykjavík.

Zóphóníasson, S. (1973) Jarðfræði Skaftártunguafrétts [**Námsritgerð**]: Reykjavík, Háskóli Íslands.

4.2 Vatnajökull sjálfur

4.2.1 Grímsvötn, Gjálp

Alfaro, R., Brandsdóttir, B., Rowlands, D.P., White, R.S., and Guðmundsson, M.T. (2005) "Structure of the Grímsvötn central volcano under the Vatnajökull ice cap, Iceland": Geophysical Journal International, v. **in press**.

Alsdorf, D.E., and Smith, L.C. (1999) "Interferometric SAR observations of ice topography and velocity changes related to the 1996, Gjálp subglacial eruption, Iceland": International Journal of Remote Sensing, v. **20**(15-16): p. 3031-3050.

A major volcanic eruption beneath the Vatnajökull ice cap from 30 September to 13 October 1996 melted up to 500m of overlying ice and produced 3.5km(3) of water that was later released catastrophically onto the Skeiðarársandur outwash plain. Here, we present pre- and post-event topography and velocity field maps of the ice cap surface derived from ERS-1/2 synthetic aperture radar (SAR) interferometry. Within the errors of this method our results reveal local topographic and ice flow variations near the eruption site and incision of a 140m meltwater trench. A 24-hour, 50cm subsidence of the frozen surface of the Grimsvötn caldera lake was also detected. However, despite the large increases in geothermal heat flux and basal meltwater availability associated

with this event, there appears to be no regional-scale ice subsidence and little to no alteration in flow dynamics of the Vatnajökull ice cap.

Ágústsdóttir, A.M. (1993) Heat and volatile fluxes integrated over four decades at Grímsvötn volcano, Iceland [**M.Sc. thesis**], Pennsylvania State University.

Ágústsdóttir, A.M., and Brantley, S.L. (1994) "Volatile fluxes integrated over four decades at Grímsvötn volcano, Iceland": Journal of geophysical research, v. **99**(B5): p. 9505-9522.

Ágústsdóttir, A.M., Brantley, S.L., Guðmundsson, M.T., and Björnsson, H. (1992) Volatile release rates from the Grímsvötn volcano, Iceland, *in* Kharaka, Y., and Maest, A.S., eds., Proceedings of the 7th International Symposium on Water-Rock Interaction: Rotterdam, A.A. Balkema, p. 465-468.

Áskelsson, J. (1936) "Investigations at Grímsvötn, Iceland 1934-1935": Polar Record, v. **11**: p. 45-47.

— (1959) "Skeiðarárhlaupið og umbrotin í Grímsvötnum": Jökull, v. **9**: p. 22-29.

Bárðarson, H.R. (1971) Ís og eldur : andstæður íslenzkrar náttúru: Reykjavík, 171, [1] s. : að meginhluta myndir, kort p.

— (1991) Ice and fire : contrasts of Icelandic nature: Reykjavík, 244 s. : myndir, kort, línurit p.

Benediktsson, S., and Helgadóttir, S. (1997) Skeiðarárhlaup: Reykjavík, Náttúruverndarráð.

Berthier, E., Björnsson, H., Pálsson, F., Feigl, K.L., Llubes, M., and Remy, F. (2006) "The level of the Grimsvötn subglacial lake, Vatnajökull, Iceland, monitored with SPOT5 images": Earth and Planetary Science Letters, v. **243**(1-2): p. 293-302.

We describe the vertical displacement field of an ice shelf floating on a subglacial lake, Grimsvötn, located underneath the Vatnajokull ice cap (Iceland). The uplift is measured using the correlation of two satellite optical SPOT5 images acquired 5 days apart with similar, non-vertical incidence angles. This is the first time correlation of optical images has been used to measure vertical displacements. Our technique is suitable for mapping short-term elevation changes of glaciers. If the surface features are preserved, vertical displacements can be measured every 25 m with an accuracy of about 0.5 m.The uplift map of Grimsvotn shows that 10.9 (+/- 1) km2 of ice was floating between 11 and 16 August 2004. The ice shelf rose by 1.7 (+/- 0.6) m indicating that the volume of liquid water in the lake increased by 0.018 (+/- 0.007) km3. Our field observations show that surface melting due to meteorological processes contributed 70% of the accumulated water, hence, the rest originated from ice melted by the subglacial geothermal activity. The power required to melt 0.005 *km3 (water equivalent) of basal ice in 5 days is 4000 MW. The applicability of the technique can be extended to volcanology and seismology, and even landslides or subsidence, when finer-resolution optical images become available. Applied to two pairs of images, it could solve for the 3-dimensional displacements of the Earth's surface.*

Björnsson, H. (1974) "Explanation of jökulhlaups from Grímsvötn, Vatnajökull, Iceland. Skýring á jökulhlaupum úr Grímsvötnum (Ágrip)": Jökull, v. **24**: p. 1-26.

— (1975) "Subglacial water reservoirs, jökulhlaups and volcanic eruptions": Jökull, v. **25**: p. 1-14.

Water may accumulate in a reservoir that forms beneath a depression in a glacier surface. The water reservoir will grow unstable. The accumulation will cause a jökulhlaup from the reservoir. Water may also accumulate beneath a slightly inclined or a convex glacier surface. The reservoir will remain stable. A jökulhlaup will not result under these conditions. A depression in the glacier surface may be created by melting above a permanent geothermal area. The depression at Grímsvötn in Vatnajökull is a well known example. Jökulhlaups at Skeiðarársandur originate at Grimsvötn. An ice cauldron which is situated 10 km north-west of Grímsvötn is an other example. Jökulhlaups in the river Skaftá drain from a reservoir, which is situated beneath the ice cauldron.

A depression may also be created by a subglacial volcanic eruption. The eruption will cause considerable subglacial melting. A depression is formed in the glacier surface if the meltwater drains towards the glacier rivers. The subglacial waterways around the depression may become sealed. Meltwater would then be trapped beneath the depression. A dome-shaped subglacial water reservoir will be formed at the bed of the glacier. Jökulhlaups will occur from the reservoir. Pillow lava and hyaloclastic materials are piled up within such a reservoir during subglacial volcanic eruptions.

— (1982) Varmamælirinn í Grímsvötnum, eldvirkni, orsakir og eðli jarðhita, Eldur er í norðri: Reykjavík, Sögufélagið, p. 139-144.

— (1983) "A natural calorimeter at Grímsvötn; an indicator of geothermal and volcanic activity (Varmamælirinn í Grímsvötnum, jarðhiti og eldvirkni) ": Jökull, v. **33**: p. 13-18.

— (1984) "Photos from Grímsvötn 22nd June 1984": Jökull, v. **34**

— (1985) "The winter balance in Grímsvötn, Vatnajökull 1950-1985 (Summarizes available data for snow depths down to summer surface and winter balance calculated from snow density measurements)": Jökull, v. **35**: p. 107-109.

— (1992) "Jökulhlaups in Iceland: prediction, characteristics and simulation": Annals of Glaciology, v. **16**: p. 95-106.

Jökulhlaups drain regularly from six subglacial geothermal areas in Iceland. From Grímsvötn in Vatnajökull, jökulhlaups have occurred at a 4-6 year interval since the 1940s with a peak discharge of 1,000 - 10,000 m3/s, 2 -3 weeks duration and total volumes of 0.5-3 km3. Prior to that, about one jökulhlaup occurred per decade with an estimated discharge of 5 km3 of water and a peak discharge of approximately 30,000 m3/s. Clarke½s (1982) modification of Nye's (1976) general model of discharge of jökulhlaups gives in many respects satisfactory simulations for jökulhlaups from Grímsvötn. The best fit is obtained for the Manning roughness coefficients n = 0.08-0.09 m-1/3 s and a constant lake temperature of 0.2 °C (which is the present lake temperature). The rapid ascent of the exceptional jökulhlaup in 1938, which accompanied a volcanic eruption, can only be simulated for a lake temperature of the order of 4 °C. Jökulhlaups originating at geothermal areas beneath ice cauldrons located 10-15 km northwest of Grímsvötn have a peak discharge of 200 - 1,500 m3/s in 1-3 days, the total volume is 50-350x106m3, and they recede slowly in 1-2 weeks. The form is in that respect a mirror image of the typical Grímsvötn hydrograph. The reservoir water temperature must be well above the melting point (10-20 °C) and the flowing water seems not to be confined to a tunnel but spread out beneath the glacier and later gradually collected back to conduits. Since the time of the settlement of Iceland (870 A.D.), at least 80 subglacial volcanic eruptions have been reported, many of them causing tremendous jökulhlaups with dramatic impact on inhabitated areas and landforms. The peak discharge of the largest floods (from Katla) has been estimated at the order of 100-300,000 m3/s, duration was 3 -5 days and the total volume of the order of 1 km3. It is now apparent that the potentially largest and most catastrophic jökulhlaups may be caused by eruptions in the voluminous ice-filled calderas in northern Vatnajökull (of Bárdarbunga and Kverkfjöll). They may be the source of prehistoric jökulhlaups, with estimated peak discharge of 400,000 m3/s. At present, jökulhlaups originate from some fifteen marginal ice-dammed lakes in Iceland. Typical values for peak discharges are 1,000 - 3,000 m3/s, duration 2-5 days and total volumes of 2,000 x 106 m3. Hydrographs for jökulhlaups from marginal lakes have a shape similar to those of the typical Grímsvötn jökulhlaup. Simulations give reasonable ascent of the hydrographs for constant lake temperature of about 1 °C but fail to show the recession. Some floods from marginal lakes, however, have reached their peaks exceptionally rapidly, in one day. That ascent could be simulated by drainage of lake water of 4-8 °C. An empirical power law relationship is obtained between peak discharge and total volume of the jökulhlaups from Grímsvötn; Qmax = K Vtb, where Qmax is measured in m3/s, Vt in 106 m3, K = 4.15 10-3 s-1 m-2.52 and b = 1.84. In general, the jökulhlaups (excepting those caused by eruptions) occur when the lake has risen to a critical level, but before a lake level required for simple flotation of the ice dam is reached. The difference between the hydrostatic water pressure maintained by the lake and the ice overburden pressure of the ice dam is of the order 2-6 bar.

— (1997) Grímsvatnahlaup fyrr og nú, *in* Haraldsson, H., ed., Vatnajökull : gos og hlaup 1996 : skýrsla unnin fyrir Vegagerðina af Raunvísindastofnun Háskólans og Orkustofnun: Reykjavík, Vegagerðin, p. 61-78.

— (1998) "Hydrological characteristics of the drainage system beneath a surging glacier": Nature, v. **395**: p. 771-774.

A unique combination of natural circumstances allows us to assess current theories about water flow beneath glaciers. Outburst floods from the subglacial lake, Grímsvötn, have *taken place before, during and subsequent to surging of Skeiðarárjökull, the glacier beneath which they drain. The observable drainage patterns associated with these floods show the different nature of the basal water conduit system of the glacier during surge and non-surge phases. During surge, basal water is dispersed slowly across the bed in a distributed drainage system; but when the glacier is not surging, water is transported rapidly through a system of tunnels.*

— (2002) "Subglacial lakes and jökulhlaups in Iceland": Global and planetary change, v. **35**: p. 255-271.

Active volcanoes and hydrothermal systems underlie ice caps in Iceland. Glacier–volcano interactions produce meltwater that either drains toward the glacier margin or accumulates in subglacial lakes. Accumulated meltwater drains periodically in jökulhlaups from the subglacial lakes and occasionally during volcanic eruptions. The release of meltwater from glacial lakes can take place in two different mechanisms. Drainage can begin at pressures lower than the ice overburden in conduits that expand slowly due to melting of the ice walls by frictional and sensible heat in the water. Alternatively, the lake level rises until the ice dam is lifted and water pressure in excess of the ice overburden opens the waterways; the glacier is lifted along the flowpath to make space for the water. In this case, discharge rises faster than can be accommodated by melting of the conduits. Normally jökulhlaups do not lead to glacier surges but eruptions in ice-capped stratovolcanoes have caused rapid and extensive glacier sliding. Jökulhlaups from subglacial lakes may transport on the order of 107 tons of sediment per event but during violent volcanic eruptions, the sediment load has been 108 tons.

Björnsson, H., Björnsson, S., and Sigurgeirsson, T. (1982) "Penetration of Water into Hot Rock Boundaries of Magma at Grimsvötn": Nature, v. **295**: p. 580-581.

Björnsson, H., Björnsson, S., and Sigurgeirsson (1980) "Geothermal effects of water penetrating onto hot rock boundaries of magma bodies": Geothermal Resources Council, Transactions, v. **4**: p. 13-15.

Björnsson, H., and Einarsson, P. (1990) "Volcanoes beneath Vatnajökull, Iceland: Evidence from radio echo-sounding earthquakes and jökulhlaups": Jökull, v. **40**: p. 147-168.

Integration of knowledge of subglacial topography, earthquake activity and jökulhlaups has contributed to more precise locations of the volcanic systems beneath Vatnajökull. Bárðarbunga is the centre of a volcanic system which includes the fissure swarms of Veiðivötn to the SW and Dyngjuháls to the NE. The Grímsvötn volcano is the centre of a system that comprises the Laki fissure swarm in the SW and extends for an unknown distance to the NE of the volcano. Þórðarhyrna is probably a separate central volcano within this system. The Kverkfjöll system can be traced 10 km to the SW of the Kverkfjöll volcano. It appears to be separated from the Grímsvötn volcano. The Askja fissure swarm extends beneath Dyngjujökull and can possibly be traced to the Grímsvötn volcano. Hamarinn and the ridge striking eastward from Hamarinn (Loki Ridge) are central volcanoes which together with the Fögrufjöll fissure swarm form a volcanic system. No support can be found in the topographic data for the existence of a central volcano near Breiðabunga. Volcanic activity in historical times has mainly been limited to the Grímsvötn and Bárðarbunga systems. Major rifting events have

affected large sections of these volcanic systems but both have been remarkably quiet for the past decades. A few volcanic events are presumed to have occurred on the Hamarinn - Loki system and on the Askja fissure swarm beneath Dyngjujökull, but no event is known with certainty on the Kverkfjöll system. The rivers Skeiðará and Súla have the most frequent eruption-related jökulhlaups. They receive meltwater from the Grímsvötn caldera and the area to the SW of it, including Þórðarhyrna. Núpsvötn, Djúpá and Hverfisfljót drain the southwestern part of the Grímsvötn system, an area bounded by Þórðarhyrna, Geirvörtur, Hágöngur and Pálsfjall. Skaftá drains the Loki Ridge and the area west of Grímsvötn. Jökulhlaups in Kaldakvísl, and ultimately Þjórsá, must originate in the Bárðarbunga or the Hamarinn - Loki systems, and the only possible source for volcanic jökulhlaups in Skjálfandafljót is the northern part of the Bárðarbunga system. Jökulsá á Fjöllum may drain meltwater from activity in all the volcanic systems in northern Vatnajökull: Bárðarbunga, the Askja fissure swarm and Kverkfjöll. This includes the voluminous, ice-filled calderas of Bárðarbunga and Kverkfjöll. Activity in the northern part of the Grímsvötn system may cause floods in Jökulsá á Fjöllum. Meltwater from volcanic activity on the SE flank of a ridge that strikes south from Kverkfjöll may drain to Jökulsá á Brú. Volcanic activity farther north on the E flanks of this ridge would cause floods in Kreppa.

Björnsson, H., Guðmundsson, G.H., and Aðalgeirsdóttir, G. Flow modelling of a temperate ice cap, Vatnajökull Iceland.

The project aims at defining and testing two and three dimensional stationary and time dependent flow models to describe the ice cap Vatnajökull: general dynamics, flowlines, location of ice divides, velocity distribution, shape, thickness and extent, how close the ice cap is to an equilibrium state for the present mass balance distribution, its sensitivity to changes in mass balance and its response to climatic variations. The models will be tested on available boundary values from detailed maps of the ice surface and the bedrock, internal volcanic ash layers, observed mass balance and surface velocidy, and existing data of glacier variations for the last centuries. Mass balance models derived from the ongoing international Vatnajökull project TEMBA will be used as an input to studies of the glacier response to various scenarios of climatic change. Detailed observations and model studies will be carried out of the effect of bedrock irregularities. Field work started in August 1998, when GPS instruments from ETH, Zürich were used to measure velocity of the ice around a canyon that was created in the jökulhlaup that followed the 1996 eruption in Gjálp, Vatnajökull.

Björnsson, H., and Guðmundsson, M.T. (1993) "Variations in the Thermal Output of the Subglacial Grimsvötn Caldera, Iceland": Geophysical Research Letters, v. **20**(19): p. 2127-2130.

A 69 year record (1922-1991) of heat release has been obtained from the subglacial geothermal system of the Grimsvötn caldera within the Vatnajökull ice cap. The data were derived from in situ measurements of the volume of meltwater accumulated in the caldera lake, subtracting climatically induced melting. The overall fluctuations in the heat flux are closely related to volcanic activity and are dominated by a main pulse of 11,600 MW, caused by a major eruption in 1938, gradually declining to 1600 MW in 1976-1982. Heat extracted from the roof of a magma chamber, with the aid of hydrothermal convection, may have given a basic contribution to the heat flux of 1500 to 2000 MW (an upper bound). The variable part of the heat flux (from 0 to 10,000 MW) was released from magma erupted at the base of the glacier and from shallow intrusions. The total heat released over the period 1922 to 1991 was (8.1+/-1.6) x

10(18)J, equivalent to the energy released by the solidification and cooling of 2.1+/-0.4 km3 of basaltic magma. The contribution to the total heat flux was 45% (max.) from a magma chamber, 35% (min.) from shallow intrusions, and 20% from eruptions. This implies that magma at the roof of a chamber solidified and cooled at the rate of 1.2-1.6 x 10(7) m3 a-1 or about 1 km3 over the last 69 years. Heat release at Grimsvotn was probably more intense in the 19th century when volcanic eruptions were more frequent.

Björnsson, H., and Hallgrímsson, M. (1976) "Mælingar í Grímsvötnum við Skeiðarárhlaup 1972 og 1976": Jökull, v. **26**: p. 91-92.

Björnsson, H., and Kristmannsdóttir, H. (1984) "The Grímsvötn geothermal area, Vatnajökull, Iceland (Jarðhitasvæðið í Grímsvötnum)": Jökull, v. **34**: p. 25-50.

Melting of ice at the Grímsvötn geothermal area has created a depression in the surface of the ice cap Vatnajökull and produced a subglacial lake from which jökulhlaups drain to Skeiðarársandur. The geothermal activity is also expressed by small cauldrons on the surface of the ice as well as by fumaroles on two nunataks that rise 300 m above the lake level. Vapour from the fumaroles yields little information about the deep reservoir fluid. The vapour seeps upwards from the water table and repeatedly condenses and evaporates on the way to the surface. The chemistry of the water in jökulhlaups, however, provides information about the fluid in the geothermal system. This information is not easy to interpret because of water-rock interaction in the lake. Silica solubility data and assumptions about the likely reservoir temperature, however, indicate that about 15% of the total mass in the lake is fluid discharged from the geothermal reservoir. This information about the geothermal mass fraction together with mass and energy balances for the lake enables one to calculate the masses of water and steam discharged from the geothermal reservoir as well as the mass of ice melted in the lake. The steam mass fraction os estimated to be 20-35% when the fluid enters the lake. From this, new estimates of the thermal power of the geothermal system are obtained. The total thermal power of the system is 4700-4900 MW, of which 2100-2300 MW are transported by steam and the rest by water.

Grímsvötn is one of few geothermal areas where active volcanism is observed and where there is a direct interaction between magma and geothermal water. Evidence of volcanic activity was found in the water chemistry of the jökulhlaup in December 1983. The high content of sulphate and the presence of iron indicated eruption of magma into the geothermal fluid.

Since the nineteen-fifties jökulhlaups have occurred regularly at 4-6 year intervals when the lake level has risen up to a critical level required for draining water from the bottom of the lake. However, jökulhlaups may occur at lower water levels. In 1983 a jökulhlaup was triggered at a water level 20-30 m lower than the critical level. This jökulhlaup may have been triggered by the opening of waterways into the lake along the slopes of Grímsfjall, where increased geothermal or volcanic activity has melted ice in places. An odour of hydrogen sulphide was detected for two months on Skeiðarársandur before the jökulhlaup commenced. Sulphurous odour for long periods may warrant a forecast of such premature jökulhlaups.

Björnsson, H., Rott, H., Guðmundsson, S., Fischer, A., Siegel, A., and Guðmundsson, M.T. (2001) "Glacier-volcano interactions deduced by SAR interferometry": Journal of Glaciology, v. **47**(156): p. 58-70.

Glacier-surface displacements produced by geothermal and volcanic activity beneath Vatnajökull ice cap in Iceland are described by field surveys of the surface topography combined with interferograms acquired from repeat-pass synthetic aperture radar images. A simple ice-flow model serves well to confirm the basic interpretation of the observations. The observations cover the period October 1996-January 1999 and comprise: (a) the ice-flow field during the infilling of the depressions created by the subglacial Gjálp eruption of October 1996, (b) the extent and displacement of the floating ice cover of the subglacier lakes of Grímsvötn and the Skaftá cauldrons, (c) surface displacements above the subglacier pathways of the jökulhlaups from the Gjálp eruption site and the Grimsvötn lake, (d) detection of areas of increased basal sliding due to lubrication by water, and (e) detection of spots of temporal displacement that may be related to altering subglacial volcanic activity. At the depression created by the Gjálp eruption, the maximum surface displacement rate away from the radar decreased from 27 cm d(-1) to 2 cm d(-1) over the period January 1997-January 1999. The observed vertical displacement of the ice cover of Grimsvötn changed from an uplift rate of 50 cm d(-1) to sinking of 48 cm d(-1), and for Skafta cauldrons from 2 cm d(-1) to 25 cm d(-1).

Brandsdóttir, B. (1999) Hvað er að gerast í Grímsvötnum?, Vorráðstefna 1999: ágrip erinda: Reykjavík.

Briem, E.V. (1976) "Hugleiðingar um Grímsvötn": Jökull, v. **26**: p. 65-68.

Einarsson, G. (1946) Eldgos við Grímsvötn, Fjallamenn: Reykjavík, Bókaútgáfa Guðjóns Ó. Guðjónssonar, p. 47-62.

Einarsson, P., and Brandsdóttir, B. (1984) "Seismic activity preceeding and during the 1983 volcanic eruption in Grímsvötn, Iceland (Skjálftavirkni tengd eldgosinu í Grímsvötnum 1983)": Jökull, v. **34**: p. 13-23.

The eruption of Grímsvötn in May - June 1983 was preceded by increased earthquake activity. The premonitory activity began in December 1982 - March 1983 and increased gradually in April and May. The earthquakes originated under the SE rim of the Grímsvötn caldera and are interpreted as being caused by brittle failure of the crust above and around an inflating magma chamber. An intense earthquake swarm (Mmax=4.0) occurred in the same area on May 28, presumably related to the failure of the magma chamber walls and subsequent migration of magma towards the surface. The eruption is inferred to have begun shortly after the swarm ceased or about the time, when continuous volcanic tremor was first recorded on the nearest seismograph between 11:47h and 12:00h on May 28. The tremor was most intense in the first 12 hours and then gradually diminished until it disappeared early on June 2. It came in bursts of several minutes duration, separated by longer periods of more uniform background tremor. If the tremor amplitude is taken as an indicator of extrusion rate, the eruption was most vigorous during the first 26 hours. The several km high eruption columns observed in the last two days of the eruption thus probably reflect the reduced water pressure on the magma, when the volcanic orifice approached the surface of the caldera lake, rather than high extrusion rate. Earthquake activity was *very low in Grímsvötn during the eruption and remained so for three months afterwards, probably indicating the relaxed stress state around the feflated magma chamber. The 1983 eruption demonstrates that small eruptions can occur in Grímsvötn without causing or being triggered by jökulhlaups, and without being noticed from the inhabited lowlands. Eruptions are, however, likely to be detected by the seismograph network in SE-Iceland. The absence of any abnormal seismic activity in Grímsvötn prior to 1983 and since at least 1971 indicates that no eruptions occurred during this time, in particular not during the jökulhlaups of 1972, 1976 and 1982.*

Einarsson, P., Brandsdóttir, B., Guðmundsson, M., Björnsson, H., Grönvold, K., and Sigmundsson, F. (1997) "Centre of Iceland's hotspot experiences unrest": Eos, Transactions, American Geophysical Union, v. **78**(35): p. 369, 374-375.

Eiríksson, J., and Larsen, G. (1997) Gjóska úr Vatnajökulsgosi 1996: Gjóskufall og áhrif gosumhverfis á kornagerð, *in* Sveinbjörnsdóttir, Á.E., ed., Ráðstefna Jarðfræðafélags Íslands: Eldgos í Vatnajökli 1996, ágrip erinda og veggspjalda: Reykjavík, Jarðfræðafélag Íslands, p. 14-16.

Eiríksson, J., and others (1994) Roadlog : Nordic geological excursion in Iceland : quaternary geology - glaciology Reykjavík, myndir, kort, línurit p.

Elíasson, J., Kjaran, S.P., Holm, S.L., Guðmundsson, M.T., and Larsen, G. (In Press) "Large hazardous floods as translatory waves": Environmental Modelling & Software, v. **Corrected Proof**. (Aðallega um Kötlu)

The theory for non-stationary flow in translatory waves is developed for an inclined plane in a prismatic channel and a funneling channel. The existence of translatory waves traveling over dry land or superimposed on constant flow is established, and the dependance on the initial flow value is discussed. Inherent instabilities of the wave tail are discussed. Data from a CFD simulation of a jökulhlaup (volcanic glacial burst) down the Markarfljót valley in Iceland are shown, and the similarities to the translatory wave established. Geological evidence of such large floods exists, and it is concluded that some historical floods like Katla 1918 have most likely been of this type. It is concluded that in simulation and hazard assessment of great floods, the translatory flow theory has an advantage over estimates based on Manning and alike methods, since the often subjective determination of the Manning n is avoided.

Flowers, G.E., Bjornsson, H., Palsson, F., and Clarke, G.K.C. (2004) "A coupled sheet-conduit mechanism for jökulhlaup propagation": Geophysical Research Letters, v. **31**(5).

The largest glacier outburst flood (jokulhlaup) ever recorded in Iceland occurred in 1996 and came from subglacial lake Grimsvotn in Vatnajokull ice cap. Among other noteworthy features, this flood was characterized by an unprecedentedly high lake level prior to flood initiation, extremely rapid linear rise in lake discharge, delay between the onset of lake drainage and floodwater arrival at the glacier terminus, formation of short-lived supraglacial fountains, and initially unchannelized outbursts of floodwater at the terminus. Observations suggest that the 1996 flood propagation mechanism was fundamentally different than that of previously observed floods from Grimsvotn. We *advance a new model whereby floodwater initially propagates in a turbulent subglacial sheet, which feeds a nascent system of conduits. This model is able to explain key observations made of the 1996 jokulhlaup and may shed light on other outburst floods that do not conform to the standard model.*

Fowler, A.C. (1999) "Breaking the seal at Grimsvotn, Iceland": Journal of Glaciology, v. **45**(151): p. 506-516.

Of several problems associated with theoretical explanations of the jökulhlaups which emerge from the outlet glacier Skeiðarárjökull of the ice cap Vatnajökull in southeast Iceland, the mechanism of flood initiation is one that has hitherto defied explanation. We provide, such an explanation based on a careful analysis of the classical Nye-Rothlisberger model; near the subglacial lake Grimsvötn, the hydraulic potential gradient is towards the lake, and there is therefore a catchment boundary under the ice, whose location depends on the subglacial meltwater drainage characteristics. As the conditions for a flood approach, we show that the water divide migrates towards the lake, while at the same time the lake pressure increases. When the hydraulic potential gradient towards the lake is low and the refilling rate is slow, the seal will "break" when the catchment boundary reaches the lake, while the lake level is still below flotation pressure, whereas if refilling is rapid, flotation can be achieved before a flood is initiated. This theory can thus explain why the seal is normally broken when the lake level at Grimsvotn is still some 60 m below flotation level. In addition, we are able to explain why the jokulhlaup following the 1996 eruption did not occur until flotation level was achieved, and we show how the cyclicity and magnitude of jökulhlaups can be explained within this theory.

Ghatan, G.J., and Head, J.W. (2002) "Candidate subglacial volcanoes in the south polar region of Mars: Morphology, morphometry, and eruption conditions": Journal of Geophysical Research-Planets, v. **107**(E7): p. -. (aðallega um Mars)

[1] A number of isolated mountains mapped in the south polar region of Mars are documented using Mars Global Surveyor (MGS) Mars Orbiter Laser Altimeter (MOLA) and Mars Orbiter Camera (MOC) data. These mountains have average separation distances of similar to175 km, they are typically 30-40 km in diameter and 1000-1500 m high, and their bases fall near an elevation of similar to1200 m. A significant number of the population are located on or very close to a 660 km long line extending toward the south pole. The summits of a number of these mountains have unusual shapes: flat-topped, flat-topped with a cone, and large summit craters relative to the summit diameter. Sinuous channels are found in association with the margins of several of the mountains. Several modes of origin are considered for these mountains, including impact, tectonic, and volcanic. These mountains occur in intimate association with the Hesperian-aged Dorsa Argentea Formation, a unit containing features and structures interpreted to be related to a thick, areally extensive ice sheet. On the basis of these observations and analyses it is concluded that the most plausible origin for these mountains is volcanic and that they represent extrusion of lava from vents, many of which lay underneath an ice sheet. The unusual shape of many of the mountains is consistent with construction of a volcanic edifice underneath an ice sheet and melting of adjacent ice-rich material, sometimes forming drainage channels. The topography of these mountains suggests that the ice sheet averaged at least 1.4 km thick at the time of eruption. These features appear to be associated with Early Hesperian-aged ridged plains (Hr).

Ghatan, G.J., Head, J.W., and Pratt, S. (2003) "Cavi Angusti, Mars: Characterization and assessment of possible formation mechanisms": Journal of Geophysical Research-Planets, v. **108**(E5): p. -. (aðallega um Mars)

[1] Cavi Angusti represent a series of large irregular depressions localized in part of the south circumpolar area previously mapped as the Hesperian-aged Dorsa Argentea Formation. Their origin has primarily been interpreted to be due to eolian deflation or subglacial melting. We use MGS MOLA and MOC data to analyze the largest of these features (similar to100 x 50 km, and up to about 1500 m deep). These data reveal terraced interiors, centrally located equidimensional and elongated edifices, and lava-flow-like structures that strongly suggest that this basin formed as a result of magmatic intrusion and extrusion, causing heating and melting of a volatile-rich substrate and drainage and loss of the liquid water. Volume estimates and heat transfer calculations are consistent with a mechanism involving a combination of intrusion and extrusion very similar to that observed to be responsible for Icelandic subglacial eruptions and meltwater generation. Mounds and ridges in the floors of other depressions suggest that this mechanism may have operated in at least several other features of the Cavi. Eolian activity, sublimation, and solution are also likely to have played a role in further modification of these features. Meltwater from basin formation appears to have drained laterally and may also have reentered the regional subsurface groundwater system.

Grönvold, K., and Jóhannesson, H. (1984) "Eruption of Grímsvötn 1983; course of events and chemical studies of tephra (Grímsvatnagosið 1983, atburðarás og efnagreining á gjósku)": Jökull, v. **34**: p. 1-11.

A short eruption took place in the Grímsvötn volcano in May - June 1983. The eruption most probably started on May 28th. Activity was last observed on June 1st and by June 5th it was certainly over.

The Grímsvötn volcano is situated within the western part of the Vatnajökull ice cap. It is almost totally ice covered and the caldera lake is covered by an ice chelf about 200 metres thick. The eruption site is within the caldera near the southern rim and a lake, about 500 m in diameter, formed in the ice shelf with a small island in the middle. The eruption was subaquatic and intermittent ash explosions were observed in the lake. Usually these were about 50-100 m high and a steam column rose up to about 5000 m height a. s. l.

Three small ash fans formed on the surrounding ice sheet; two by explosions, one to the south early in the eruption and another to the east most likely on June 1st; the third to the north within the caldera was most likely caused mainly by an avalanche from the overhanging caldera wall into the lake.

The glass phase of the ash was analyzed in a number of samples and found to be evolved basalt with a uniform chemical composition but minor variations are indicated. Samples from the 1934, 1922 and 1903 Grímsvötn eruptions were analyzed for comparison and show very similar chemical composition as the 1983 ash. This composition is also very similar to that of the glass phase of the eruption of the Laki craters 1783-84.

The Grímsvötn volcano is also the site of a major geothermal system, stimated at 5000 MW. The heat source of this system is assumed to be magmatic intrusions, most *likely with the same compostion as the ash. It appears unlikely that the heat extraction takes place in the same parts of the magmatic system as the evolution of the basalt.*

Guðmundsson, M.T., Björnsson, H., and Pálsson, F. (1995) "Changes in jökulhlaup sizes in Grímsvötn, Vatnajökull, Iceland, 1934-91, deduced from in-situ measurements of subglacial lake volume": Journal of Glaciology, v. **41** (138): p. 263-272.

A record of volumes of jökulhlaups from the subglacial Grimsvötn lake, Vatnajökull, Iceland, has been derived for the period 1934-91. The change in lake volume during jokulhlaups is estimated from the lake area, ice-cover thickness and the drop in lake level. The jökulhlaup volumes have decreased gradually during this period of low volcanic activity and declining geothermal power. The two Jokulhlaups in the 1930s each discharged about 4.5 km(3) (peak discharge 25-30 x 10(3) m(3) s(-1)). In the 1980s, jökulhlaup volumes were 0.6.-1.2 km(3) (peak discharge 2 x 10(3) m(3) s(-1)). The lake level required to trigger a jökulhlaup has risen as an ice dam east of the lake has thickened. Water flow in a jökulhlaup ceases when the base of a floating ice shelf covering Grimsvötn settles to about 1160 m a.s.l. Apparently, the jökulhlaups are cut off when the base of the ice shelf collapses on to a subglacial ridge bordering the lake on its eastern side. The decline in melting rates has resulted in a positive mass balance of the 160-170 km(2) Grimsvotn ice-drainage basin. Comparison of maps shows that the average positive mass-balance rate was 0.12 km(3) a(-1) (25% of the total accumulation) in the period 1946-87. A gradually increasing positive mass balance has prevailed since 1954, reaching 0.23 km(3) a(-1) in 1976-86 (48% of total accumulation).

Guðmundsson, M.T., Högnadottir, Þ., Larsen, G., Sigmundsson, F., and Langley, K. (2004) The 1998 eruption in Grímsvotn, Iceland: An eruption through thin ice, IAVCEI General Assembly: Abstracts: Pucon, Chile.

Guðmundsson, M.T., Sigmundsson, F., and Björnsson, H. (1997) "Ice-volcano interaction of the 1996 Gjalp subglacial eruption, Vatnajokull, Iceland": Nature, v. **389**: p. 954-957.

Volcanic eruptions under glaciers can cause dangerous floods and lahars(1-3) and create hyaloclastite (fragmented glassy rock) mountains(4-8), But processes such as the rate of heat transfer between ice and magma, edifice formation, and the response of the surrounding glacier are poorly understood, because of the lack of data. Here we present observations from the fissure eruption at Vatnajokull ice cap, Iceland, in October 1996. In the 13 days of the eruption 3 km(3) of ice were melted and the erupted magma fragmented into glass forming a hyaloclastite ridge 6-7 km long and 200-300 m high under 500-750 m of ice. Meltwater of temperatures of 15-20 degrees C flowed along a narrow channel at the glacier bed into the Grimsvotn subglacial lake for five weeks, before draining in a sudden flood, or jokulhlaup. Subsidence and crevassing of the ice cap occurred over the eruptive fissure and the meltwater path, whereas elsewhere the glacier surface remained intact, suggesting that subglacial eruptions do not trigger widespread basal sliding in warm-based glaciers.

Guðmundsson, M.T., Sigmundsson, F., Björnsson, H., and Högnadottir, Þ. (2004) "The 1996 eruption at Gjálp, Vatnajökull ice cap, Iceland: efficiency of heat transfer, ice deformation and subglacial water pressure": Bulletin of Volcanology, v. **66**(1): p. 46-65.

The 13-day-long Gjálp eruption within the Vatnajökull ice cap in October 1996 provided important data on ice-volcano interaction in a thick temperate glacier. The eruption produced 0.8 km(3) of mainly volcanic glass with a basaltic icelandite composition (equivalent to 0.45 km(3) of magma). Ice thickness above the 6-km-long volcanic fissure was initially 550-750 m. The eruption was mainly subglacial forming a 150-500 m high ridge; only 2-4% of the volcanic material was erupted subaerially. Monitoring of the formation of ice cauldrons above the vents provided data on ice melting, heat flux and indirectly on eruption rate. The heat flux was 5-6x10(5) W m(-2) in the first 4 days. This high heat flux can only be explained by fragmentation of magma into volcanic glass. The pattern of ice melting during and after the eruption indicates that the efficiency of instantaneous heat exchange between magma and ice at the eruption site was 50-60%. If this is characteristic for magma fragmentation in subglacial eruptions, volcanic material and meltwater will in most cases take up more space than the ice melted in the eruption. Water accumulation would therefore cause buildup of basal water pressure and lead to rapid release of the meltwater. Continuous drainage of meltwater is therefore the most likely scenario in subglacial eruptions under temperate glaciers. Deformation and fracturing of ice played a significant role in the eruption and modified the subglacial water pressure. It is found that water pressure at a vent under a subsiding cauldron is substantially less than it would be during static loading by the overlying ice, since the load is partly compensated for by shear forces in the rapidly deforming ice. In addition to intensive crevassing due to subsidence at Gjálp, a long and straight crevasse formed over the southernmost part of the volcanic fissure on the first day of the eruption. It is suggested that the feeder dyke may have overshot the bedrock-ice interface, caused high deformation rates and fractured the ice up to the surface. The crevasse later modified the flow of meltwater, explaining surface flow of water past the highest part of the edifice. The dominance of magma fragmentation in the Gjálp eruption suggests that initial ice thickness greater than 600-700 m is required if effusive eruption of pillow lava is to be the main style of activity, at least in similar eruptions of high initial magma discharge.

Guðmundsson, A.T. (1985) "Leiðangur til Grímsvatna 1934": Jökull, v. **35**: p. 103-106.

— (1986) Íslandseldar : eldvirkni á Íslandi í 10.000 ár Reykjavík, Vaka-Helgafell, 168 s. : myndir, teikn., kort, línurit, töflur p.

— (2001) Íslenskar eldstöðvar: Reykjavík, Vaka-Helgafell, 320 s. : myndir, kort, línurit, töflur

— (2003) "Upp Grímsfjall": Jökull, v. **52**: p. 68.

— (2004) "Upp Grímsfjall": Jökull, v. **54**: p. 84.

Guðmundsson, M.T. (1989) "The Grímsvötn caldera, Vatnajökull: subglacial topography and structure of caldera infill": Jökull, v. **39**: p. 1-19.

Results of seismic reflection survey, undertaken in 1987, to determine structure, elevation and topography of floor of main caldera, to measure area and volume of subglacial *lake and thus to assess flood potential, and also to obtain information on material deposited on lake floor by volcanic eruptions and sedimentation*

— (1996) Ice-volcano interaction at the subglacial Grímsvötn volcano, Iceland, *in* Colbeck, S., ed., Glaciers, Ice Sheets and Volcanoes: A Symposium honouring Mark Meier: CCREL Special Report 96-27, p. 34-40.

For at least two centuries, volcanic activity in Grímsvötn has been characterized by frequent small eruptions within the composite Grímsvötn caldera and larger, less frequent, fissure eruptions outside the caldera. The caldera eruptions take place within a subglacial lake and rapidly melt the ice above the vents, forming openings in the ice shelf covering the lake. Mounds of hyaloclastites are piled up at the vents, attaining elevations similar to the lake level. Volume of ice melted during these eruptions is less than 0.1 km³. In contrast, the fissure eruption in 1938, which occurred to the north of the Grímsvötn caldera, melted 2 km³ of ice over several days as a subglacial hyaloclastite ridge with a volume of 0.3-0.5 km³ was formed. Simultaneously, meltwater was drained away in a jökulhlaup. In eruptions that break through the ice cover, it appears that the water level at the eruption sites controls the elevation of ridges and mounds formed. For eruptions that penetrate the ice cover outside the caldera, this water level seems to lie several hundred meters below the ice surface prior to eruption. Locally enhanced melting of ice at eruption sites suggest that thermal effects of individual eruptions last 5-20 years.

Guðmundsson, M.T., and Björnsson, H. (1990) Breytingar á Grímsvötnum 1919-1989: Reykjavík, Raunvísindastofnun Háskólans, p. 35.

— (1991) "Eruptions in Grímsvötn, Iceland, 1934-1991": Jökull, v. **41**: p. 21-45.

During the period 1934 to 1991 evidence has only been found for three or four volcanic eruptions within the Grímsvötn volcanic centre, i.e. the directly observed eruptions in 1934, 1938, 1983, and probably a small eruption in 1984, deduced from seismic tremors. Tephra layers observed by visitors in the northwestern part of the Grímsvötn depression in the period 1934 to the 1960's have been misinterpreted as signs of eruptions; the very same ash cover was observed throughout the period. This ash cover dates back to the eruption of 1934, but earlier Grímsvötn eruptions may have contributed to its formation. Reported openings in the ice shelf (1945, 1954, 1960) are considered not to be signs of eruptions but could be explained by either steam explosions of hydrothermal reservoirs sealed by impermeable caprock or by increased upwelling of hydrothermal fluid in reservoirs of high permeability due to pressure release during lowering of the Grímsvötn lake level in jökulhlaups. Frequent jökulhlaups in the period 1938-1948 can be adequately explained by high melting rate at the site of the eruption of 1938. The eruptions of 1934 and 1983 produced hyaloclastites of volume 30-40 m³ and 10 m³, respectively. The eruption of 1938, on the other hand, produced volcanic material of the order of 400 m³ and may have been the third largest eruption in Iceland this century, after Hekla in 1947 and Surtsey in 1963-1967.

Guðmundsson, M.T., and Högnadottir, Þ. (2007) "Volcanic systems and calderas in the Vatnajökull region, central Iceland: Constraints on crustal structure from gravity

data": Journal of Geodynamics, v. **43**(1): p. 153-169.

A Bouguer anomaly map is presented of southern central Iceland, including the western part of Vatnajökull and adjacent areas. A complete Bouguer reduction for both ice surface and bedrock topography is carried out for the glaciated regions. Parts of the volcanic systems of Vonarskarð-Hágöngur, Barðarbunga-Veiðivötn, Grimsvötn-Laki, and to a lesser extent Kverkfjöll, show up as distinct features on the gravity map. The large central volcanoes with calderas: Vonarskarð, Barðarbunga, Kverkfjöll and Grimsvötn, are associated with 15-20 mGal gravity highs caused by high density bodies in the uppermost 5 km of the crust. Each of these bodies is thought to be composed of several hundred km3 of gabbros that have probably accumulated over the lifetime of the volcano. The Skaftarkatlar subglacial geothermal areas are not associated with major anomalous bodies in the upper crust. The central volcanoes of Vonarskarð and Hagöngur belong to the same volcanic system; this also applies to Barðarbunga and Hamarinn, and Grimsvötn and Þórðarhyrna. None of the smaller of the two volcanoes sharing a system (Hagöngur, Hamarinn and Þórðarhyrna) is associated with distinct gravity anomalies and clear caldera structures have not been identified. However, ridges in the gravity field extend between each pair of central volcanoes, indicating that they are connected by dense dyke swarms. This suggests that when two central volcanoes share the same system, one becomes the main pathway for magma, forming a long-lived crustal magma chamber, a caldera and large volume basic intrusive bodies in the upper crust. Short residence times of magma in the crust beneath these centres favour essentially basaltic volcanism. In the case of the second, auxillary central volcano, magma supply is limited and occurs only sporadically. This setting may lead to longer residence times of magma in the smaller central volcanoes, favouring evolution of the magma and occasional eruption of rhyolites. The eastern margin of the Eastern Volcanic Zone is marked by a NE-SW lineation in the gravity field, probably caused by accumulation of low density, subglacially erupted volcanics within the volcanic zone. This lineation lies 5-10 km to the east of Grimsvötn.

Guðmundsson, M.T., and Högnadóttir (2001) Gravity surveying 1988-2001: central volcanoes in the eastern volcanic zone and hyaloclastite regions in the western volcanic zone, RH-22-2001: Reykjavík, Raunvísindastofnun Háskólans.

A programme of gravity surveying aimed at studying the internal structure of active central volcanoes in Iceland was started in 1988. About 1200 gravity points were collected in 1988-2001 in the Eastern Volcanic Zone, mainly in the Vatnajökull area and around Mýrdalsjökull. The majority of these data have been collected on glaciers, using snowmobiles as the means of transport. Another survey programme in the Western Volcanic Zone has been aimed at mapping the thickness of subaerially formed lava piles in the region between Þingvellir and Langjökull. About 350 gravity points have been collected in this area since 1999, on profiles crossing lava fields and hyaloclastite mountains. This report provides an overview of the surveys and describes processing of the gravity data. In 1988-1991 gravity point elevation was determined with barometric levelling, tied to optically levelled control points. This method provided elevation accuracy of 2 m in favourable conditions but for gravity points near the margins of the survey areas, the accuracy dropped to 5 m. A breakthrough in surveying occurred in 1994, when submeter DGPS was first used for elevation determination, consistently providing an accuracy of 2 m. The much greater elevation span and distance range provided by the submeter DGPS has made the work since 1994 much easier than previously and increased the number of points

collected and the size of the areas covered. The surveying in 1988-1998 was done with the National Energy Authority LaCoste-Romberg G-445 gravity meter. Since September 1998 a Scintrex Autograv CG-3M, owned jointly by five research institutions in Iceland, has been used in the surveying. The reduction of the data, after elevations have been determined, is achieved using software developed at the Department of Geological Sciences University College London in 1989. The main part of the software is a topographic correction programme that calculates Bouguer anomalies. It uses digital elevation models (DEM) to calculate the effects of mass above sea level within a 100 x100 km square with the station at its centre. Outside this square the topography is assumed flat and at sea level. DEMs have been obtained by digitizing topographic maps and by making use of DEMs of glaciated areas based on ice surface mapping and radio echo soundings of the Science Institute, University of Iceland. The gravity data collected in 1988-2001 is presented as a table in the report.

— (2003) Gjálp 1997-2002: Mælingar á ísskriði og varmaafli, RH-02-2003, Raunvísindastofnun Háskólans, p. 38.

Guðmundsson, M.T., and Högnadóttir, Þ. (2004) Rannsóknir á jarðhita í Grímsvötnum árið 2003, RH-02-2004, Raunvísindastofnun Háskólans, p. 14 pp.

— (2005) Jarðhiti í Grímsvötnum árið 2004, tengsl eldgoss og jarðhita, RH-02-2005, Jarðvísindastofnun Háskólans, p. 14 pp.

Guðmundsson, M.T., Högnadóttir, Þ. and Langley, K. (2003) Jarðhiti, gosstöðvar og skilyrði til vatnssöfnunar í Grímsvötnum 2001-2002, RH-01-2003, Raunvísindastofnun Háskólans, p. 30.

Guðmundsson, M.T., Högnadóttir, Þ., Pálsson, F., and Björnsson, H. (2000) Grímsvötn: Eldgosið 1998 og breytingar á botni, rúmmáli og jarðhita 1996-1999, RH-03-2000: Reykjavík, Raunvísindastofnun Háskólans, p. 32.

Guðmundsson, M.T., and Milsom, J. (1990) The geophysical structure of a subglacial volcano, Grímsvötn, Iceland., *in* Reynolds, J.M., Tarling, D.H., Scott, S.C., Ford, M., and Caswell, S., eds., Abstracts for the Fourteenth UK geophysical assembly.Geophysical Journal International 278.

— (1997) "Gravity and magnetic studies of the subglacial Grímsvötn volcano, Iceland. Implications for crustal and thermal structure." Journal of geophysical research, v. **102**: p. 7691-7704.

Guðmundsson, M.T., Pálsson, F., Björnsson, H., and Högnadóttir, Þ. (2002) The hyaloclastite ridge formed in the subglacial 1996 eruption in Gjálp, Vatnajökull, Iceland: present day shape and future preservation, *in* Smellie, J.L., and Chapman, M.G., eds., Volcano-Ice Interaction on Earth and Mars., Volume **202**: London, The Geological Society of London, p. 319-335.

Guðmundsson, M.T., Pálsson, F., Högnadóttir, Langley, K., and Björnsson, H. (2001) Rannsóknir í Grímsvötnum árið 2000: Reykjavík, Raunvísindastofnun Háskólans, p. 25.

Guðmundsson, M.T., Sigmundsson, F., and Björnsson, H. (1997) "Gosið í Gjálp og myndun móbergsfjalla": Morgunblaðið(23rd of November 1997): p. 26-27.

Guðmundsson, M.T., Sigmundsson, F., Guðrún Larsen, Þórdís Högnadóttir, Helgi Björnsson, and Finnur Pálsson (1999) Grímsvatnagosið 1998, Vorráðstefna 1999, Ágrip erinda og veggspjalda: Reykjavík, Jarðfræðafélag Íslands, p. 47.

Guðmundsson, S., Guðmundsson, M.T., Björnsson, H., Sigmundsson, F., Rott, H., and Carstensen, J.M. (2002) "Three-dimensional glacier surface motion maps at the Gjálp eruption site, Iceland, inferred from combining InSAR and other ice-displacement data": Annals of Glaciology, v. **34**: p. 315-322.

We use topographically corrected interferograms, repeated global positioning system observations of locations of stakes and time series of elevation data to produce time series of high-resolution three-dimensional (3-D) ice surface motion maps for the infilling of the ice depression created by the 1996 subglacial eruption at the Gjalp volcano in Vatnajokull, Iceland. The ice inflow generated uplift in the central parts of the depression. During the first months, the uplift was much reduced by basal melting as the subglacial volcano cooled. For those motions surface-parallel ice flow cannot be assumed. The 3-D motion maps are created by an optimization process that combines the complementary datasets. The optimization is based on a Markov random-field regularization and a simulated annealing algorithm. The 3-D motion maps show the pattern of gradually diminishing ice flow into the depression. They provide a consistent picture of the 3-D motion field, both spatially and with time, which cannot be seen by separate interpretation of the complementary observations. The 3-D motion maps were used to calculate the cooling rate of the subglacial volcano for the first year after the eruption. First an uplift rate resulting solely from the inflow of ice was calculated from inferred horizontal motions. Basal melting was then estimated as the difference between the calculated uplift generated by the inflow of ice, and the observed uplift that was the combined result of ice inflow and basal melting. The basal melting was found to decline from 55 m(3) s(-1) (due to power of 18 GW) in January 1997 to 5 m(3) s(-1) (2 GW) in October 1997.

Halldórsson, S.A. (2004) Þórðarhyrna : dæmi um nýtt eldstöðvakerfi í Eystra-gosbeltinu? [**BSc thesis**]: Reykjavík, Háskóli Íslands.

Halldórsson, S.M. (1996) "Eldgos í Vatnajökli": Eystrahorn,**34. tbl. 14. árg.**(fimmtud. 3. okt. 1996): p. Forsíða.

Frásögn Sigurðar M. Halldórssonar með tilvitnunum í Pál Imsland

— (1996) "Samgöngur ekki sjálfsagður hlutur ": Eystarhorn,**39. tbl. 14. árg.**(fimmtud. 7. nóv. 1996): p. 4.

Frásögn Sigurðar M. Halldórssonar með tilvitnun í Pál Imsland

— (1996) "Verður hlaupið verra en 1938? " Eystrahorn,**36. tbl. 14. árg.**(fimmtud. 17. okt. 1996): p. 3.

Frásögn Sigurðar M. Halldórssonar með fléttuðu viðtali við Pál Imsland

Hannesson, S.Ö. (2005) "Minnisvarði um náttúruhamfarir": Glettingur, v. **15 (39-40. tölubl.)**(2-3): p. 18.

Hróarsson, B. (1992) Geysers and hot springs in Iceland: Reykjavík, Mál og menning, 158 s. : myndir, kort p.

Hróarsson, B., and Jónsson, S.S. (1991) Hverir á Íslandi: Reykjavík Mál og menning, 160 s. : myndir, kort, uppdr. p.

Höskuldsson, A., and Sparks, R.S.J. (1997) "Thermodynamics and fluid dynamics of effusive subglacial eruptions": Bulletin of Volcanology, v. **59**(3): p. 219-230.

We consider the thermodynamic and fluid dynamic processes that occur during subglacial effusive eruptions. Subglacial eruptions typically generate catastrophic floods (jokulhlaups) due to melting of ice by lava and generation of a large water cavity. We consider the heat transfer from basaltic and rhyolitic lava eruptions to the ice for typical ranges of magma discharge and geometry of subglacial lavas in Iceland. Our analysis shows that the heat flux out of cooling lava is large enough to sustain vigorous natural convection in the surrounding meltwater. In subglacial eruptions the temperature difference driving convection is in the range 10-100 degrees C. Average temperature of the meltwater must exceed 4 degrees C and is usually substantially greater. We calculate melting rates of the walls of the ice cavity in the range 1-40 m/day, indicating that large subglacial lakes can form rapidly as observed in the 1918 eruption of Katla and the 1996 eruption of Gjalp fissure in Vatnajokull. The volume changes associated with subglacial eruptions can cause large pressure changes in the developing ice cavity. These pressure changes can be much larger than those associated with variation of bedrock and glacier surface topography. Previous models of water-cavity stability based on hydrostatic and equilibrium conditions may not be applicable to water cavities produced rapidly in volcanic eruptions. Energy released by cooling of basaltic lava at the temperature of 1200 degrees C results in a volume deficiency due to volume difference between ice and water, provided that heat exchange efficiency is greater than approximately 80%. A negative pressure change inhibits escape of water, allowing large cavities to build up, Rhyolitic eruptions and basaltic eruptions, with less than approximately 80% heat exchange efficiency, cause positive pressure changes promoting continual escape of meltwater. The pressure changes in the water cavity can cause surface deformation of the ice. Laboratory experiments were carried out to investigate the development of a water cavity by melting ice from a finite source area at its base, The results confirm that the water cavity develops by convective heat transfer.

Jarosch, A.H., Guðmundsson, M.T., and Högnadóttir, Þ.. (2005) Gjálp 2003-2005: Depression development, ice flux and heat output, RH-20-2005, Jarðvísindastofnun Háskólans, p. 12

Jóhannesson, H. (1983) "Gossaga Grímsvatna 1900-1983 í stuttu máli (A brief review of the volcanic activity of the Grímsvötn volcanic system 1900-1983)": Jökull, v. **33**: p. 146-147.

— (1984) "Grímsvatnagos 1933 og fleira frá því ár (The Grímsvötn eruption in 1933). " Jökull, v. **34**: p. 151-158.

— (1996) Eldgosin í Vatnajökli á árunum 1902-1910 í ljósi síðustu umbrota, Vorrráðstefna 1996: ágrip erinda: Reykjavík.

Jóhannesson, T. (2002) The initiation of the 1996 jökulhlaup from Lake Grímsvötn, Vatnajökull, Iceland, *in* Snorrason, A., ed., The Extremes of the Extremes: Extraordinary Floods (Proceedings of a symposium held at Reykjavik, Iceland): International Association of Hydrological Sciences Publication 271.

The jökulhlaup from Lake Grímsvötn in Vatnajökull Ice Cap in1996 was initiated by a different physical mechanism to that assumed in traditional theories of jökulhlaups. The maximum discharge was reached only 16 h after the start of the flood at the terminus. Water outbursts, through a >300 m thick glacier near the terminus, indicate water pressures several bars in excess of ice overburden at the beginning of the flood. A deep ice canyonwas formed in the ice cap near Lake Grímsvötn extending along about 10% of the subglacial floodpath. Frozen sediments formed in crevasses and frazil ice on the surface of the flood waters indicate the flow of supercooled water in the terminus region. These observations can be interpreted such that the jökulhlaup was initiated by the movement of a localized pressure wave that travelled 50 km in 10 h from Lake Grímsvötn to the terminus, forming a subglacial pathway along the glacier bed. Shortly after this wave reached the terminus, the jökulhlaup was flowing at a high discharge through a tunnel which would have needed much a longer time to form by ice melting as assumed in existing theories of jökulhlaups. The observations also indicate that in current theories the rate of heat transfer from subglacial flood water to the overlying ice is greatly underestimated.

— (2002) "Propagation of a subglacial flood wave during the initiation of a jökulhlaup": Hydrological Sciences Journal-Journal Des Sciences Hydrologiques, v. **47**(3): p. 417-434.

Observations from the jokulhlaup from Grimsvötn in Vatnajökull, southeastern Iceland, in 1996 indicate that the jökulhlaup was initiated by the movement of a localised pressure wave that travelled 50 km in 10 h from Grimsvötn to the terminus, forming a subglacial pathway along the glacier bed. Shortly after this wave reached tire terminus, the jökulhlaup was flowing at a high discharge through a tunnel that would have needed much longer time to form by ice melting as assumed in existing theories of jokulhlaups. Frozen sediments formed in crevasses and frazil ice on the surface of *the flood waters indicate the flow of supercooled water in the terminus region, demonstrating that the rate of heat transfer from subglacial flood water to the overlying ice is greatly underestimated in current theories.*

Jónsdóttir, K., and Hjörleifsdóttir, V. (1998) Heitur reitur: rannsókn á gosstöðvunum í Vatnajökli með skjálftamælingum: skýrsla til Nýsköpunarsjóðs haust 1998, p. 67, myndir, gröf, kort.

Jónsson, L. (1993) "Grímsvötn": Útivist, ársrit Útivistar, v. **19**: p. 25-30.

Kaldal, J. (1996) "A potent cocktail : shaken and stirred : the fire and ice of the Vatnajökull glacier": Iceland review, v. **34**(4): p. 8-14.

Konstantinou, K.I., Kao, H., Lin, C.H., and Liang, W.T. (2003) "Analysis of broad-band regional waveforms of the 1996 September 29 earthquake at Bárdarbunga volcano, central Iceland: investigation of the magma injection hypothesis": Geophysical Journal International, v. **154**(1): p. 134-145.

Large earthquakes near active volcanoes, that exhibit non-double-couple source properties are usually interpreted as result the of either magma intrusion or geometrical complexity along the fault plane. Such an earthquake occurred in 1996 September 29 at Bárdarbunga volcano in central Iceland, to be followed 2 days later by a major volcanic eruption at the area between Bárdarbunga and the nearby Grimsvötn volcano. Both of these active volcanic centres lie underneath the Vatnajökull glacier, a permanent ice cap that covers a large area of central Iceland. This event was recorded by a temporary network (HOTSPOT) that consisted of 30 broad-band three-component seismometers covering most of Iceland. The waveforms of this event at all stations show an emergent, low-amplitude, high-frequency onset that is superposed on a longer-period signal. The corresponding amplitude spectra show a low-frequency content (<1 Hz) and prominent peaks around the corner frequency (similar to0.25 Hz) and higher frequencies. These regional waveforms were inverted in order to obtain the best-fitting deviatoric and full moment tensor using a linear, time-domain inversion method. The results for the deviatoric moment tensor indicate a large (similar to60 per cent) compensated linear vector dipole (CLVD) component, a hypocentral depth of 3.5 km, a moment magnitude of 5.4 and a best double-couple solution showing thrust motion in good agreement with the previously published Harvard CMT solution. The results for the full moment tensor on the other hand, indicate an implosive isotropic component of 8.5 per cent, a reduced CLVD component of 47.2 per cent and a best double-couple solution showing normal faulting. However, a statistical F-test revealed that the full moment tensor does not fit the data significantly better than the deviatoric at a confidence level of not more than 76 per cent. All of these results were found not to change substantially when a different source time function was used or when the data were weighted according to their distance from the source. The data are consistent with an earthquake of this magnitude, caused by the failure of an asperity and the formation of a tensile crack due to increasing fluid pressure. The dimensions of the crack may have been 10 x 3 km(2) and 0.5 m thickness and the volume of the injected fluid was found to be 15 x 10(6) m(3). The calculated viscosity for the fluid (0.04 Pa s) points to the possibility of water being injected rather than magma, that is also supported by the short source duration of the earthquake (similar to5 s). Taking

into account the water saturation of the upper crust in Vatnajökull due to the presence of the glacier, this event may have been caused by increased pressure of water that was heated by magma injected through a dyke below the asperity.

Konstantinou, K.I., Nolet, G., Morgan, W.J., Allen, R.M., and Pritchard, M.J. (2000) "Seismic phenomena associated with the 1996 Vatnajökull eruption, central Iceland": Journal of Volcanology and Geothermal Research, v. **102**(1-2): p. 169-187.

During late September 1996, a major eruption took place at the NW part of the Vatnajokull glacier in central Iceland. The eruption was preceded by intense seismic activity, which began with a Mw=5.6 earthquake two days previously. Two very active volcanic systems, Bardarbunga and Grimsvotn, are situated in that area underneath the permanent ice cap. The volcanoseismic phenomena associated with the eruption were recorded on both temporary (HOTSPOT) and permanent (SIL) seismic networks, covering most parts of the country. The recorded events were categorised, according to their waveform shape and frequency content, into three groups: (1) low-frequency events; (2) mixed-frequency events; and (3) volcanic tremor. The large earthquake at Bardarbunga volcano, which initiated the seismic activity before the eruption, was located inside the caldera and had the characteristics of a non-double couple event. The epicentres of the earthquake swarm that followed it initially delineated the caldera rim and then migrated towards Grimsvotn, possibly indicating lateral movements of magma from a shallow chamber beneath Bardarbunga. The eruption affected an area much larger than that between these two volcanoes, since seismic activity was also observed at distances 20 km away, at the Tindafjallajokull volcanic system. The spectral analysis of tremor, recorded at the nearest station to the eruption site, revealed its existence before the onset of the eruption in five narrow frequency bands (0.5-0.7, 1.6, 2.2, 2.8, 3.2 Hz) representing fundamental frequencies with their half- and quarter-subharmonics. This pattern continued until the last day of the eruption. It is believed that the eruption was caused by a dyke injection that had been going on beneath the Vatnajokull area for a period of 10 years.

Kristmannsdóttir, H., Björnsson, A., Pálsson, S., and Sveinbjörnsdóttir, A.E. (1999) "The impact of the 1996 subglacial volcanic eruption in Vatnajökull on the river Jökulsá á Fjöllum, North Iceland": Journal of Volcanology and Geothermal Research, v. **92**(3-4): p. 359-372.

A subglacial volcanic eruption took place in October 1996 beneath the Vatnajökull glacier, Iceland. The volcanic fissure erupted for some 14 days and it extended between two known subglacial central volcanoes. Most of the melt water drained to the south into the Grimsvötn caldera from where it escaped a month later during a major jökulhlaup (extreme flood) into the glacial rivers flowing to the south from Vatnajökull. At the start of the eruption, the northernmost part of the volcanic fissure extended across the water divide beneath the glacier and into the river basin of Jökulsá á Fjöllum, flowing to the north. A few days later, signs of melt water from the volcanic site were detected in the glacial river Jökulsá á Fjöllum. Distinct changes in the chemical composition of the water were observed. Both discharge and turbidity of the river were somewhat higher than normal for the season, but there was no extreme flood (jökulhlaup). Total dissolved solids (TDS) and conductivity of the river water, as well as bicarbonate, were found to be higher than previously observed. Traces of sulphide and mercury were detected, which are never recorded at normal conditions. The stable isotope ratios,

[delta]D and [delta]18O, the 14C apparent age and the [delta]13C value were also found to be anomalous. In a few weeks the chemistry was back to normal. The chemical changes were most likely caused by a direct flow of melt water from the northernmost part of the main volcanic fissure or from small cauldrons created at the rim of the Bárdarbunga caldera. The flow of melt water to the north from the volcanic centre ebbed soon after or even just before the volcanic eruption in Vatnajökull ended. This experience shows clearly that simultaneous monitoring of chemical changes and flow rate in glacial rivers can deliver valuable data for following subglacial volcanic activity in space and time and may be used to give warning before a major catastrophic flood. Chemical study of glacial rivers can also be used to find out if a jökulhlaup is connected with a simultaneous volcanic eruption or not.

Kristmannsdóttir, H., and Björnsson, H. (1984) "Subglacial geothermal and volcanic activity at Grímsvötn, Vatnajökull, Iceland deduced from glacial water chemistry": EOS, Transactions, American Geophysical Union, v. **65**: p. 1149.

Larsen, G., Guðmundsson, M.T., and Björnsson, H. (1997) Gos í eldstöðvum undir Vatnajökli á sögulegum tíma: Vitnisburður gjóskulaga og ritaðra heimilda, Vorráðstefna 1997: "Eldgos í Vatnajökli 1996", ágrip erinda og veggspjalda: Reykjavík, Jarðfræðafélag Íslands, p. 7-9.

Maria, A., Carey, S., Sigurðsson, H., Kincaid, C., and Helgadóttir, G. (2000) "Source and dispersal of jökulhlaup sediments discharged to the sea following the 1996 Vatnajökull eruption": Geological Society of America Bulletin, v. **112**(10): p. 1507-1521.

The October 1996 Gjálp eruption beneath Vatnajökull glacier led to one of the largest jökulhlaups (glacial floods) in Iceland in the twentieth century. A catastrophic discharge of meltwater and sediment swept across the Skeidararsandur flood plain to the sea. Tephra from the eruption consists of vesicular sideromelane shards with a basaltic andesite composition (53% SiO2, 3% MgO, 0.8% K2O). After the flood, sediment samples were collected from the hood plain and off the southeast coast of Iceland, where a major sediment plume had been created by the discharge. Compositions of glass shards from hood-plain and seafloor deposits do not match those of the Gjálp magma. Flood-plain samples consist primarily of blocky to poorly vesicular sideromelane clasts with compositions that are characteristic of Grimsvötn volcanic products (similar to 50% SiO2, 5.5% MgO, 0.4% K2O). Marine samples collected near the jökulhlaup outflow into the sea also consist primarily of blocky to poorly vesicular sideromelane clasts with compositions that are, for the most part, similar to products of the Grimsvötn volcanic center. Distal marine samples have more vesicular sideromelane clasts with compositions that are similar to products of the Katla volcanic center (e.g., 48% SiO2, 4.5% MgO, 0.8% K2O). Significant deposition to the seafloor was apparently limited to an area just offshore of the Skeiðarársandur. There is no indication that juvenile volcanic material from the Gjálp eruption was carried by the 1996 jökulhlaup onto the flood plain or into the ocean, Instead, the jökulhlaup carried primarily older volcaniclastic material eroded by the flood.

Mouritzen, M.L., and others (1950) "Volcanic Ash from the Grímsvötn-eruption in 1903, Iceland": Meddelelser fra Dansk Geologisk Forening, v. **Bd. 11**(h. 5): p. 583-584.

N.N. (1990) "Vatnajökull: eitt mesta jökulhvel jarðarinnar": Áfangar: tímarit um Ísland, v. **11**(1): p. 12-17.

Ng, F., and Björnsson, H. (2003) "On the Clague-Mathews relation for jökulhlaups": Journal of Glaciology, v. **49**(165): p. 161-172.

In the empirical study of jokulhlaups, the peak discharge, Q(max),and water volume drained by the ice-dammed lake during the floods, V-t, appear to follow a power-law relation Q(max) = KVtb, where K are b are constants determined from field data. First identified by Clague and Mathews (1973), this relation is a useful reference for predicting flood magnitude, but its physical origin remains unclear. Here, we develop the theory that connects it to contemporary models for Simulating the flood hydrograph. We explain how the function Q(max) = f(V-t) arises from Nye's (1976) theory of time-dependent water flow in a subglacial channel coupled to a lake, and we describe how discharge volume data record the (monotonically increasing) form of this function so long as the lake is not emptied in the floods. The Grimsvötn jökulhlaups present an example where, because of partial draining of the lake, agreement between the model-derived f and data is excellent. It is documented that other lake systems drain completely, but we explain how the exponent b approximate to 2/3 observed for them collectively is due primarily to a scaling effect related to their size, modified by other factors such as the flood initiation process.

Noe-Nygaard, A. (1951) "Materials from the Eruption in Grímsvötn, Vatnajökull in 1934": Folia Geographica Danica, v. **1**(no. 4): p. 3-20.

— (1952) A group of Liparite Occurrences in Vatnajökull, Iceland, Folia Geographica Danica, Volume **1**, Hagerups forl., p. 5-59.

— (1988) "Dansk-íslenskar náttúrurannsóknir á Íslandi á milli 1920 og 1940": Náttúrufræðingurinn, v. **58**(3.h.): p. 121-144.

Oeland, G. (1997) "Iceland's trial by fire": National Geographic, v. **191**(no.5): p. 58-71.

Pálmason, G. (1964) "Gravity measurements in the Grímsvötn Area": Jökull, v. **14**: p. 61-66.

Pálsson, S., and others (1999) Grímsvatnahlaupið fyrra 1996; greinargerð, unnið fyrir Vegagerðina, OS-99115: Reykjavík, Orkustofnun, Vatnamælingar, p. 26 s. : línurit, töflur.

Rist, S. (1976) "Grímsvatnahlaupið 1976. The jökulhlaup from Grímsvötn in 1976. (Abstract)": Jökull, v. **26**: p. 80-90.

— (1990) Vatns er þörf: Reykjavík, Menningarsjóður, 248 s. : myndir, kort, línurit, töflur, uppdr. p.

Scharrer, K., Mayer, C., Nagler, T., Rott, H., Münzer, U., and Gudmundsson, Á. (2007 (in press)) "Effects of ash-layers of the 2004 Grímsvötn eruption on SAR backscatter in the accumulation area of Vatnajökull": Annals of Glaciology, v. **45**.

Sigbjarnarson, G. (1990) Vatnið og landið : ávörp , erindi og ágrip : vatnafræðiráðstefna haldin 22.-23. október 1987 í tilefni 40 ára afmælis Vatnamælinga og 20 ára afmælis Orkustofnunar : tileinkuð Sigurjóni Rist vatnamælingamanni sjötugum, Vatnafræðiráðstefna: Reykjavík : Orkustofnun, p. 307 s. : myndir, kort, línurit, töflur

Sigmarsson, O., Karlsson, H., and Larsen, G. (1999) The 1996 and 1998 subglacial eruptions beneath Vatnajökull, EOS, Transactions, American Geophysical Union, Volume **80(Supplement)**: San Francisco, AGU Fall Meeting.

Sigmarsson, O., Karlsson, H.R., and Larsen, G. (2000) "The 1996 and 1998 subglacial eruptions beneath the Vatnajökull ice sheet in Iceland: contrasting geochemical and geophysical inferences on magma migration ": Bulletin of Volcanology v. **61**(7): p. 468-476

The spectacular 1996 jökulhlaup from the subglacial lake at Grímsvötn central volcano, beneath the Vatnajökull ice sheet in Iceland, was generated by a subglacial eruption at Gjálp midway between Bárdarbunga and Grímsvötn central volcanoes. This eruption was preceded by a 24-h earthquake swarm that originated at Bárdarbunga and migrated 20 km southward toward the eruption site. To test the hypothesis that a horizontal dyke fed the 1996 eruption from Bárdarbunga volcano, we measured major and trace element abundances and O, Sr, and Nd isotope compositions in the 1996 volcanic rocks and selected samples from the Bárdarbunga, Grímsvötn, and Öræfajökull volcanic systems. Lava flows and tephra from a given volcanic system beneath the Vatnajökull ice sheet have indistinguishable isotope compositions. Gjálp and Grímsvötn products have identical 87Sr/86Sr (0.70322) and i18O (~2.9‰), whereas significantly lower and higher values, respectively, are found in samples from the Bárdarbunga volcanic system (0.70307 and 3.8‰). These results strongly indicate that the Gjálp magma originated from the Grímsvötn magma system. The 1996 magma is of an intermediate composition, representing a basaltic icelandite formed by 50% fractional crystallization of a tholeiite magma similar in composition to that expelled by the 1998 Grímsvötn eruption. The differentiation that produced the Gjálp magma may have taken place in a subsidiary magma chamber that last erupted in 1938 and would be located directly beneath the 1996 eruption site. This chamber was ruptured when a tectonic fracture propagated southward from Bárdarbunga central volcano, as indicated by the seismicity that preceded the eruption. Our geochemical results are therefore not in agreement with lateral magma migration feeding the 1996 Gjálp eruption. Moreover, the results clearly demonstrate that isotope ratios are excellent tracers for deciphering pathways of magma migration and permit a clear delineation of the volcanic systems beneath Vatnajökull ice sheet.

Sigmundsson, F., and Guðmundsson, M.T. (2004) "Eldgosið í Grímsvötnum 1.-6. nóvember 2004 - The Grímsvötn eruption, November 1-6, 2004": Jökull, v. **54**: p. 139-142.

Sigmundsson, F., Pedersen, R., Pagli, C., Sturkell, E., Einarsson, P., Árnadóttir, ó., Feigl, K., and Pinel, V. (2006) Deformation of Icelandic volcanoes: overview and examples from Hengill, Bárðarbunga and Gjálp, Haustfundur Jarðfræðafélags Íslands 2006: Reykjavík, p. 16.

Sigurðsson, S. (1984) "Grímsvatnaför sumarið 1942 (An expedition to Grímsvötn in 1942). Útvarpserindi frá 1942": Jökull, v. **34**: p. 180-185.

— (2004),,Lífið er enn dásamlegt", *in* Björnsson, H., ed., Jöklaveröld, náttúra og mannlíf: Reykjavík, Skrudda, p. 319-390.

Sigvaldason, G.E. (1965) "The Grímsvötn Thermal Area. Chemical Analysis of Jökulhlaup Water": Jökull, v. **15. árg.**: p. 125-128.

Smith, L.C., Alsdorf, D.E., Magilligan, F.J., Gomez, B., Mertes, L.A.K., Smith, N.D., and Garvin, J.B. (2000) "Estimation of erosion, deposition, and net volumetric change caused by the 1996 Skeiðarársandur jökulhlaup, Iceland, from synthetic aperture radar interferometry": Water Resources Research, v. **36**(6): p. 1583-1594.

Using repeat-pass satellite synthetic aperture radar interferometry, we develop a methodology to measure flood-induced erosion and deposition and apply it to a record 1996 glacier outburst flood (jökulhlaup) on Skeiðarársandur, Iceland. The procedures include (1) coregistration of backscatter intensity images to observe morphological differences; (2) mapping of interferometric phase correlation to identify preserved and modified surfaces; and (3) construction, correction, and differencing of pre-jökulhlaup and post-jökulhlaup topography. Procedures 1 and 2 are robust and should be widely applicable to other fluvial environments, while procedure 3 is complicated by uncertainties in phase measurement, baseline estimate, and atmospheric effects. After a correction procedure involving interpolation of digital elevation model elevation differences across low-correlation areas, we find similar to 4 m of elevation change are required to calculate volumes of erosion or deposition. This condition was satisfied for the 40 km(2) proglacial zone of Skeiðarársandur, where we estimate +38 x 10(6) m(3) of net sediment deposition along the ice margin, -25 x 10(6) m(3) of net erosion in channels downstream, and a total net balance of +13 x 10(6). These estimates are supported by field observations and survey data collected in 1997.

Spring, U., and Hutter, K. (1981) "Numerical studies of Jökulhlaups": Cold Regions Science and Technology, v. **4**(3): p. 227-244.

The aim of this paper is to investigate Jökulhlaups: outbursts of ice-dammed lakes. The governing equations of unsteady water flow through straight, circular conduits, as derived by the authors in a previous paper, are compared with the equations of Nye, and for the steady state situation with Rothlisberger's theory. The dynamic theory is treated numerically by a finite-difference technique. Run-off simulations are illustrated for a model of the Grimsvötn Jökulhlaup, a periodic outburst of a subglacial lake beneath the Vatnajökull in Iceland. We study how various parameters, such as the friction coefficient of the conduit, and constants in the flow law of ice, influence the

evolution of the outburst. In particular, we compute discharge hydrographs both incorporating and neglecting the rate of change of internal energy. It is shown that this term is not negligible and that the lake temperature, as a boundary condition, strongly influences the time-discharge relation and might explain the abrupt end of the outburst well before the lake has been emptied.

Stefánsdóttir, M.B., and Gíslason, S.R. (2005) "The erosion and suspended matter/seawater interaction during and after the 1996 outburst flood from the Vatnajökull Glacier, Iceland": Earth and Planetary Science Letters, v. **237**(3-4): p. 433-452.

The Gjálp subglacial eruption 1996 within the Vatnajökull Glacier, Iceland triggered a catastrophic outburst flood, bringing at least 180 million tonnes of suspended solids to the sea in only 42 h. This amounts to 1% of the total annual global river suspended flux to the oceans. The specific BET-surface area of the suspended solids was measured to be 11.8-18.9 m2/g, translating to the average total BET-surface area of 2.8 x 10 9 km2, providing enormous potential for adsorption/desorption and precipitation/dissolution fluxes at the suspended solids-ocean water interface. Altered basalt glass was the major constituent of the suspended matter (80%), secondary minerals such as zeolites and calcite amounted to 11%, but only 5% was fresh volcanic glass. The suspended grains were generally rounded. The glass carried by the flood is different in chemical composition from the glass produced by the Gjálp eruption. The Gjalp material has higher FeOtotal / TiO2 and TiO2 / P2O5 ratios than the suspended glass in the flood waters. The majority of the flood samples match the composition of the volcanic system, down stream from the eruption site. The large amount of altered material in the flood and its chemical composition suggests erosion conforming to a 2 m deep, 1000 m wide and 50 000 m long channel in less than 42 h. The behaviour of 28 elements on the surface of the suspended solids exposed to seawater was quantified by experiments in the laboratory. The altered basaltic glass dissolved in seawater, as recorded by the Si release from the glass. The dissolved concentrations of Na, Ca, Si, Ba, Cd, Co, Cu, Hg, Mn, Ni, and total dissolved inorganic N increased considerably when the suspended solids come into contact with the seawater, but the concentrations of Mg, K, S, Sr, Fe, Pb and Zn decreased. The experimental seawater solutions were supersaturated with respect to calcite, Mg-montmorillonite and amorphous iron-hydroxide. The rate of release (mol/m2/s) of Si, Mn, Ba, Co, Ni and Cd decreased continuously during the one week exposure to sweater. After one week, the logarithm of the dissolution rate of the altered basaltic glass was - 11.9 to - 11.6 (Si mole/m2/sec). Significantly lower than the steady-state rates for fresh basaltic glass at similar conditions. Calculated one day desorbed/dissolution suspended material fluxes are greater than the integrated dissolved flood fluxes for Mn, Ba, Ni, Co and Cd, but the Si dissolved food flux was greater than the one day desorbed/dissolved suspended material flux.

Stefánsdóttir, M.B., Gíslason, S.R., and Arnórsson, S. (1999) Flood from Grímsvötn subglacial caldera 1996 : composition of suspended matter, *in* Ármannsson, H., ed., 5th International Symposium on Geochemistry of the earth's surface: Reykjavík, Iceland, A.A. Balkema, Rotterdam, p. 539-542.

Steinþórsson, S., Hardarson, B.S., Ellam, R.M., and Larsen, G. (1998) Petrochemistry of the 1996 subglacial Vatnajökull eruption, RH-24-98: Reykjavík, Science Institute, p. 18

Steinþórsson, S. (1997) Vatnajökulsgosið 1996 - Bergefnafræði., Vorráðstefna 1997: Ágrip erinda og veggspjalda: Reykjavík, Jarðfræðifélag Íslands, p. 43.

Steinþórsson, S., Harðarson, B.S., Ellam, R.M., and Larsen, G. (2000) "Petrochemistry of the Gjálp-1996 subglacial eruption, Vatnajökull, SE Iceland": Journal of Volcanology and Geothermal Research, v. **98**(1-4): p. 79-90.

In October 1996 a subglacial fissure to the north of the Grimsvotn caldera in W-Vatnajokull produced about 0.4 km3 of Fe-rich basaltic andesite-icelandite--in an area characterized mostly by tholeiitic basalt. In this paper the chemical composition of volcanic systems in the region is discussed with the help of six new analyses and others from the literature, and a tentative model for their evolution is proposed, in which magma produced by the partial melting of a two-component mantle mixes with hydrous, silicic melt in the crust. The Vatnajokull 1996 magma belongs to a separate volcanic system, intermediate between Bardarbunga and Grimsvotn.

Steinþórsson, S., Harðarson, B.S., and Larsen, G. (1997) Jarðefnafræði eldstöðvakerfa undir vestanverðum Vatnajökli, Vorráðstefna 1997: "Eldgos í Vatnajökli 1996", ágrip erinda og veggspjalda: Reykjavík, Jarðfræðafélag Íslands, p. 27-28.

— (1997) Vatnajökulsgosið 1996 - Bergefnafræði, Vorráðstefna 1997, ágrip erinda og veggspjalda: Reykjavík, Jarðfræðafélag Íslands, p. 43.

Steinþórsson, S., and Óskarsson, N. (1983) "Chemical monitoring of jökulhlaup water in Skeiðará and the geothermal system in Grímsvötn, Iceland. (Uppleyst efni í hlaupvatni Skeiðarár og jarðhitasvæðið í Grímsvötnum)": Jökull v. **33**: p. 73-86.
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Sturkell, E. (1999) "Vulkanutbrott i Grímsvötn 18-28 december 1998": Geologiskt forum, v. **21**: p. 10-11.

Sturkell, E., Einarsson, L., Sigmundsson, F., Hreinsdóttir, S., and Geirsson, H. (2003) "Deformation of Grimsvötn volcano, Iceland: 1998 eruption and subsequent inflation": Geophysical Research Letters, v. **30**(4): p. 1182.

[1] Grimsvotn is a subglacial volcano, under the Vatnajökull ice cap at the center of the Icelandic hotspot. This highly active volcano erupted in December 1998. GPS measurements at a single station on a nunatak at the caldera rim were made 7 times during 1992-2001. The measurements prior to the 1998 eruption reveal pre-eruption inflation, but subsidence of more than 15 cm was measured during the eruption. Following the eruption, re-inflation occurred initially, at a rate of 20 mm/month, then declined to 5 mm/month. Measurements were fitted to a Mogi model, assuming that the source was located under the center of the Grimsvotn caldera complex. Results indicate a source depth of at least 1.6-km. The calculated amount of magma outflow during the eruption is comparable to field estimates of the erupted volume. Grimsvötn continues to inflate, but has not reached its 1998 pre-eruption level.

Sturkell, E., Einarsson, P., Sigmundsson, F., Geirsson, H., Olafsson, H., Pedersen, R., de Zeeuw-van Dalfsen, E., Linde, A.T., Sacks, S.I., and Stefansson, R. (2006) "Volcano, geodesy and magma dynamics in Iceland": Journal of Volcanology and Geothermal Research, v. **150**(1-3): p. 14-34.

Here we review the achievements of volcano geodesy in Iceland during the last 15 years. Extensive measurements of crustal deformation have been conducted using a variety of geodetic techniques, including leveling, electronic distance measurements, campaign and continuous Global Positioning System (GPS) geodesy, and interferometric analysis of synthetic aperture radar images (InSAR). Results from these measurements provide a comprehensive view of the behavior of Icelandic volcanoes. Between inflation, intrusion, and eruption episodes, volcanoes are likely to deflate or show no sign of seismic activity. Subsidence rates are often in the range of a few millimeters to a few centimeters a year, reducing progressively with time since the last eruption or intrusion at the volcano. Subsidence can be caused by cooling and contraction of magma, outflow of magma, it can be related to plate spreading. Volcano subsidence or lack of deformation is often interrupted by episodic magma flow towards near-surface locations. Such magma recharge has been observed geodetically at Hengill, Hekla, Eyjafiallajokull, Katla, Grimsvotn, and Krafla volcanoes, with inflow inferred to last from a few months up to two decades. In the last 15 years, five volcanic eruptions, three intrusive events and two > M6 earthquakes have occurred. In recent years, the Grimsvotn and Katla volcanoes have exhibited continuous inflation of a few centimeters per year, which at Grimsvotn culminated in an eruption on I November 2004. Hekla and Torfajokull volcanoes have inflated at rates an order-of-magnitude less. Subsidence is occurring presently at the Askja and Krafla volcanoes. Within the period of geodetic measurement, signals consistent with no deformation are typical for most of the 35 active volcanoes in Iceland. (c) 2005 Elsevier B.V. All rights reserved.

Sturkell, E., Einarsson, P., Sigmundsson, F., Geirsson, H., Soosalu, H., Knox, C., Ólafsson, H., Pedersen, R., and Theodórsson, T. (2006) Present-day deformation at the Grímsvötn, Askja and Krafla volcanoes, Haustfundur Jarðfræðafélags Íslands 2006: Reykjavík, p. 17.

Thoroddsen, Þ. (1908-1922) Eldgos í Vatnajökli, Lýsing Íslands: Kaupmannahöfn, Hið íslenska bókmenntafélag, p. 159-165.

Tómasson, H. (1974) "Grímsvatnahlaup 1972, mechanism and sediment discharge. Grímsvatnahlaupið 1972, orsakir, hegðun og aurburður (Ágrip)": Jökull, v. **24** p. 27-39.

Tómasson, H., and others (1974) Efnisflutningar í Skeiðarárhlaupi 1972, OS-ROD-7407: Reykjavík, Orkustofnun. Raforkudeild, p. Óreglul. bls.tal : myndir, línurit, töflur.

Tweed, F.S., and Russell, A.J. (1999) "Controls on the formation and sudden drainage of glacier-impounded lakes: implications for jökulhlaup characteristics ": Progress in Physical Geography, v. **23**(No. 1): p. 79-110.

Over the past few years there has been an increase in understanding of glacier-impounded or 'ice-dammed' lake behaviour. The spectacular jökulhlaup (catastrophic flood) from

Grímsvötn, Iceland in November 1996 has both raised the profile of such events and emphasized the need for awareness of the processes involved. This review summarizes the extent of current knowledge of ice-dammed lakes, highlighting key developments and outlining areas of study still subject to difficulties. Controls on ice-dammed lake formation and persistence are identified, and cycles of jökulhlaup activity are related to glacier fluctuations. Ice-dammed lake drainage trigger mechanisms are reviewed and recent progress in the understanding of such mechanisms is emphasized. Controls on jökulhlaup routing and the development and character of jökulhlaup conduits are discussed and recent advances in jökulhlaup prediction, hydrograph modelling and peak discharge estimation are assessed. A process-based schematic model, drawing on published research, links ice-dammed lake occurrence and drainage to jökulhlaup characteristics. It is demonstrated that ice-dammed lake and ice-dam characteristics ultimately control seven key jökulhlaup attributes which determine the potential impact of jökulhlaups on both landscape and human activity in glaciated regions.

Zobin, V.M. (1999) "The fault nature of the M-s 5.4 volcanic earthquake preceding the 1996 subglacial eruption of Grímsvötn volcano, Iceland": Journal of Volcanological and Geothermal Research, v. **92**(3-4): p. 349-358.

The seismic activity preceding and accompanying the September 30, 1996 subglacial eruption of the Grimsvötn volcano, Iceland, developed in three stages. (1) The first stage (first 19 h) included the main shock of magnitude Ms 5.4 and its aftershocks along the northern slope of the Bardarbunga volcano, situated about 20 km NW from Grimsvötn. (2) Seismic foci during the next 17 h marked a line connecting two volcanoes, Bardarbunga and Grimsvötn. This stage culminated in the opening of a fissure and the beginning of eruption. (3) The third stage was observed during the eruption (midnight of September 30–October 7), and included continuous seismic activity along the northern slope of the Bardarbunga volcano as well as more western distributed epicenters, which together had clustered the ring-fault epicentral zone. A finite-fault, broadband teleseismic P waveform inversion was applied to the main shock of September 29. The inversion showed that the rupture had developed downdip from the hypocenter in about 3 s, and the main asperity was ruptured at depths between 4 and 6 km. A comparison with the deep distribution of aftershocks showed that their hypocenters were situated above the destroyed asperities at the depths between 0 and 4 km. These space-time seismic patterns and the results of the finite-fault inversion may be interpreted in the following way. There was a magma chamber under Bardarbunga volcano covered by the strong rocks, or asperities. The main shock of September 29 broke the asperity and formed a path for magma transport. Then a fissure was formed connecting the opened magma chamber with the feeding structures of Grimsvötn volcano, and magma was injected laterally to the site of eruption. The continuous seismic activity during the third period was related to the collapse of rocks around the released parts of the magma chamber. The role of the Ms 5.4 earthquake in this sequence was decisive.

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Þorsteinsson, T., Jóhannesson, T., Larsen, G., and Sigurðsson, O. (2003) Ice core drilling on the ice shelf covering the Grímsvötn subglacial lake, Research Report, National Geographic Society, p. 13.

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Þórðarson, Þ., and Larsen, G. (2007) "Volcanism in Iceland in historical time: Volcano types, eruption styles and eruptive history": Journal of Geodynamics, v. **43**(1): p. 118-152.

The large-scale volcanic lineaments in Iceland are an axial zone, which is delineated by the Reykjanes, West and North Volcanic Zones (RVZ, WVZ, NVZ) and the East Volcanic Zone (EVZ), which is growing in length by propagation to the southwest through pre-existing crust. These zones are connected across central Iceland by the Mid-Iceland Belt (MIB). Other volcanically active areas are the two intraplate belts of Oraefajokull (OVB) and Snaefellsnes (SVB). The principal structure of the volcanic zones are the 30 volcanic systems, where 12 are comprised of a fissure swarm and a central volcano, 7 of a central volcano, 9 of a fissure swarm and a central domain, and 2 are typified by a central domain alone.Volcanism in Iceland is unusually diverse for an oceanic island because of special geological and climatological circumstances. It features nearly all volcano types and eruption styles known on Earth. The first order grouping of volcanoes is in accordance with recurrence of eruptions on the same vent system and is divided into central volcanoes (polygenetic) and basalt volcanoes (monogenetic). The basalt volcanoes are categorized further in accordance with vent geometry (circular or linear), type of vent accumulation, characteristic style of eruption and volcanic environment (i.e. subaerial, subglacial, submarine).Eruptions are broadly grouped into effusive eruptions where >95% of the erupted magma is lava, explosive eruptions if >95% of the erupted magma is tephra (volume calculated as dense rock equivalent, DRE), and mixed eruptions if the ratio of lava to tephra occupy the range in between these two end-members. Although basaltic volcanism dominates, the activity in historical time (i.e. last 11 centuries) features expulsion of basalt, andesite, dacite and rhyolite magmas that have produced effusive eruptions of Hawaiian and flood lava magnitudes, mixed eruptions featuring phases of Strombolian to Plinian intensities, and explosive phreatomagmatic and magmatic eruptions spanning almost the entire intensity scale; from Surtseyan to Phreatoplinian in case of "wet" eruptions and Strombolian to Plinian in terms of "dry" eruptions. In historical time the magma volume extruded by individual eruptions ranges from ~1 m3 to ~20 km3 DRE, reflecting variable magma compositions, effusion rates and eruption durations.All together 205 eruptive events have been identified in historical time by detailed mapping and dating of events along with extensive research on documentation of eruptions in historical chronicles. Of these 205 events, 192 represent individual eruptions and 13 are classified as "Fires", which include two or more eruptions defining an episode of volcanic activity that lasts for months to years. Of the 159 eruptions verified by identification of their products 124 are explosive, effusive eruptions are 14 and mixed eruptions are 21. Eruptions listed as reported-only are 33. Eight of the Fires are predominantly effusive and the remaining five include explosive activity that produced extensive tephra layers. The record indicates an average of 20-25 eruptions per century in Iceland, but eruption frequency has varied on time scale of decades. An apparent stepwise increase in eruption frequency is observed over the last 1100 years that reflects improved documentation of eruptive events with time. About 80% of the verified eruptions took place on the EVZ where the four most active volcanic systems (Grimsvotn, Bardarbunga-Veidivotn, Hekla and Katla) are located and 9%, 5%, 1%

and 0.5% on the RVZ-WVZ, NVZ, OVB, and SVB, respectively. Source volcano for ~4.5% of the eruptions is not known.Magma productivity over 1100 years equals about 87 km3 DRE with basaltic magma accounting for about 79% and intermediate and acid magma accounting for 16% and 5%, respectively. Productivity is by far highest on the EVZ where 71 km3 (~82%) were erupted, with three flood lava eruptions accounting for more than one half of that volume. RVZ-WVZ accounts for 13% of the magma and the NWZ and the intraplate belts for 2.5% each. Collectively the axi l zone (RVZ, WVZ, NVZ) has only erupted 15-16% of total magma volume in the last 1130 years.

Þórðarson, Þ., Larsen, G., Steinþórsson, S., and Self, S. (2003) "The 1783-1785 A.D. Laki-Grímsvötn eruptions II: Appraisal based on contemporary accounts": Jökull, v. **53**: p. 11-48.

Þórðarson, Þ., and Self, S. (1993) "The Laki (Skaftár Fires) and Grímsvötn eruptions in 1783-1785": Bulletin of Volcanology, v. **55**(4): p. 233-263.

Þórdarson, Þ., Self, S., Miller, D.J., Larsen, G., and Vilmundardóttir, E.G. (2003) "Sulphur release from flood lava eruptions in the Veidivötn, Grímsvötn and Katla volcanic systems, Iceland. In: "Volcanic Degassing"": Special Publications, v. **213**: p. 103-121.

4.2.2 Bárðarbunga

Björnsson, H. (1992) "Jökulhlaups in Iceland: prediction, characteristics and simulation": Annals of Glaciology, v. **16**: p. 95-106.

Jökulhlaups drain regularly from six subglacial geothermal areas in Iceland. From Grímsvötn in Vatnajökull, jökulhlaups have occurred at a 4-6 year interval since the 1940s with a peak discharge of 1,000 - 10,000 m3/s, 2 -3 weeks duration and total volumes of 0.5-3 km3. Prior to that, about one jökulhlaup occurred per decade with an estimated discharge of 5 km3 of water and a peak discharge of approximately 30,000 m3/s. Clarke½s (1982) modification of Nye's (1976) general model of discharge of jökulhlaups gives in many respects satisfactory simulations for jökulhlaups from Grímsvötn. The best fit is obtained for the Manning roughness coefficients n = 0.08-0.09 m-1/3 s and a constant lake temperature of 0.2 °C (which is the present lake temperature). The rapid ascent of the exceptional jökulhlaup in 1938, which accompanied a volcanic eruption, can only be simulated for a lake temperature of the order of 4 °C. Jökulhlaups originating at geothermal areas beneath ice cauldrons located 10-15 km northwest of Grímsvötn have a peak discharge of 200 - 1,500 m3/s in 1-3 days, the total volume is 50-350x106m3, and they recede slowly in 1-2 weeks. The form is in that respect a mirror image of the typical Grímsvötn hydrograph. The reservoir water temperature must be well above the melting point (10-20 °C) and the flowing water seems not to be confined to a tunnel but spread out beneath the glacier and later gradually collected back to conduits. Since the time of the settlement of Iceland (870 A.D.), at least 80 subglacial volcanic eruptions have been reported, many of them causing tremendous jökulhlaups with dramatic impact on inhabitated areas and landforms. The peak discharge of the largest floods (from Katla) has been estimated at the order of 100-300,000 m3/s, duration was 3 -5 days and the total volume of the order of 1 km3. It is now apparent that the potentially largest and most catastrophic jökulhlaups may be caused by eruptions in the voluminous ice-filled

calderas in northern Vatnajökull (of Bárdarbunga and Kverkfjöll). They may be the source of prehistoric jökulhlaups, with estimated peak discharge of 400,000 m3/s. At present, jökulhlaups originate from some fifteen marginal ice-dammed lakes in Iceland. Typical values for peak discharges are 1,000 - 3,000 m3/s, duration 2-5 days and total volumes of 2,000 x 106 m3. Hydrographs for jökulhlaups from marginal lakes have a shape similar to those of the typical Grímsvötn jökulhlaup. Simulations give reasonable ascent of the hydrographs for constant lake temperature of about 1 °C but fail to show the recession. Some floods from marginal lakes, however, have reached their peaks exceptionally rapidly, in one day. That ascent could be simulated by drainage of lake water of 4-8 °C. An empirical power law relationship is obtained between peak discharge and total volume of the jökulhlaups from Grímsvötn; Qmax = K Vtb, where Qmax is measured in m3/s, Vt in 106 m3, K = 4.15 10-3 s-1 m-2.52 and b = 1.84. In general, the jökulhlaups (excepting those caused by eruptions) occur when the lake has risen to a critical level, but before a lake level required for simple flotation of the ice dam is reached. The difference between the hydrostatic water pressure maintained by the lake and the ice overburden pressure of the ice dam is of the order 2-6 bar.

Björnsson, H., and Einarsson, P. (1990) "Volcanoes beneath Vatnajökull, Iceland: Evidence from radio echo-sounding earthquakes and jökulhlaups": Jökull, v. **40**: p. 147-168.

Integration of knowledge of subglacial topography, earthquake activity and jökulhlaups has contributed to more precise locations of the volcanic systems beneath Vatnajökull. Bárðarbunga is the centre of a volcanic system which includes the fissure swarms of Veiðivötn to the SW and Dyngjuháls to the NE. The Grímsvötn volcano is the centre of a system that comprises the Laki fissure swarm in the SW and extends for an unknown distance to the NE of the volcano. Þórðarhyrna is probably a separate central volcano within this system. The Kverkfjöll system can be traced 10 km to the SW of the Kverkfjöll volcano. It appears to be separated from the Grímsvötn volcano. The Askja fissure swarm extends beneath Dyngjujökull and can possibly be traced to the Grímsvötn volcano. Hamarinn and the ridge striking eastward from Hamarinn (Loki Ridge) are central volcanoes which together with the Fögrufjöll fissure swarm form a volcanic system. No support can be found in the topographic data for the existence of a central volcano near Breiðabunga. Volcanic activity in historical times has mainly been limited to the Grímsvötn and Bárðarbunga systems. Major rifting events have affected large sections of these volcanic systems but both have been remarkably quiet for the past decades. A few volcanic events are presumed to have occurred on the Hamarinn - Loki system and on the Askja fissure swarm beneath Dyngjujökull, but no event is known with certainty on the Kverkfjöll system. The rivers Skeiðará and Súla have the most frequent eruption-related jökulhlaups. They receive meltwater from the Grímsvötn caldera and the area to the SW of it, including Þórðarhyrna. Núpsvötn, Djúpá and Hverfisfljót drain the southwestern part of the Grímsvötn system, an area bounded by Þórðarhyrna, Geirvörtur, Hágöngur and Pálsfjall. Skaftá drains the Loki Ridge and the area west of Grímsvötn. Jökulhlaups in Kaldakvísl, and ultimately Þjórsá, must originate in the Bárðarbunga or the Hamarinn - Loki systems, and the only possible source for volcanic jökulhlaups in Skjálfandafljót is the northern part of the Bárðarbunga system. Jökulsá á Fjöllum may drain meltwater from activity in all the volcanic systems in northern Vatnajökull: Bárðarbunga, the Askja fissure swarm and Kverkfjöll. This includes the voluminous, ice-filled calderas of Bárðarbunga and Kverkfjöll. Activity in the northern part of the Grímsvötn system may cause floods in Jökulsá á Fjöllum. Meltwater from volcanic activity on the SE flank of a ridge that

strikes south from Kverkfjöll may drain to Jökulsá á Brú. Volcanic activity farther north on the E flanks of this ridge would cause floods in Kreppa.

Brandt, O., Björnsson, H., and Gjessing, Y. (2005) "Mass balance rates derived by mapping internal tephra layers in Myrdalsjökull and Vatnajökull ice caps, Iceland": Annals of Glaciology, v. **Vol. 42**(1): p. 284-290.

Internal tephra layers of known age have been detected by radio-echo soundings within the Mýrdalsjökull and Vatnajökull ice caps in Iceland. Assuming steady state, the estimated strain rates since these isochrones were deposited on the glacier surface have been used to calculate past average specific net balance rates in the accumulation zones along three flowlines on Mýrdalsjökull and one on Vatnajökull. For the period 1918-91 the specific mass-balance rate has been estimated to 4.5 and 3.5 m a−1 at 1350 m a.s.l. on the southern and northern slopes of Mýrdalsjökull, respectively. At 1800 m elevation on the Bárdarbunga ice dome in Vatnajökull, the specific net balance averaged over the last three centuries is estimated to be about 2.1 m a−1. Given this specific net balance, a revised age-depth timescale is presented for a 400 m deep ice core recovered in 1972 from Bárdarbunga. The ice at the bottom is estimated to be from AD 1750.

Freysteinsson, S. (1972) "Jökulhlaup í Köldukvísl": Jökull, v. **22**: p. 83-88.

Guðmundsson, A.T. (1986) Íslandseldar : eldvirkni á Íslandi í 10.000 ár Reykjavík, Vaka-Helgafell, 168 s. : myndir, teikn., kort, línurit, töflur

— (2001) Íslenskar eldstöðvar: Reykjavík, Vaka-Helgafell, 320 s. : myndir, kort, línurit, töflur

Guðmundsson, A.T. (1996) Volcanoes in Iceland : 10.000 years of volcanic history: Reykjavík, Vaka-Helgafell, 136 s. : myndir, teikn., kort, töflur

Guðmundsson, M.T., and Högnadottir, Þ. (2007) "Volcanic systems and calderas in the Vatnajökull region, central Iceland: Constraints on crustal structure from gravity data": Journal of Geodynamics, v. **43**(1): p. 153-169.

A Bouguer anomaly map is presented of southern central Iceland, including the western part of Vatnajökull and adjacent areas. A complete Bouguer reduction for both ice surface and bedrock topography is carried out for the glaciated regions. Parts of the volcanic systems of Vonarskarð-Hágöngur, Barðarbunga-Veiðivötn, Grimsvötn-Laki, and to a lesser extent Kverkfjöll, show up as distinct features on the gravity map. The large central volcanoes with calderas: Vonarskarð, Barðarbunga, Kverkfjöll and Grimsvötn, are associated with 15-20 mGal gravity highs caused by high density bodies in the uppermost 5 km of the crust. Each of these bodies is thought to be composed of several hundred km3 of gabbros that have probably accumulated over the lifetime of the volcano. The Skaftarkatlar subglacial geothermal areas are not associated with major anomalous bodies in the upper crust. The central volcanoes of Vonarskarð and Hagöngur belong to the same volcanic system; this also applies to Barðarbunga and Hamarinn, and Grimsvötn and Þórðarhyrna. None of the smaller of the two volcanoes sharing a system (Hagöngur, Hamarinn and Þórðarhyrna) is associated with distinct *gravity anomalies and clear caldera structures have not been identified. However, ridges in the gravity field extend between each pair of central volcanoes, indicating that they are connected by dense dyke swarms. This suggests that when two central volcanoes share the same system, one becomes the main pathway for magma, forming a long-lived crustal magma chamber, a caldera and large volume basic intrusive bodies in the upper crust. Short residence times of magma in the crust beneath these centres favour essentially basaltic volcanism. In the case of the second, auxillary central volcano, magma supply is limited and occurs only sporadically. This setting may lead to longer residence times of magma in the smaller central volcanoes, favouring evolution of the magma and occasional eruption of rhyolites. The eastern margin of the Eastern Volcanic Zone is marked by a NE-SW lineation in the gravity field, probably caused by accumulation of low density, subglacially erupted volcanics within the volcanic zone. This lineation lies 5-10 km to the east of Grimsvötn.*

Guðmundsson, M.T., and Högnadóttir (2001) Gravity surveying 1988-2001: central volcanoes in the eastern volcanic zone and hyaloclastite regions in the western volcanic zone, RH-22-2001: Reykjavík, Raunvísindastofnun Háskólans.

A programme of gravity surveying aimed at studying the internal structure of active central volcanoes in Iceland was started in 1988. About 1200 gravity points were collected in 1988-2001 in the Eastern Volcanic Zone, mainly in the Vatnajökull area and around Mýrdalsjökull. The majority of these data have been collected on glaciers, using snowmobiles as the means of transport. Another survey programme in the Western Volcanic Zone has been aimed at mapping the thickness of subaerially formed lava piles in the region between Þingvellir and Langjökull. About 350 gravity points have been collected in this area since 1999, on profiles crossing lava fields and hyaloclastite mountains. This report provides an overview of the surveys and describes processing of the gravity data. In 1988-1991 gravity point elevation was determined with barometric levelling, tied to optically levelled control points. This method provided elevation
accuracy of 2 m in favourable conditions but for gravity points near the margins of the survey areas, the accuracy dropped to 5 m. A breakthrough in surveying occurred in 1994, when submeter DGPS was first used for elevation determination, consistently providing a accuracy of 2 m. The much greater elevation span and distance range provided by the submeter DGPS has made the work since 1994 much easier than previously and increased the number of points collected and the size of the areas covered. The surveying in 1988-1998 was done with the National Energy Authority LaCoste-Romberg G-445 gravity meter. Since September 1998 a Scintrex Autograv CG-3M, owned jointly by five research institutions in Iceland, has been used in the surveying. The reduction of the data, after elevations have been determined, I achieved using software developed at the Department of Geological Sciences University College London in 1989. The main part of the software is a topographic correction programme that calculates Bouguer anomalies. It uses digital elevation models (DEM) to calculate the effects of mass above sea level within a 100 x100 km square with the station at its centre. Outside this square the topography is assume flat and at sea level. DEMs have been obtained by digitizing topographic maps and by making use of DEMs of glaciated areas based on ice surface mapping and radio echo soundings of the Science Institute, University of Iceland. The gravity data collected in 1988-2001 is presented as a table in the report.

Hreinsdóttir, S., Einarsson, P., Jónsson, S., and Sigmundsson, F. (1998) GPS Geodetic Measurements around Bárðarbunga Volcano, Central Iceland, in 1997, RH-

13-98: Reykjavík, Raunvísindastofnun Háskóla Íslands.

Jakobsson, S.P. (1979) Petrology of recent Basalts of the Eastern Volcanic Zone, Iceland: Reykjavík.

Jóhannesson, H. (1996) Eldgosin í Vatnajökli á árunum 1902-1910 í ljósi síðustu umbrota, Vorrráðstefna 1996: ágrip erinda: Reykjavík.

Konstantinou, K.I., Kao, H., Lin, C.H., and Liang, W.T. (2003) "Analysis of broad-band regional waveforms of the 1996 September 29 earthquake at Bárdarbunga volcano, central Iceland: investigation of the magma injection hypothesis": Geophysical Journal International, v. **154**(1): p. 134-145.

Large earthquakes near active volcanoes, that exhibit non-double-couple source properties are usually interpreted as result the of either magma intrusion or geometrical complexity along the fault plane. Such an earthquake occurred in 1996 September 29 at Bárdarbunga volcano in central Iceland, to be followed 2 days later by a major volcanic eruption at the area between Bárdarbunga and the nearby Grimsvötn volcano. Both of these active volcanic centres lie underneath the Vatnajökull glacier, a permanent ice cap that covers a large area of central Iceland. This event was recorded by a temporary network (HOTSPOT) that consisted of 30 broad-band three-component seismometers covering most of Iceland. The waveforms of this event at all stations show an emergent, low-amplitude, high-frequency onset that is superposed on a longer-period signal. The corresponding amplitude spectra show a low-frequency content (<1 Hz) and prominent peaks around the corner frequency (similar to0.25 Hz) and higher frequencies. These regional waveforms were inverted in order to obtain the best-fitting deviatoric and full moment tensor using a linear, time-domain inversion method. The results for the deviatoric moment tensor indicate a large (similar to60 per cent) compensated linear vector dipole (CLVD) component, a hypocentral depth of 3.5 km, a moment magnitude of 5.4 and a best double-couple solution showing thrust motion in good agreement with the previously published Harvard CMT solution. The results for the full moment tensor on the other hand, indicate an implosive isotropic component of 8.5 per cent, a reduced CLVD component of 47.2 per cent and a best double-couple solution showing normal faulting. However, a statistical F-test revealed that the full moment tensor does not fit the data significantly better than the deviatoric at a confidence level of not more than 76 per cent. All of these results were found not to change substantially when a different source time function was used or when the data were weighted according to their distance from the source. The data are consistent with an earthquake of this magnitude, caused by the failure of an asperity and the formation of a tensile crack due to increasing fluid pressure. The dimensions of the crack may have been 10 x 3 km(2) and 0.5 m thickness and the volume of the injected fluid was found to be 15 x 10(6) m(3). The calculated viscosity for the fluid (0.04 Pa s) points to the possibility of water being injected rather than magma, that is also supported by the short source duration of the earthquake (similar to5 s). Taking into account the water saturation of the upper crust in Vatnajökull due to the presence of the glacier, this event may have been caused by increased pressure of water that was heated by magma injected through a dyke below the asperity.

Konstantinou, K.I., Nolet, G., Morgan, W.J., Allen, R.M., and Pritchard, M.J. (2000) "Seismic phenomena associated with the 1996 Vatnajökull eruption, central

Iceland": Journal of Volcanology and Geothermal Research, v. **102**(1-2): p. 169-187.

During late September 1996, a major eruption took place at the NW part of the Vatnajökull glacier in central Iceland. The eruption was preceded by intense seismic activity, which began with a Mw=5.6 earthquake two days previously. Two very active volcanic systems, Bárdarbunga and Grimsvötn, are situated in that area underneath the permanent ice cap. The volcanoseismic phenomena associated with the eruption were recorded on both temporary (HOTSPOT) and permanent (SIL) seismic networks, covering most parts of the country. The recorded events were categorised, according to their waveform shape and frequency content, into three groups: (1) low-frequency events; (2) mixed-frequency events; and (3) volcanic tremor. The large earthquake at Bardarbunga volcano, which initiated the seismic activity before the eruption, was located inside the caldera and had the characteristics of a non-double couple event. The epicentres of the earthquake swarm that followed it initially delineated the caldera rim and then migrated towards Grimsvötn, possibly indicating lateral movements of magma from a shallow chamber beneath Bárdarbunga. The eruption affected an area much larger than that between these two volcanoes, since seismic activity was also observed at distances 20 km away, at the Tindafjallajökull volcanic system. The spectral analysis of tremor, recorded at the nearest station to the eruption site, revealed its existence before the onset of the eruption in five narrow frequency bands (0.5-0.7, 1.6, 2.2, 2.8, 3.2 Hz) representing fundamental frequencies with their half- and quarter-subharmonics. This pattern continued until the last day of the eruption. It is believed that the eruption was caused by a dyke injection that had been going on beneath the Vatnajökull area for a period of 10 years.

Sigmundsson, F., Pedersen, R., Pagli, C., Sturkell, E., Einarsson, P., Árnadóttir, ó., Feigl, K., and Pinel, V. (2006) Deformation of Icelandic volcanoes: overview and examples from Hengill, Bárðarbunga and Gjálp, Haustfundur Jarðfræðafélags Íslands 2006: Reykjavík, p. 16.

Sigurðsson, O. (1978) "Bárðarbunga": Jökull, v. **28**: p. 80-81.

Steintþórsson, S., Harðarson, B.S., Ellam, R.M., and Larsen, G. (2000) "Petrochemistry of the Gjálp-1996 subglacial eruption, Vatnajökull, SE Iceland": Journal of Volcanology and Geothermal Research, v. **98**(1-4): p. 79-90.

In October 1996 a subglacial fissure to the north of the Grimsvötn caldera in W-Vatnajökull produced about 0.4 km3 of Fe-rich basaltic andesite-icelandite--in an area characterized mostly by tholeiitic basalt. In this paper the chemical composition of volcanic systems in the region is discussed with the help of six new analyses and others from the literature, and a tentative model for their evolution is proposed, in which magma produced by the partial melting of a two-component mantle mixes with hydrous, silicic melt in the crust. The Vatnajökull 1996 magma belongs to a separate volcanic system, intermediate between Bárdarbunga and Grimsvötn.

Steinþórsson, S. (1977) "Tephra layers in a drill core from Vatnajökull ice cap. (Gjóskulögin í Bárðarbungukjarnanum) ": Jökull, v. **27**: p. 2-27.

— (1982) Gjóskulög í jökulkjarna frá Bárðarbungu, *in* Þórarinsdóttir, H., and aðrir, o., eds., Eldur er í norðri: afmælisrit helgað Sigurði Þórarinssyni sjötugum 8. janúar 1982 Reykjavík, Sögufélagið, p. [361]-368; Myndir, línurit, tafla.

Theodórsson, P. (1970) "Rannsóknir á Bárðarbundur 1969 og 1970 (Abstract. Deuterium and tritium in ice cores from Bárðarbunga on Vatnajökull)": Jökull, v. **20**: p. 1-14.

Deuterium and tritium in ice cores recovered from this part of Vatnajökull, Iceland; use in study of climate change

— (1973) "Djúpborun í Bárðarbungu": Jökull, v. **23**: p. 67-69.

Published 1974. Results of deep core drilling in this north-western part of Vatnajökull

— (2001) "Djúpborgun í Bárðarbungu. Minningabrot": Jökull, v. **50**: p. 109-118.

4.2.3 Kverkfjöll

Bailey, J.P.C. (1981) "A topographical map of Hveradalur, Kverkfjöll, Iceland": Jökull, v. **31**: p. 116-117.

Bárðarson, H.R. (1971) Ís og eldur : andstæður íslenzkrar náttúru: Reykjavík, 171, [1] s. : að meginhluta myndir, kort p.

Björgvinsson, J. (1985) "Undirheimar elds og jökla": Áfangar: tímarit um Ísland, v. **6**(4): p. 8-15.

Björnsson, H. (1992) "Jökulhlaups in Iceland: prediction, characteristics and simulation": Annals of Glaciology, v. **16**: p. 95-106.

Jökulhlaups drain regularly from six subglacial geothermal areas in Iceland. From Grímsvötn in Vatnajökull, jökulhlaups have occurred at a 4-6 year interval since the 1940s with a peak discharge of 1,000 - 10,000 m3/s, 2 -3 weeks duration and total volumes of 0.5-3 km3. Prior to that, about one jökulhlaup occurred per decade with an estimated discharge of 5 km3 of water and a peak discharge of approximately 30,000 m3/s. Clarke½s (1982) modification of Nye's (1976) general model of discharge of jökulhlaups gives in many respects satisfactory simulations for jökulhlaups from Grímsvötn. The best fit is obtained for the Manning roughness coefficients n = 0.08-0.09 m-1/3 s and a constant lake temperature of 0.2 °C (which is the present lake temperature). The rapid ascent of the exceptional jökulhlaup in 1938, which accompanied a volcanic eruption, can only be simulated for a lake temperature of the order of 4 °C. Jökulhlaups originating at geothermal areas beneath ice cauldrons located 10-15 km northwest of Grímsvötn have a peak discharge of 200 - 1,500 m3/s in 1-3 days, the total volume is 50-350x106m3, and they recede slowly in 1-2 weeks. The form is in that respect a mirror image of the typical Grímsvötn hydrograph. The reservoir water temperature must be well above the melting point (10-20 °C) and the flowing water seems not to be confined to a tunnel but spread out beneath the glacier and later gradually collected back to conduits. Since the time of the settlement of Iceland (870 A.D.), at least 80 subglacial volcanic eruptions have been reported, many of them causing tremendous jökulhlaups with dramatic impact on inhabitated areas

and landforms. The peak discharge of the largest floods (from Katla) has been estimated at the order of 100-300,000 m3/s, duration was 3 -5 days and the total volume of the order of 1 km3. It is now apparent that the potentially largest and most catastrophic jökulhlaups may be caused by eruptions in the voluminous ice-filled calderas in northern Vatnajökull (of Bárdarbunga and Kverkfjöll). They may be the source of prehistoric jökulhlaups, with estimated peak discharge of 400,000 m3/s. At present, jökulhlaups originate from some fifteen marginal ice-dammed lakes in Iceland. Typical values for peak discharges are 1,000 - 3,000 m3/s, duration 2-5 days and total volumes of 2,000 x 106 m3. Hydrographs for jökulhlaups from marginal lakes have a shape similar to those of the typical Grímsvötn jökulhlaup. Simulations give reasonable ascent of the hydrographs for constant lake temperature of about 1 °C but fail to show the recession. Some floods from marginal lakes, however, have reached their peaks exceptionally rapidly, in one day. That ascent could be simulated by drainage of lake water of 4-8 °C. An empirical power law relationship is obtained between peak discharge and total volume of the jökulhlaups from Grímsvötn; Qmax = K Vtb, where Qmax is measured in m3/s, Vt in 106 m3, K = 4.15 10-3 s-1 m-2.52 and b = 1.84. In general, the jökulhlaups (excepting those caused by eruptions) occur when the lake has risen to a critical level, but before a lake level required for simple flotation of the ice dam is reached. The difference between the hydrostatic water pressure maintained by the lake and the ice overburden pressure of the ice dam is of the order 2-6 bar.

Björnsson, H., and Einarsson, P. (1990) "Volcanoes beneath Vatnajökull, Iceland: Evidence from radio echo-sounding earthquakes and jökulhlaups": Jökull, v. **40**: p. 147-168.

Integration of knowledge of subglacial topography, earthquake activity and jökulhlaups has contributed to more precise locations of the volcanic systems beneath Vatnajökull. Bárðarbunga is the centre of a volcanic system which includes the fissure swarms of Veiðivötn to the SW and Dyngjuháls to the NE. The Grímsvötn volcano is the centre of a system that comprises the Laki fissure swarm in the SW and extends for an unknown distance to the NE of the volcano. Þórðarhyrna is probably a separate central volcano within this system. The Kverkfjöll system can be traced 10 km to the SW of the Kverkfjöll volcano. It appears to be separated from the Grímsvötn volcano. The Askja fissure swarm extends beneath Dyngjujökull and can possibly be traced to the Grímsvötn volcano. Hamarinn and the ridge striking eastward from Hamarinn (Loki Ridge) are central volcanoes which together with the Fögrufjöll fissure swarm form a volcanic system. No support can be found in the topographic data for the existence of a central volcano near Breiðabunga. Volcanic activity in historical times has mainly been limited to the Grímsvötn and Bárðarbunga systems. Major rifting events have affected large sections of these volcanic systems but both have been remarkably quiet for the past decades. A few volcanic events are presumed to have occurred on the Hamarinn - Loki system and on the Askja fissure swarm beneath Dyngjujökull, but no event is known with certainty on the Kverkfjöll system. The rivers Skeiðará and Súla have the most frequent eruption-related jökulhlaups. They receive meltwater from the Grímsvötn caldera and the area to the SW of it, including Þórðarhyrna. Núpsvötn, Djúpá and Hverfisfljót drain the southwestern part of the Grímsvötn system, an area bounded by Þórðarhyrna, Geirvörtur, Hágöngur and Pálsfjall. Skaftá drains the Loki Ridge and the area west of Grímsvötn. Jökulhlaups in Kaldakvísl, and ultimately Þjórsá, must originate in the Bárðarbunga or the Hamarinn - Loki systems, and the only possible source for volcanic jökulhlaups in Skjálfandafljót is the northern part of the Bárðarbunga system. Jökulsá á Fjöllum may drain meltwater from activity in all the volcanic systems in northern Vatnajökull: Bárðarbunga, the Askja fissure swarm and

Kverkfjöll. This includes the voluminous, ice-filled calderas of Bárðarbunga and Kverkfjöll. Activity in the northern part of the Grímsvötn system may cause floods in Jökulsá á Fjöllum. Meltwater from volcanic activity on the SE flank of a ridge that strikes south from Kverkfjöll may drain to Jökulsá á Brú. Volcanic activity farther north on the E flanks of this ridge would cause floods in Kreppa.

Bruun, D. (1913) "Islænderfærder til hest over Vatna-Jökull í ældre tider ": Úrtak úr DEt Kongelige Danske Geographiske Selskap Tidskrift: p. 14 s. : myndir, kort

Carrivick, J.L. (2004) Palaeohydraulics of a glacier outburst flood (jökulhlaup) from Kverkfjöll, Iceland, *in* Beylich, A.A., Sæmundsson, Decaulne, A., and Sandberg, O., eds., Sedimentary source-to-sink-fluxes in cold environments: Sauðárkrókur, Náttúrustofa Norðurlands vestra, p. 104.

— (2006) "Application of 2D hydrodynamic modelling to high-magnitude outburst floods: An example from Kverkfjoll, Iceland": Journal of Hydrology, v. **321**(1-4): p. 187-199.

High-magnitude outburst floods cause rapid landscape change and are a hazard to life, property and infrastructure. However, high-magnitude fluvial processes and mechanisms of erosion, transport and deposition are very poorly understood, and remain largely unquantified. This poor understanding is partly because of the inherent difficulty of directly measuring high-magnitude outburst floods, but also because of the limitations and assumptions of 1D models and other palaeohydrological methods, which reconstructions of high-magnitude floods have to date relied upon. This study therefore applies a 2D hydrodynamic model; SOBEK, to reconstructing a high-magnitude outburst flood. This method offers the first calculations of high-magnitude fluvial flow characteristics within an anastomosing network of simultaneously inundated channels, including; sheet or unconfined flow, simultaneous channel and sheet flow, flow around islands, hydraulic jumps, multi-directional flow including backwater areas, hydraulic ponding and multiple points of flood initiation. 2D-modelling of outburst floods clearly has the potential to revolutionise understanding of high-magnitude spatial and temporal hydraulics and high-magnitude flow phenomena, geomorphological and sedimentological processes, and hence rapid fluvial landscape change. This potential for new understanding is because of the now wide availability of high-resolution DEM data for large and often inaccessible areas, and the availability of remotely-sensed data that can parameterise outburst flood sources, such as glacial lakes, for example. Additionally, hydraulic models and computing power are now sufficient to cope with large (5,000,000 grid cells) areas of inundation and large (100,000 m3 s-1) peak discharges.

— (2007 (in press)) "Modelling transient hydrodynamics and rapid landscape change due to a high-magnitude outburst flood: an example from Kverkfjöll volcano, Iceland": Annals of Glaciology, v. **45**.

— (Submitted) "Hydrodynamics and geomorphic work of jökulhlaups (glacial outburst floods) from Kverkfjöll volcano, Iceland": Hydrological Processes.

— (Submitted) Impacts and characteristics of jökulhlaups from Kverkfjöll, Iceland [**PhD thesis**], University of Keele.

Carrivick, J.L., Pringle, J.K., Russell, A.J., and Cassidy, N.J. (2007 (In press)) "Architecture and stratigraphy of high-magnitude outburst flood sedimentation within a bedrock valley system": Journal of Environmental and Engineering Geophysics.

Jökulhlaups and lahars are both types of high-magnitude outburst flood that commonly comprise a glacial meltwater and volcaniclastic sediment mix, and have discharges that are typically several orders of magnitude greater than perennial flows. Both types thus constitute a serious threat to life, property and infrastructure but are too powerful and too short-lived for direct measurements of flow characteristics to be made. Consequently a variety of indirect methods have been used to reconstruct flow properties, processes and mechanisms. Unfortunately, a lack of observations of sedimentary architecture, geometry and stratigraphic relationships, are hampering our ability to discriminate fluvial magnitude-frequency regimes and styles of deposition, particularly within rapidly-varied flows. This paper therefore uses Ground Penetrating Radar (GPR) to obtain quantitative data on subsurface sedimentary character of high-magnitude outburst flood sediments, including geometry, architecture and stratigraphy, from a bedrock-valley system in north-central Iceland. Basement pillow lava and subaerial lava flows are distinguished based upon a chaotic, and hummocky signature, and thickness, lack of coherent internal structure, and upper rough surface as evidenced by concentration of hyperbole point sources, respectively. Unconsolidated sedimentary units are interpreted due to the presence of coherent internal structures of a horizontal and sub horizontal nature. Deposition produced spatially diverse sediments due to rapidly-varied flow conditions. Observations include prograding and backfilling architecture, intercalated slope material and fluvial sediments, and multiphase deposition of sediments. Specifically, outburst flood sediments were initially deposited by traction load of coarse-grained material on prograding bedforms, and subsequently by drop-out from suspension of finer-grained material. The latter phase produces laterally extensive tabular sedimentary architectures that in-fill pre-existing topography and mask the complexity of bedrock forms beneath. Existing qualitative concepts of high-magnitude fluvial deposition within a topographically confined bedrock channel are therefore now refined with quantitative data on sediment architecture and thus flow regimes.

Carrivick, J.L., Russell, A.J., and Tweed, F.S. (2004) "Geomorphological evidence for jökulhlaups from Kverkfjöll volcano, Iceland": Geomorphology v. **63**: p. 81-102.

Jökulhlaups (glacial outburst floods) are known to have drained along the Jökulsá á Fjöllum river in Iceland during the Holocene. However, little is known about their number, age, source, and flow characteristics. This paper provides detailed geomorphological evidence for jökulhlaups that have routed from the Kverkfjöll ice margin and hence into the Jökulsá á Fjöllum. Erosional evidence of jökulhlaups from Kverkfjöll includes gorges, cataracts, spillways, subaerial lava steps, and valley-wide scoured surfaces. Depositional evidence includes wash limits, boulder bars, cataract-fill mounds, terraces, slackwater deposits, and outwash fans. Some of these landforms have been documented previously in association with jökulhlaups. However, subaerial lava surfaces that have been scoured of the upper clinker, gorges within pillow–hyaloclastite ridges, gorges between pillow–hyaloclastite ridges and subaerial lava flows, subaerial lava lobe steps, cataract-fill mounds, and boulder run-ups are *previously undocumented in the literature. These landforms may therefore be diagnostic of jökulhlaups within an active volcanic rifting landscape. The nature and spatial distribution of these landforms and their stratigraphic association with other landforms suggest that there have been at least two jökulhlaups through Kverkfjallarani. The Biskupsfell eruption occurred between these two jo¨kulhlaups. Kverkfjallarani jökulhlaups were very strongly influenced by topography, geology, and interevent processes that together determined the quantity and nature of sediment availability. Such controls have resulted in jökulhlaups that were probably fluidal, turbulent, and supercritical over large areas of the anastomosing channel bed. Kverkfjallarani jökulhlaups would have had highly variable hydraulic properties, both spatially and temporally. The knowledge of flow characteristics that can be gained from jökulhlaup impacts has implications for recognising jökulhlaups in the rock record and for hazard analysis and mitigation within similar landscapes and upon other glaciated volcanoes.*

— (2004) Glacier outburst floods (jökulhlaups) from Kverkfjöll, Iceland:flood routeways, flow characteristics and sedimentary impacts, *in* Beylich, A.A., Sæmundsson, Decaulne, A., and Sandberg, O., eds., Sedimentary source-to-sink-fluxes in cold environments: Sauðárkrókur, Náttúrustofa Norðurlands vestra, p. 104.

Carrivick, J.L., Russell, A.J., Tweed, F.S., and Twigg, D. (2004) "Palaeohydrology and sedimentary impacts of jokulhlaups from Kverkfjöll, Iceland": Sedimentary Geology, v. **172**(1-2): p. 19-40.

Jökulhlaups (glacial outburst floods) occur frequently within Iceland and within most glaciated regions of the world. The largest jökulhlaups known to have occurred within Iceland drained from the northern margin of the Vatnajökull and along the Jökulsá á Fjöllum during the Holocene. However, little is known about the number, age and flow characteristics of the Jökulsá á Fjöllum jökulhlaups. One source of meltwater into the Jökulsá á Fjöllum is Kverkfjöll, a glaciated stratovolcano. This paper provides detailed sedimentological evidence demonstrating that jökulhlaups have routed through Kverkfjallarani and hence from Kverkfjöll. Sedimentological evidence of jökulhlaups includes valley-fill deposits and slack water deposits. Lithofacies, which are indicative of high-magnitude fluvial sedimentation, show that these deposits cannot be the result of nonjökulhlaup processes. The situation and nature of the sediments permit palaeoflow reconstructions. Fine-grained deposits within slack water deposits mark a break in jökulhlaup deposition and suggest that at least three jökulhlaups have drained through Hraundalur, the predominant valley within Kverkfjallarani. Evidence of lava overrunning `wet' jökulhlaup deposits indicates that jökulhlaups occurred in close association with volcanic eruptions in the Biskupsfell fissure. The largest jökulhlaup was initially hyperconcentrated and subsequently became more fluid. Slope-area reconstructions indicate that the largest jokulhlaup had a probable average peak discharge of 45,000-50,000 m3 s-1; however, the peak discharge attenuated by 25-30% in just 25 km. These observations quantify the number, rheology, hydraulics and chronology of jökulhlaups from Kverkfjöll and hence within the Jökulsá á Fjöllum. This study presents a model of jökulhlaup impacts and characteristics from glaciated volcanoes and/or within volcanic rifting zones.

Carrivick, J.L., and Twigg, D.R.T. (2004) "Jökulhlaup-influenced Topography and Geomorphology at Kverkfjöll, Iceland": Journal of Maps p. 17-27.

High magnitude jökulhlaups (glacial outburst floods) are known to have drained along the Jökulsá á Fjöllum river from the northern margin of Vatnajökull, Iceland during the Holocene. However, little is known of the number, age, source and flow characteristics of these jökulhlaups. Ongoing research therefore seeks to quantitatively analyse jökulhlaups from Kverkfjöll, which is a discrete source of meltwater into the Jökulsá á Fjöllum. To this end a high-resolution digital elevation model was produced and extensive geomorphological mapping and sedimentary analyswere accomplished in the field.The digital elevation model was produced by processing digitally scanned aerial photographs with the ERDAS Imagine Orthobase software. Processing incorporated twenty-nine ground control points, which were surveyed with a differential global positioning system. Ground control points allow photographic distortion to be remove and the elevation model to be located on the Earth's surface. A DEM with 10m horizontal resolution was resampled from a 5m horizontal resolution extraction. The DEM has sub-metre vertical accuracy. The DEM is substantially more detailed than presently available topographic maps an is therefore of interest for a whole range of recreational and scientific purposes. This research has identified geomorphological surfaces that distinguish at least three jökulhlaups from Kverkfjöll during the Holocene. These jökulhlaups routed into the Jökulsá á Fjöllum. Ongoing research has also sought to examine flow characteristics of jökulhlaups through Kverkfjallarani and to compare calculations of spatial and tempo hydraulics to maps of geomorphological and sedimentological jökulhlaup products.

Cassidy, N.J., Russell, A.J., Pringle, J.K., and Carrivick, J.L. (2004) GPR-Derived Architecture of Large-Scale Icelandic Jökulhlaup Deposits, North-East Iceland, Tenth International Conference on Ground Penetrating Radar: Delft, The Netherlands, .

Jökulhlaups (glacial outburst floods) occur frequently throughout Iceland and across most of the glaciated regions of the world. The largest of these jökulhlaups are known to have occurred along the northern margin of the Vatnajökull Icecap and drained down the Jökulsá á Fjöllum river during the Holocene. Unfortunately, little is known about the number, frequency, age and flow characteristics of the Jökulsá á Fjöllum jökulhlaups and the relationship between their deposit architectures and the underlying volcanic lavas. During the summer of 2003, a total of over 20 km of GPR data was collected from a variety of jökulhlaup outwash sediments across the Jökulsá á Fjöllum flood plain. GPR results and corresponding facies interpretations are presented for the outwash deposits at two locations: Kverkfjöll, (approximately 20 Km from the jökulhlaup source) and Möðrudalur (approximately 100 Km downstream from the glacial margin). By combining the GPR data with ground surveying, photogrammetry and detailed sedimentary outcrop evidence, this study adds new perspectives to the sedimentary analysis of high-magnitude jökulhlaup events and their large-scale bars and bedforms. The results indicate that sedimentary architectures are controlled by the topographic nature of the underling lavas and the flow conditions in each region. By analysing the GPR derived facies in detail, it is also possible to identify different phases of jökulhlaup deposition. This information is vital for the assessment of jökulhlaup magnitudes, frequencies, and pathways and can be used for the prediction of future jökulhlaup impacts.

Einarsson, T. (1976) "Tilgáta um orsök hamfarahlaupsins í Jökulsá á Fjöllum og um jarðvísindalega þýðingu þessa mikla hlaups": Jökull, v. **26**: p. 61-64.

Fenn, C., and Ashwell, I. (1985) "Some observations on the characteristics of the drainage system of Kverkfjöll, central Iceland": Jökull, v. **35**: p. 79-82.

Friedman, J.D. (1972) "Infrared emission from Kverkfjöll subglacial volcanic and geothermal area, Iceland": Jökull, v. **22**: p. 27-43.

Guðmundsson, A.T. (1986) "Eldgos á Dyngjuhálsi á 18. öld": Náttúrufræðingurinn, v. **56**(1. hefti).

— (1986) Íslandseldar : eldvirkni á Íslandi í 10.000 ár Reykjavík, Vaka-Helgafell, 168 s. : myndir, teikn., kort, línurit, töflur p.

— (2001) Íslenskar eldstöðvar: Reykjavík, Vaka-Helgafell, 320 s. : myndir, kort, línurit, töflur

Guðmundsson, Á. (1995) Áhrif spennusviðs utan rekbeltis á landslagsþróun og eldvirkni, Vorráðstefna 1995: Ágrip erinda: Reykjavík, Jarðfræðifélag Íslands.

Guðmundsson, M.T., and Högnadottir, Þ. (2007) "Volcanic systems and calderas in the Vatnajökull region, central Iceland: Constraints on crustal structure from gravity data": Journal of Geodynamics, v. **43**(1): p. 153-169.

A Bouguer anomaly map is presented of southern central Iceland, including the western part of Vatnajökull and adjacent areas. A complete Bouguer reduction for both ice surface and bedrock topography is carried out for the glaciated regions. Parts of the volcanic systems of Vonarskarð-Hágöngur, Barðarbunga-Veiðivötn, Grimsvötn-Laki, and to a lesser extent Kverkfjöll, show up as distinct features on the gravity map. The large central volcanoes with calderas: Vonarskarð, Barðarbunga, Kverkfjöll and Grimsvötn, are associated with 15-20 mGal gravity highs caused by high density bodies in the uppermost 5 km of the crust. Each of these bodies is thought to be composed of several hundred km3 of gabbros that have probably accumulated over the lifetime of the volcano. The Skaftarkatlar subglacial geothermal areas are not associated with major anomalous bodies in the upper crust. The central volcanoes of Vonarskarð and Hagöngur belong to the same volcanic system; this also applies to Barðarbunga and Hamarinn, and Grimsvötn and Þórðarhyrna. None of the smaller of the two volcanoes sharing a system (Hagöngur, Hamarinn and Þórðarhyrna) is associated with distinct gravity anomalies and clear caldera structures have not been identified. However, ridges in the gravity field extend between each pair of central volcanoes, indicating that they are connected by dense dyke swarms. This suggests that when two central volcanoes share the same system, one becomes the main pathway for magma, forming a long-lived crustal magma chamber, a caldera and large volume basic intrusive bodies in the upper crust. Short residence times of magma in the crust beneath these centres favour essentially basaltic volcanism. In the case of the second, auxillary central volcano, magma supply is limited and occurs only sporadically. This setting may lead to longer residence times of magma in the smaller central volcanoes, favouring evolution of the magma and occasional eruption of rhyolites. The eastern margin of the Eastern Volcanic Zone is marked by a NE-SW lineation in the gravity *field, probably caused by accumulation of low density, subglacially erupted volcanics within the volcanic zone. This lineation lies 5-10 km to the east of Grimsvötn.*

Hallgrímsson, H. (2004) "Kynjaverur í Kverkfjöllum [ritdómur]": Glettingur, v. **14 (36. tölubl.)**(2): p. 49.

Hannesson, P. (1953) "Iagttagelser over vulkanismen i Kverkfjallarani i Island--Vulcanism in Kverkfjallarani, Iceland": Geog Tidssk, v. **68**: p. 66-68.

Hróarsson, B. (1992) Geysers and hot springs in Iceland: Reykjavík, Mál og menning, 158 s. : myndir, kort p.

Hróarsson, B., and Jónsson, S.S. (1991) Hverir á Íslandi: Reykjavík Mál og menning, 160 s. : myndir, kort, uppdr. p.

Höskuldsson, Á., Sparks, R.S.J., and Carroll, M.R. (2006) "Constraints on the dynamics of subglacial basalt eruptions from geological and geochemical observations at Kverkfjöll, NE-Iceland": Bulletin of Volcanology, v. **68**(7-8): p. 689-701.

The Kverkfjöll area, NE Iceland is characterised by subglacial basalt pillow lavas erupted under thick ice during the last major glaciation in Iceland. The water contents of slightly vesiculated glassy rims of pillows in six localities range from 0.85 +/- 0.03 to 1.04 +/- 0.03 wt%. The water content measurements allow the ice thickness to be estimated at between 1.2 and 1.6 km, with the range reflecting the uncertainty in the CO_2 and water contents of the melt. The upper estimates agree with other observations and models that the ice thickness in the centre of Iceland was 1.5-2.0 km at the time of the last glacial maximum. Many of the pillows in the Kverkfjöll area are characterised by vesiculated cores (40-60% vesicles) surrounded by a thick outer zone of moderately vesicular basalt (15-20% vesicles). The core contains similar to 1 mm diameter spherical vesicles distributed uniformly. This observation suggests a sudden decompression and vesiculation of the still molten core followed by rapid cooling. The cores are attributed to a jökulhlaup in which melt water created by the eruption is suddenly released reducing the environmental pressure. Mass balance and solubility relationships for water allow a pressure decrease to be calculated from the observed change of vesicularity of between 4.4 and 4.7 MPa depressurization equivalent to a drop in the water level in the range 440-470 m. Consideration of the thickness of solid crust around the molten cores at the time of the jökulhlaup indicates an interval of 1-3 days between pillow emplacement and the jökulhlaup. Upper limits for ice melting rates of order 10(-3) m/s are indicated. This interpretation suggests that jökulhlaups can reactivate eruptions.

Ísdal, J.E. (1978) "Sæluhús Jöklarannsóknafélags Íslands í Esjufjöllum og Kverkfjöllum": Jökull, v. **28** p. 94.

Jóhannsson, M. (1983) "Kverkfjöll": Ársrit Útivistar, v. **9**.

Jónsson, Ó. (1946) "Frá Kverkfjöllum": Náttúrufræðingurinn, v. **16. árg.**(2. hefti): p. 87-92.

Kaldal, I. (2002) Umhverfi og orkuöflun - jöklalandslag. Norðvestanverður Vatnajökull frá Sylgjujökli að Kverkfjöllum. Staða gagnasafns í árslok 2002- Greinargerð, IK-0301, Orkustofnun, Rannsóknasvið.

Karhunen, R. (1988) Eruption mechanism and rheonmorphism during the basaltic fissure eruption in Biskupsfell, Kverkfjöll, north-central Iceland, NorVol 8802 Nordic Volcanological Institute, p. [6), 91 s. : myndir, kort, töflur

Marren, P.M., Russell, A.J., Knudsen, Ó., and Rushmer, E.L. (In revision) Sedimentology and architecture of an outwash fan formed by multiple jökulhlaups, Kverkfjöll, Iceland: new insights into the role of jökulhlaups in controlling sandur stratigraphy, Sedimentary Geology.

Metúsalemsson, G. (2000) "Kverkfjallaferð hin fyrsta": Glettingur v. **10**(3): p. 15-17.

N.N. (1990) "Vatnajökull: eitt mesta jökulhvel jarðarinnar": Áfangar: tímarit um Ísland, v. **11**(1): p. 12-17.

Rushmer, E.L. (2006) "Sedimentological and geomorphological impacts of the Jökulhlaup (glacial outburst flood) in January 2002 at Kverkfjöll, Northern Iceland": Geografiska Annaler Series a-Physical Geography, v. **88A**(1): p. 43-53.

Jökulhlaups (glacial outburst floods) are common hazards in many glaciated environments. However, research on the controls on the sedimentological and geomorphological impact of jökulhlaups is rare. Developing a more comprehensive understanding of flood impacts may be useful for hazard identification, prediction and mitigation. This study determines the controls on the sedimentological and geomorphological impact of a jökulhlaup in January 2002 at Kverkfjoll, northern Iceland. This jökulhlaup, caused by geothermal activity, reached a peak discharge of 490 m(3)s(-1) as recorded at a permanent gauging station 40 km downstream from the glacier snout. However, reconstructed peak discharges in the proximal part of the jökulhlaup channel near the glacier snout indicate a peak discharge of 2590 m(3)s(-1). The jokulhlaup hydrograph was characterized by a rapid rising stage and a more gradual falling stage. As a result, sedimentary and geomorphological impacts included poorly sorted, structureless, matrix-supported deposits; massive sand units; clast-supported units; ice-proximal cobbles, rip-up clasts and kettle-holes; and steep-sided kettle-holes. These features are proposed to be characteristic of rapid rising stage deposition. Additionally, large-scale gravel bars and bedload sheets prograded and migrated during the rapid rising stage. The development of these bedforms was facilitated by high bedload transport rates, due to high discharge acceleration rates during the rapid rising stage. During the more prolonged falling stage, there was sufficient time for sediment incision and erosion to occur, exhuming cobbles, ice blocks and rip-up clasts, and creating well-defined terrace surfaces. This study provides a clearer understanding of hydrological and sedimentological processes and mechanisms operating during jökulhlaups, and helps to identify flood hazards more accurately, which is fundamental for hazard management and minimizing risk.

Sigvaldason, G.E., and Steinthórsson, S. (1974) Chemistry of tholeiitic basalts from Iceland and their relation to the Kverkfjöll hot spot, *in* Kristjansson, L., ed., Geodynamics of Iceland and the North Atlantic Area: Dordrecth-Holland, D. Reidel Publ. Company, p. 155-164.

Sigvaldason, G.E., Steinthórsson, S., Óskarsson, N., and Imsland, P. (1974) "Compositional variation in Recent Icelandic tholeiites and the Kverkfjöll hot spot": Nature, v. **251**: p. 579-582.

Geochemical studies of recent igneous rocks from Iceland lend support to the 'hot spot' theory. There is a geographical variation in basaltic composition between Iceland and the submerged parts of the Reykjanes Ridge and Mid-Atlantic Ridge, which suggests that the single-source model for basalts of this region may be correct.

Stefánsson, Ó. (1996) "Mesta leit sem farið hefur fram á Íslandi": Múlaþing, v. **23**: p. 30-35.

Thoroddsen, o. (1908-1922) Eldgos í Vatnajökli, Lýsing Íslands: Kaupmannahöfn, Hið íslenska bókmenntafélag, p. 159-165.

— (1908-1922) Öræfi og óbyggðir norðan jökla, *in* Thoroddsen, o., ed., Lýsing Íslands: Kaupmannahöfn, Hið íslenska bókmenntafélag, p. 1.b. s. 167-191.

Wegner, R. (1993) "The cold heart of glaciers": Geographical Magazine, v. **65**(8): p. 18-23, ill.

Author's photographs illustrate brief account of sport of ice caving. Refers especially to ice caves on Mer de Glace, France and Kverkfjöll ice cave, on Vatnajökull, Iceland

Þorleifsson, P., and Reynisson, Á. (1985) "Kverkfjallaskáli reistur": Jökull, v. **35**: p. 127-128.

Þórarinsson, S. (1975) Glacier : adventure on Vatnajökull, Europe's largest ice cap: Reykjavík, Iceland Review [2], 95, [3] s. : myndir, kort

— (1975) Vatnajökull : tignarheimur frosts og funa: Reykjavík, Heimskringla, [2], 95, [3] s. : myndir, kort

4.2.4 Hágöngur

Björnsson, H., and Einarsson, P. (1990) "Volcanoes beneath Vatnajökull, Iceland: Evidence from radio echo-sounding earthquakes and jökulhlaups": Jökull, v. **40**: p. 147-168.

Integration of knowledge of subglacial topography, earthquake activity and jökulhlaups has contributed to more precise locations of the volcanic systems beneath Vatnajökull. Bárðarbunga is the centre of a volcanic system which includes the fissure swarms of Veiðivötn to the SW and Dyngjuháls to the NE. The Grímsvötn volcano is the centre of

a system that comprises the Laki fissure swarm in the SW and extends for an unknown distance to the NE of the volcano. Þórðarhyrna is probably a separate central volcano within this system. The Kverkfjöll system can be traced 10 km to the SW of the Kverkfjöll volcano. It appears to be separated from the Grímsvötn volcano. The Askja fissure swarm extends beneath Dyngjujökull and can possibly be traced to the Grímsvötn volcano. Hamarinn and the ridge striking eastward from Hamarinn (Loki Ridge) are central volcanoes which together with the Fögrufjöll fissure swarm form a volcanic system. No support can be found in the topographic data for the existence of a central volcano near Breiðabunga. Volcanic activity in historical times has mainly been limited to the Grímsvötn and Bárðarbunga systems. Major rifting events have affected large sections of these volcanic systems but both have been remarkably quiet for the past decades. A few volcanic events are presumed to have occurred on the Hamarinn - Loki system and on the Askja fissure swarm beneath Dyngjujökull, but no event is known with certainty on the Kverkfjöll system. The rivers Skeiðará and Súla have the most frequent eruption-related jökulhlaups. They receive meltwater from the Grímsvötn caldera and the area to the SW of it, including Þórðarhyrna. Núpsvötn, Djúpá and Hverfisfljót drain the southwestern part of the Grímsvötn system, an area bounded by Þórðarhyrna, Geirvörtur, Hágöngur and Pálsfjall. Skaftá drains the Loki Ridge and the area west of Grímsvötn. Jökulhlaups in Kaldakvísl, and ultimately Þjórsá, must originate in the Bárðarbunga or the Hamarinn - Loki systems, and the only possible source for volcanic jökulhlaups in Skjálfandafljót is the northern part of the Bárðarbunga system. Jökulsá á Fjöllum may drain meltwater from activity in all the volcanic systems in northern Vatnajökull: Bárðarbunga, the Askja fissure swarm and Kverkfjöll. This includes the voluminous, ice-filled calderas of Bárðarbunga and Kverkfjöll. Activity in the northern part of the Grímsvötn system may cause floods in Jökulsá á Fjöllum. Meltwater from volcanic activity on the SE flank of a ridge that strikes south from Kverkfjöll may drain to Jökulsá á Brú. Volcanic activity farther north on the E flanks of this ridge would cause floods in Kreppa.

Guðmundsson, M.T., and Högnadottir, ó. (2007) "Volcanic systems and calderas in the Vatnajökull region, central Iceland: Constraints on crustal structure from gravity data": Journal of Geodynamics, v. **43**(1): p. 153-169.

A Bouguer anomaly map is presented of southern central Iceland, including the western part of Vatnajökull and adjacent areas. A complete Bouguer reduction for both ice surface and bedrock topography is carried out for the glaciated regions. Parts of the volcanic systems of Vonarskarð-Hágöngur, Barðarbunga-Veiðivötn, Grimsvötn-Laki, and to a lesser extent Kverkfjöll, show up as distinct features on the gravity map. The large central volcanoes with calderas: Vonarskarð, Barðarbunga, Kverkfjöll and Grimsvötn, are associated with 15-20 mGal gravity highs caused by high density bodies in the uppermost 5 km of the crust. Each of these bodies is thought to be composed of several hundred km3 of gabbros that have probably accumulated over the lifetime of the volcano. The Skaftarkatlar subglacial geothermal areas are not associated with major anomalous bodies in the upper crust. The central volcanoes of Vonarskarð and Hagöngur belong to the same volcanic system; this also applies to Barðarbunga and Hamarinn, and Grimsvötn and Þórðarhyrna. None of the smaller of the two volcanoes sharing a system (Hagöngur, Hamarinn and Þórðarhyrna) is associated with distinct gravity anomalies and clear caldera structures have not been identified. However, ridges in the gravity field extend between each pair of central volcanoes, indicating that they are connected by dense dyke swarms. This suggests that when two central volcanoes share the same system, one becomes the main pathway for magma, forming a long-lived crustal magma chamber, a caldera and large volume basic

intrusive bodies in the upper crust. Short residence times of magma in the crust beneath these centres favour essentially basaltic volcanism. In the case of the second, auxillary central volcano, magma supply is limited and occurs only sporadically. This setting may lead to longer residence times of magma in the smaller central volcanoes, favouring evolution of the magma and occasional eruption of rhyolites. The eastern margin of the Eastern Volcanic Zone is marked by a NE-SW lineation in the gravity field, probably caused by accumulation of low density, subglacially erupted volcanics within the volcanic zone. This lineation lies 5-10 km to the east of Grimsvötn.

Noe-Nygaard, A. (1950) "Hágöngur. A Partially Sub-Glacial Volcano in SW-Vatnajökull": Meddelelser fra Dansk Geologisk Forening, v. **Bd. 11**(h. 5): p. 513-521.

— (1952) "Eldgígur at Hágöngur, a Prehistoric Subaeric Volcano at the SW-Edge of Vatnajökull": Meddelelser fra Dansk Geologisk Forening, v. **Bd. 12**(h. 2): p. 223-226.

4.2.5 Þórðarhyrna

Björnsson, H., and Einarsson, P. (1990) "Volcanoes beneath Vatnajökull, Iceland: Evidence from radio echo-sounding earthquakes and jökulhlaups": Jökull, v. **40**: p. 147-168.

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strikes south from Kverkfjöll may drain to Jökulsá á Brú. Volcanic activity farther north on the E flanks of this ridge would cause floods in Kreppa.

Guðmundsson, A.T. (1986) Íslandseldar : eldvirkni á Íslandi í 10.000 ár Reykjavík, Vaka-Helgafell, 168 s. : myndir, teikn., kort, línurit, töflur p.

Guðmundsson, M.T., and Högnadottir, Þ. (2007) "Volcanic systems and calderas in the Vatnajökull region, central Iceland: Constraints on crustal structure from gravity data": Journal of Geodynamics, v. **43**(1): p. 153-169.

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Halldórsson, S.A. (2004) Þórðarhyrna : dæmi um nýtt eldstöðvakerfi í Eystra-gosbeltinu? [**BSc thesis**]: Reykjavík, Háskóli Íslands.

4.2.6 Hamarinn

Björnsson, H., and Einarsson, P. (1990) "Volcanoes beneath Vatnajökull, Iceland: Evidence from radio echo-sounding earthquakes and jökulhlaups": Jökull, v. **40**: p. 147-168.

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Guðmundsson, A.T. (2001) Íslenskar eldstöðvar: Reykjavík, Vaka-Helgafell, 320 s. : myndir, kort, línurit, töflur p.

Guðmundsson, M.T., and Högnadottir, Þ. (2007) "Volcanic systems and calderas in the Vatnajökull region, central Iceland: Constraints on crustal structure from gravity data": Journal of Geodynamics, v. **43**(1): p. 153-169.

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III: heimildir flokkaðar eftir atriðisorðum

5. Heimildir um jarðfræði, flokkaðar eftir atriðisorðum

5.1 Jöklabreytingar, hop og framskrið jökla (glacier variations)

5.1.1 Jöklamælingar

Björnsson, H., and Eydal, G.P. (1998) Rannsóknir á stærð jökla á Íslandi s.l. 300 ár, Field report RH-1998, Raunvísindastofnun Háskóla Íslands (Science Institute, University of Iceland), p. 250 bls. .

— (1999) Rannsóknir á stærð jökla á Íslandi s.l. 300 ár. Verkþáttur: Breytingar á Langjökli, Hofsjökli, Mýrdalsjökli, Drangajökli og tveimur skriðjöklum Vatnajökuls: Reykjavík, Raunvísindastofnun Háskólans.

Eiríksson, H.H. (1932) "Observations and measurements of some glaciers in Austur-Skaftafellssýsla: in the summer 1930": Societas Scientiarum Islandica v. **Rit 12**: p. 24

Eyþórsson, J. (1931) "On the present position of the glaciers in Iceland. Some preliminary studies and investigations in the summer 1930." Societas Scientiarum Islandica v. **Rit 10**: p. 35

— (1934) "Jöklamælingar haustið 1933": Náttúrufræðingurinn, v. **4 árg.**: p. 97-98.

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— (1951) "Jöklamælingar 1950 og 1951": Jökull, v. **1**: p. 16.

— (1952) "Jöklamælingar 1951/1952": Jökull, v. **2**: p. 31.

— (1953) "Jöklabreytingar, Glacier variations": Jökull, v. **3**: p. 49.

— (1954) "Jöklabreytingar 1954 (Glacier variations)": Jökull, v. **4**: p. 46.

— (1955) "Jöklabreytingar, Glacier variations in meters": Jökull, v. **5**: p. 40.

— (1956) "Jöklabreytingar 1954/55 og 1955/56 (Glacier variations)." Jökull, v. **6**: p. 35-37.

— (1957) "Jöklabreytingar (Glacier variations)1955/56 og 1956/57": Jökull, v. **7**: p. 50-52.

— (1958) "Jöklabreytingar (Glaciers variations) 1956/57 og 1957/58": Jökull, v. **8**: p. 30-33.

— (1959) "Jöklabreytingar (Glacier variations)1957/58 og 1958/59": Jökull, v. **9**: p. 47-48.

— (1960) "Jöklabreytingar (Glacier variations) 1958/59 og 1959/60": Jökull, v. **10**: p. 30-32.

— (1961) "Jöklabreytingar (Glacier variations) 1959/60 og 1960/61": Jökull, v. **11**: p. 26-28.

— (1962) "Jöklabreytingar (Glacier variations) 1960/61 og 1961/62": Jökull, v. **12**: p. 37-38.

— (1963) "Jöklabreytingar (Glacier variations) 1961/62 og 1962/63." Jökull, v. **13**: p. 29-31.

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Jóhannesson, T., and Sigurðsson, O. (1998) "Interpretation of glacier variations in Iceland 1930-1995": Jökull, v. **45**: p. 27-33.

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— (1968) "Jöklabreytingar (Glacier variations) 1965/66, 1966/67 og 1967/68": Jökull, v. **18**: p. 401-405.

— (1970) "Jöklabreytingar (Glacier variations)1966/67, 1967/68 og 1968/69": Jökull, v. **20**: p. 78-82.

— (1970) "Jöklabreytingar (Glacier variations)1966/67, 1967/68 og 1968/69": Jökull, v. **20**: p. 93.

— (1970) "Jöklabreytingar (Glacier variations)1967/68, 1968/69 og 1969/70": Jökull, v. **20**: p. 83-87.

— (1971) "Jöklabreytingar (Glacier variations): 1931/64, 1964/70 og 1970/71": Jökull, v. **21**: p. 73-77.

— (1972) "Jöklabreytingar (Glacier variations): 1931/64, 1964/1971 og 1971/72": Jökull, v. **22**: p. 89-95.

— (1973) "Jöklabreytingar (Glacier variations): 1931/64, 1964/72 og 1972/73": Jökull, v. **23**: p. 61-66.

— (1974) "Jöklabreytingar (Glacier variations) 1931/64, 1964/73 og 1973/74": Jökull, v. **24**: p. 77-82.

— (1975) "Jöklabreytingar (Glacier variations) 1931/64, 1964/74 og 1974/75": Jökull, v. **25**: p. 73-79.

— (1976) "Jöklabreytingar (Glacier variations) 1964/65-1973/74 (10 ár), 1974/75 og 1975/76": Jökull, v. **26**: p. 69-74.

— (1977) "Jöklabreytingar (Glacier variations)1964/65-1973/74 (10 ár), 1974/75-1975/76 (2 ár) og 1976/77": Jökull, v. **27**: p. 88-93.

— (1978) "Jöklabreytingar (Glacier variations)1964/65-1973/74 (10 ár), 1974/75-1976/77 (3 ár) og 1977/78": Jökull, v. **28**: p. 61-65.

— (1981) "Jöklabreytingar 1964/65-1973/74 (10 ár), 1974/75-1977/78 (4 ár) og 1978/79. (Glacier variations)": Jökull, v. **31**: p. 37-41.

— (1981) "Jöklabreytingar 1964/65-1973/74 (10 ár), 1974/75-1978/79 (5 ár) og 1979/80. (Glacier variations)": Jökull v. **31**: p. 42-46.

— (1982) "Jöklabreytingar 1964/65-1973/74 (10 ár), 1974/75-1979/80 (6 ár) og 1980/81 (Glacier variations)": Jökull, v. **32**: p. 121-125.

— (1983) "Jöklabreytingar 1964/65-1973/74 (10 ár), 1974/75-1980/81 (7 ár) og 1981/82 (Glacier variations)": Jökull, v. **33**: p. 141-144.

— (1984) "Jöklabreytingar. (Glacier variations)": Jökull v. **34**: p. 173-179.

— (1985) " Jöklabreytingar 1964/65-1973/74 (10 ár), 1974/75-1983/84 (9 ár) og 1983/84": Jökull, v. **35**: p. 111-119.

— (1986) "Jöklabreytingar 1964/65-1973/74 (10 ár), 1974/75-1983/84 (10 ár) og 1984/85": Jökull, v. **36**: p. 83-90.

— (1987) "Jöklabreytingar 1964-1974 (10 ár), 1974-1985 (11 ár) og 1985/86": Jökull, v. **37**: p. 85-90.

Sigurðsson, O. (1988) "Jöklabreytingar 1930-1960, 1960-1980, 1980-1986 og 1986-1987": Jökull, v. **38**: p. 91-97.

— (1989) "Jöklabreytingar 1930-1960, 1960-1980, 1980-1987 og 1987-1988": Jökull, v. **39**: p. 108-113.

— (1990) "Jöklabreytingar 1930-1960, 1960-1980, 1980-1988 og 1988-1989": Jökull, v. **40**: p. 169-174.

— (1991) "Jöklabreytingar 1930-1960, 1960-1990 og 1989-1990": Jökull, v. **41**: p. 88-96.

— (1993) "Jöklabreytingar 1930-1960, 1960-1990 og 1991-1992": Jökull, v. **43**: p. 73-79.

— (1994) "Jöklabreytingar 1930-1960, 1960-1990 og 1992-1993": Jökull, v. **44**: p. 71-76.

— (1998) "Glacier variations in Iceland 1930-1995": Jökull v. **45**: p. 3-26.

— (1998) "Jöklabreytingar 1930-1960, 1960-1990 og 1993-1994": Jökull, v. **45**: p. 89-94.

— (1998) "Jöklabreytingar 1930-1960, 1960-1990 og 1994-1995": Jökull, v. **46**: p. 63-68.

— (1999) "Jöklabreytingar 1930-1960, 1960-1990 og 1995-1996": Jökull, v. **47**: p. 101-107.

— (2000) "Jöklabreytingar 1930-1960, 1960-1990 og 1996-1997": Jökull, v. **48**: p. 63-69.

— (2000) "Jöklabreytingar 1930-1960, 1960-1990 og 1997-1998": Jökull, v. **49**: p. 83-90.

— (2001) "Jöklabreytingar 1930-1960, 1960-1990, 1998-1999": Jökull, v. **50**: p. 129-136.

— (2002) "Jöklabreytingar 130-1960, 1960-1990 og 1999-2000": Jökull, v. **51**: p. 79-86.

— (2003) "Jöklabreytingar 1930-1960, 1960-1990 og 2000-2001": Jökull, v. **52**: p. 61-67.

— (2003) "Jöklabreytingar 1930-1960, 1960-1990 og 2001-2002 (glacier variations)": Jökull, v. **53**: p. 55-62.

— (2004) "Jöklabreytingar 1930-1960, 1960-1990 og 2002-2003 (glacier variations)": Jökull, v. **54**: p. 75-83

— (2004) Jaðar jökla í Vestur-Skaftafellssýslu og Rangárvallasýslu ákvarðaður með fjarkönnun, OS-2004/020 Reykjavík, Orkustofnun, p. 14 s. : myndir, 2 kort brotin.

Loftmyndir og gervihnattamyndir af jöklum í Vestur-Skaftafellssýslu og Rangárvallasýslu voru „réttar upp" í hornsannri keiluvörpun Lamberts í kerfi ÍSN93. Hér er gerð grein fyrir því hvernig útlínur jökla voru ákvarðaðar með því að rekja þær á myndum sem teknar voru á tímabilinu 1999-2003. Líkur eru leiddar að hversu mikið útlínur jöklanna kunna að hafa breyst frá gildistöku þjóðlendulaga 1. júlí 1998 til þess tíma sem þær voru teknar. Hnitsetning jökuljaðars með þessum aðferðum víkur sennilega hvergi meira en 60 m frá því sem var í reynd og víðast miklu minna. Líkur eru á að jöklar minnki ört í náinni framtíð vegna loftslagsbreytinga. Náttúruhamfarir kunna einnig að breyta jöklunum verulega eins og iðulega hefur gerst á sögulegum tíma.

— (2005) "Jöklabreytingar 1930-1960, 1960-1990 og 2003-2004 (glacier variations)": Jökull, v. **55**: p. 163-170.

Þorsteinsson, o.L. (1989) "Skarphéðinn Gíslason, Vagnsstöðum ": Skaftfellingur, v. **6**: p. 22-40.

Þórarinsson, S. (1956) "On the variations of Svínafellsjökull, Skaftafellsjökull and Kvíárjökull in Öræfi (Ágrip)." Jökull v. **6**: p. 1-15.

5.1.2 Tengsl milli jöklabreytinga og loftslagsbreytinga

Aðalgeirsdóttir, G., Jóhannesson, T., Björnsson, H., Pálsson, F., and Sigurðsson, O. (2006) "Response of Hofsjökull and southern Vatnajökull, Iceland, to climate change": Journal of Geophysical Research v. **111**(F03001).

Possible changes in glacier mass balance are among the most important consequences of future climate change with both local and global implications, such as changes in the discharge of glacial rivers, changes in the vertical stratification in the upper layers of the Arctic Ocean, and a rise in global sea level. The response of the Hofsjökull and southern Vatnajökull ice caps in Iceland to climate change is analyzed with a vertically integrated, finite difference ice flow model coupled with a degree day mass balance model. Transient climate change simulations are forced with a climate change scenario for the Nordic countries, which for Iceland, specifies a warming rate of 0.15°C per decade in midsummer and 0.3°C per decade in midwinter, with a sinusoidal variation through the year starting from the baseline period 1981–2000. Precipitation is either held steady or is increased at 5% per °C of warming. Modeled ice volume is reduced by half within 100–150 years. About 2030, annual average runoff from the area that is presently covered by ice is projected to have increased by approximately 0.7 m yr−1 for Hofsjökull and by 1.4 m yr−1 for southern Vatnajökull. The sensitivity of the mass balance of the ice caps to climate change was found to be in the range 0.4–0.8 mw.e. yr−1 °C−1 for Hofsjökull and 0.8–1.3 mw.e. yr−1 °C−1 for southern Vatnajökull. The sensitivity remained within these ranges more than 150 years into the future.

Björnsson, H. (1970) "Hugleiðingar um jöklarannsóknir á Íslandi": Jökull, v. **20**: p. 15-26.

This paper gives a short outline of some aspects of glaciology with the main emphasis on topics related to meteorology and hydrology. A descriptive summary of the basic theory and modern measurement techniques is given along with suggestions for new research projects in Iceland. Following topics are discussed: The main links in the relation between glacier variations and climate, the mass balance, the energy budget, glacier response, kinematic waves, diffusion of kinematic waves, response time and lag time of a glacier. The value of measurements of glacier variations in Iceland is discussed in light of these topics. Furher, a description is given of glacier flow and glacier surges. Crystallographic problems are briefly mentioned. The paper concludes with a proposal for investigations on Tungnaárjökull.

Björnsson, H., Aðalgeirsdóttir, G., Guðmundsson, S., Jóhannesson, T., Sigurðsson, O., and Pálsson, F. (2006) Climate change response of Vatnajökull, Hofsjökull and Langjökull ice caps, Iceland, European Conference on Impacts of Climate Change on Renewable Energy Sources (EURONEW), : Reykjavik, Iceland.

Björnsson, H., Guðmundsson, G.H., and Aðalgeirsdóttir, G. Flow modelling of a temperate ice cap, Vatnajökull Iceland.

The project aims at defining and testing two and three dimensional stationary and time dependent flow models to describe the ice cap Vatnajökull: general dynamics, flowlines, location of ice divides, velocity distribution, shape, thickness and extent, how close the ice cap is to an equilibrium state for the present mass balance distribution, its sensitivity to changes in mass balance and its response to climatic variations. The

models will be tested on available boundary values from detailed maps of the ice surface and the bedrock, internal volcanic ash layers, observed mass balance and surface velocidy, and existing data of glacier variations for the last centuries. Mass balance models derived from the ongoing international Vatnajökull project TEMBA will be used as an input to studies of the glacier response to various scenarios of climatic change. Detailed observations and model studies will be carried out of the effect of bedrock irregularities.

Field work started in August 1998, when GPS instruments from ETH, Zürich were used to measure velocity of the ice around a canyon that was created in the jökulhlaup that followed the 1996 eruption in Gjálp, Vatnajökull.

Björnsson, H., Guðmundsson, S., Aðalgeirsdóttir, G., Jóhannesson, T., Pálsson, F., and Sigurðsson, O. (2006) Climate change response of Vatnajökull, Hofsjökull and Langjökull ice caps, Iceland, International Symposium on Cryospheric Indicators of Global Climate Change: Cambridge, England.

Black, T. (1990) The Late Holocene Fluctuations of Kvíárjökull, Southeastern Iceland [**Unpublished Master´s thesis**]: Boulder, Colorado, University of Colorado.

Bradwell, T. (2001) Glacier fluctuations, lichenometry and climate change in Iceland. Unpublished PhD thesis: Edinburgh, University of Edinburgh.

— (2001) "A new lichenometric dating curve for southeast Iceland": Geografiska Annaler v. **83 A**: p. 91-101.

This paper presents a new lichenometric dating curve for southeast Iceland. The temporal framework for the curve is based on reliably dated surfaces covering the last 270 years, making it the best constrained study of this nature conducted in Iceland. The growth of lichen species within Rhizocarpon Section Rhizocarpon is non-linear over time, with larger (older) thalli apparently growing more slowly. The linear 'growth' curves derived previously by former authors working in Iceland represent only part of a curve which has an overall exponential form. Reasons for the non-linearity of the new dating curve are probably physiological, although climatic change over the last three centuries cannot be ruled out. Use of linear 'growth' curves in Iceland is problematic over time-spans of more than c. 80 years. Pre-20th century moraines dated using a constant, linear relationship between lichen size and age are probably older than previously believed. Those moraines lichenometrically 'dated' to the second half of the 19th century in Iceland may actually pre-date this time by several decades (30–100 years), thus throwing doubt on the exact timing of maximum glaciation during the 'Little Ice Age'.

— (2004) "Annual moraines and summer temperatures at Lambatungnajökull, Iceland": Arctic, Antarctic and Alpine Researh, v. **36**: p. 502-508.

— (2004) "Lichenometric dating in southeast Iceland- the size-frequency approach." Geografiska Annaler v. **86 A**: p. 31-41.

The age of recent deposits can be determined using an intrinsic characteristic of the lichen 'population' growing on their surface. This paper presents a calibrated dating curve *based on the gradient of the size-frequency distribution of yellow-green Rhizocarpon lichens. The dating potential of this new curve is tested on surfaces of known age in southeast Iceland. This particular size—frequency technique is also compared with the more traditional largest-lichen approach. The results are very encouraging and suggest that the gradient can be used as an age indicator, at least on deposits formed within the last c. 150 years – and probably within the last c. 400 years – in the maritime subpolar climate of southeast Iceland. Using both lichenometric techniques, revised dates for moraines on two glacier forelands are presented which shed new light on the exact timing of the Little Ice Age glacier maximum in Iceland.*

Bradwell, T., Dugmore, A.J., and Sugden, D.E. (2006) "The Little Ice Age glacier maximum in Iceland and the North Atlantic Oscillation: evidence from Lambatungnajökull, southeast Iceland": Boreas, v. **35**(1): p. 61-80.

This article examines the link between late Holocene fluctuations of Lambatungnajökull, an outlet glacier of the Vatnajökull ice cap in Iceland, and variations in climate. Geomorphological evidence is used to reconstruct the pattern of glacier fluctuations, while lichenometry and tephrostratigraphy are used to date glacial landforms deposited over the past ~400 years. Moraines dated using two different lichenometric techniques indicate that the most extensive period of glacier expansion occurred shortly before c. AD 1795, probably during the 1780s. Recession over the last 200 years was punctuated by re-advances in the 1810s, 1850s, 1870s, 1890s and c. 1920, 1930 and 1965. Lambatungnajökull receded more rapidly in the 1930s and 1940s than at any other time during the last 200 years. The rate and style of glacier retreat since 1930 compare well with other similar-sized, non-surging, glaciers in southeast Iceland, suggesting that the terminus fluctuations are climatically driven. Furthermore, the pattern of glacier fluctuations over the 20th century broadly reflects the temperature oscillations recorded at nearby meteorological stations. Much of the climatic variation experienced in southern Iceland, and the glacier fluctuations that result, can be explained by secular changes in the North Atlantic Oscillation (NAO). Advances of Lambatungnajökull generally occur during prolonged periods of negative NAO index. The main implication of this work relates to the exact timing of the Little Ice Age in the Northeast Atlantic. Mounting evidence now suggests that the period between AD 1750 and 1800, rather than the late 19th century, represented the culmination of the Little Ice Age in Iceland.

Caseldine, C.J., Russell, A.J., Knudsen, Ó., and Harðardóttir, J. (2005) Iceland Modern Processes and Past Environments, Elsevier.

Iceland provides an unique stage on which to study the natural environment, both past and present, and it is understanding both aspects of reconstructing the past and observing and interpreting the present that form the focus of the contributions to this volume.

The papers are all written by active researchers and incorporate both reviews and new data. Although concentrating largely on the recent Quaternary timescale a wide range of topics is explored including subglacial volcanism, onshore and offshore evidence for the Last Glacial Maximum and subsequent deglaciation, current glacial characteristics including jökulhlaups and glacial landsystems, soil development, Holocene ecosystem change, current oceanography, impacts of volcanic sulphur loading, chemical weathering and the CO2 budget and documentary evidence for historical climate.

Contents

Preface. 1. Iceland. modern processes, past environments: an introduction (C. Caseldine et al.). 2. Late Quaternary marine sediment studies of the Icelandic shelf-palaeoceanography, land/ice sheet/ocean interactions and deglaciation: a review (J.T. Andrews). 3. Relative sea level change in Iceland: new aspects of the Weichselian deglaciation of Iceland (H. Norddahl and H. Petursson). 4. Recent developments in oceanographic research in Icelandic waters (S. Jonsson, H. Valdimarsson). 5. The glacier-marginal landsystems of Iceland (D.J.A. Evans). 6. Subglacial volcanic activity in Iceland (M.T. Gudmundsson). 7. Icelandic jökulhlaup impacts (A.J. Russell et al.). 8. Environmental and climatic effects from atmospheric SO2 mass-loading by Icelandic flood lava eruptions (P. Pordarson). 9. Holocene glacier history (M. Wastl, J. Stotter). 10. Variations of termini of glaciers in Iceland in recent centuries and their connection with climate (O. Sigurdsson). 11. Local knowledge and travellers' tales: a selection of climatic observations in Iceland (A. Ogilvie). 12. Chemical weathering, chemical denudation and the CO2 budget for Iceland (S.R. Gislason). 13. Icelandic soils (O. Arnalds). 14. The Holocene vegetation history of Iceland, state-of-the-art and future research (M. Hallsdottir, C. Caseldine).

Casely, A.F., and Dugmore, A.J. (2004) "Climate change and ´anomalous´ glacier fluctuations: the southwest outlets of Mýrdalsjökull, Iceland": Boreas, v. **33**: p. 108-122.

Dabski, M. (2002) "Dating of the Fláajökull moraine ridges, SE-Iceland; comparison of the glaciological, cartographic and lichenometric data": Jökull, v. **51**: p. 17-24.

de Ruyter de Wildt, M.S.D., Klok, E.J., and Oerlemans, J. (2003) "Reconstruction of the mean specific mass balance of Vatnajokull (Iceland) with a seasonal sensitivity characteristic": Geografiska Annaler Series a-Physical Geography, v. **85A**(1): p. 57-72.

We present a Seasonal Sensitivity Characteristic (SSC) of Vatnajokull (Iceland), which consists of the sensitivity of the mean specific mass balance to monthly perturbations in temperature and precipitation. The climate in Iceland is predominantly maritime (high precipitation) although often the polar air mass influences the area. This results in temperature sensitivities that are high in summer and nearly zero during the winter months. In contrast, precipitation sensitivities are high in winter and low in summer. We use the SSC of Vatnajokull as a reduced mass balance model, with which we reconstruct the mass balance of Vatnajokull since 1825. The reduced model shows that changes in temperature and precipitation like the ones observed both have a significant impact upon the mass balance. The reconstructed mass balance records for two Icelandic glaciers correlate very well with mass balance records that are extracted from length records with a linear inverse model. This places confidence in both the reduced (forward) mass balance model and in the inverse model, although the forward method produces larger mass balance variations than the inverse method. For the south of Vatnajokull we find that after 1900, the length record is well explained by temperature variations alone, while another Icelandic glacier (Solheimajokull) was also influenced by precipitation variations.

Dugmore, A.D. (1989) Tephrachronological studies of Holocene glacier fluctuations in south Iceland, *in* Oerlemans (ed.), ed., Glacier Fluctuations and Climatic Change: Dordrecht., Kluwer, p. pp.37-55. .

Evans, D.J.A., Archer, S., and Wilson, D.J.H. (1999) "A comparison of the lichenometric and Schmidt hammer dating techniques based on data from the proglacial areas of some Icelandic glaciers": Quaternary Science Reviews, v. **18**(1): p. 13-41.

Measurements of Rhizocarpon section and Schmidt hammer R-values are reported from the proglacial geomorphic features on the forelands of the Icelandic glaciers of Kvíárjökull, Hólárjökull and Heinabergsjökull (Öræfi and south Vatnajökull), Sandfellsjökull and Öldufellsjökull (east Mýrdalsjökull), and Brúárjökull, Eyjabakkajökull and west Snæfell (north Vatnajökull). These data are used in reconstructions of patterns of glacier recession since the Little Ice Age maximum, and the geomophic signals of climatic versus non-climatic events are discussed. Age control was obtained from various dated substrates by utilizing historical accounts, aerial photographs and grave stones. Three lichen growth rates are calculated: (a) 0.51 mm a−1 (corrected to 0.50 mm a−1) with a colonization lag time of < 16 yr for the arid forelands of north Vatnajökull; (b) 0.56 mm a−1 with a colonization lag time of 5 yr for the Icelandic southeast coast; and (c) 0.80 mm a−1 with a colonization lag time of 6.5 yr for the south Vatnajökull and east Mýrdalsjökull forelands. These compare favourably with a previously published growth rate of 0.44 mm a−1 for the arid north of Iceland. This regional coverage of data allows a comparison between annual precipitation totals and lichen growth rates and the construction of a growth rate prediction curve for Iceland. The success of the Schmidt hammer in differentiating moraines based upon age varied according to the geomorphological setting. Reasonable R-value/lichen size correlations were obtained on the east Mýrdalsjökull and Heinabergsjökull forelands where unrestricted glacier advance into lowlands allows for a higher degree of debris surface freshening by direct glacial processes. Weak correlations were obtained at Kvíárjökull, where the glacier was restricted by a precursor latero-frontal moraine loop and therefore the debris comprising the Little Ice Age recessional moraines was diluted with material of various ages being reworked by mass movement from the precursor moraine loop. Similar problems arise in areas affected by surging glaciers, such as Brúárjökull and Eyjabakkajökull. It appears that an accurate R-value age-prediction curve can not be constructed for a timescale of < 100 yr in Iceland.

Gardarsson, S.M., and Eliasson, J. (2006) "Influence of climate warming on Hálslon reservoir sediment filling": Nordic Hydrology, v. **37**(3): p. 235-245.

Halslon reservoir is the main reservoir of the Kárahnjúkar hydropower project in the eastern highlands of Iceland. Studies for the environmental impact assessment for the hydropower project showed that sediment will fill the reservoir in about 500 years based on the present sediment transport rate. The main source of the sediment is the Brúarjökull outlet glacier which is a part of the Vatnajökull ice cap. Recent studies of the influence of climate warming on glaciers in Iceland show that they will decrease significantly and, in some cases, completely disappear during the next few hundred years. In this study, a glacier melt model for the Brúarjökull outlet glacier is constructed to predict how fast the glacier will retreat in response to accepted climate warming scenarios. The results from the glacier model are then used as input to a sediment transport mass balance model for the Hálslon reservoir, which predicts the influence of the retreat of the glacier on the sedimentation in the reservoir. The modeling shows that, instead of the reservoir being completely full of sediment in 500 years, the Halslon reservoir will at that time still have about 50-60% of its original volume as the sediment yield will decrease as a result of the decreasing glacier size.

Gardarsson, S.M., Jonsson, B., and Elíasson, J. (2005) Sediment model of Hálslon Reservoir filling taken into account Brúarjökull Glacier recede, EGU 2005, Volume **7**: Vienna.

Guðmundsson, S., Björnsson, H., Aðalgeirsdóttir, G., Jóhannesson, T., Pálsson, F., and Sigurðsson, O. (2006) Áhrif loftlagsbreytinga á stærð og afrennsli Langjökuls, Hofsjökuls og suður Vatnajökuls, Orkuþing 2006: Reykjavík.

Ives, J.D. (1994-1996) "Glacier and Climate Reconstruction in Southeast Iceland During the Last two Millennia: a Reconnaissance. " Jahrbuch der Geographischen Gesellschaft Bern, v. **Band 59/1994-1996**.

Jóhannesson, T., Aðalgeirsdóttir, G., Björnsson, H., Ahlstrøm, A., Andreassen, L.M., Björnsson, H., de Woul, M., Elvehøy, H., Flowers, G.E., Guðmundsson, S., Hock, R., Holmlund, P., Pálsson, F., Radic, V., Sigurðsson, O., and Thorsteinsson, T. (2006) The impact of climate change on glaciers and glacial runoff in the Nordic countries, European Conference on Impacts of Climate Change on Renewable Energy Sources (EURONEW): Reykjavik, Iceland.

Jóhannesson, T., Aðalgeirsdóttir, G., Björnsson, H., Elvehøy, C.E.B.H., Guðmundsson, S., Hock, R., Holmlund, P., Jansson, P., Pálsson, F., Sigurðsson, O., and Þorsteinsson (2004) The impacts of climate change on glaciers in the Nordic countries, Report for Climate, Water and Energy (CWE).

Jóhannesson, T., Aðalgeirsdóttir, G., Björnsson, H., Pálsson, F., and Sigurðsson, O. (2004) Response of glaciers and glacier runoff in Iceland to climate change, *in* Järvert, A., ed., Nordic Hydrological Conference 2004 (NHC 2004), Volume **NHP-rapport no. 48**: Tartu, Nordic Hydrological Programme, p. 651-660.

Kaldal, I., and Víkingsson, S. (2001) "Saga jökulhörfunar og forns jökullóns sunnan Kárahnjúka": Glettingur v. **11**(2-3): p. 31-36.

Kirkbride, M.P., and Dugmore, A.J. (2001) "Can lichenometry be used to date the Little Ice Age glacial maximum in Icelands? " Climatic Change v. **48**: p. p. 151-167.

Klok, E.J., and Oerlemans, J. (2003) "Deriving historical equilibrium-line altitudes from a glacier length record by linear inverse modelling": The Holocene, v. **13**(4): p. 343 - 351.

Glaciers have fluctuated in historic times and the length fluctuations of many glaciers are known. From these glacier length records, a climate reconstruction described in terms of a reconstruction of the equilibrium-line altitude (ELA) or the mass-balance can be extracted. In order to derive a climate signal from numerous glacier length records, a model is needed that takes into account the main characteristics of a glacier, but uses little information about the glacier itself. Therefore, a simple analytical model was

developed based on the assumption that the change in glacier length can be described by a linear response equation. Historical length observations, the climate sensitivity and the response time of a glacier were needed to calculate historical equilibrium-line altitudes. Both climate sensitivity and length response time were calculated from a perturbation analysis on the continuity equation. The model was tested on 17 European glacier length records. The results revealed that the ELA of most glaciers increased on average 54 m between AD 1920 and 1950. The results of the analytical model were compared to mass-balance reconstructions calculated with a numerical flowline model and derived from historical temperature and precipitation records. The findings lead us to believe that the analytical model could be very useful to gain information about the historical mass-balance rates and ELAs.

Magnússon, E., Björnsson, H., Dall, J., and Pálsson, F. (2005) "The 20th century retreat of ice caps in Iceland derived from airborne SAR: W-Vatnajokull and N-Myrdalsjokull": Earth and Planetary Science Letters, v. **237**(3-4): p. 508-515.

We present observations of the long-term recession of surging outlets of Icelandic ice caps in response to 20th century climate. In August 1998, synthetic aperture radar (SAR) data, covering the western part of Vatnajokull and the northern part of Mýrdalsjökull in southern Iceland, were acquired with the Danish airborne EMISAR radar system. Polarimetric and interferometric SAR data reveal the margins of the present ice caps as well as a series of terminal moraines in the fore field. These moraines date back to the maximum Neoglacial extent at the end of the 19th century and the outermost allow reconstruction of the margin at that time. The data offer a unique opportunity to estimate the area decrease of these ice caps in the 20th century. The influence of the fluctuations of the surge type outlets, constituting most of W-Vatnajökull area and a good part of N-Mýrdalsjökull area, is minimal, since they had all recently surged in 1998 as was presumably the case when the outermost moraines were formed. The major contributor to the area decrease is therefore climate changes in the 20th century even though the glacier retreat has been interrupted by short-lived surges. Moraines associated with most of the surges in W-Vatnajökull in the 20th century are observed in the SAR data including the most recent surges in the 1990s. Interestingly no push moraines were observed in front of the surge advance, but the moraines appear when the glaciers start retreating. We estimate that the collective decrease of the outlets of western Vatnajokull since maximum Neoglacial extent of each outlet, is 109 km2 (6.7%) corresponding to an average retreat of 850 m over a 130 km long margin. In the same period the outlet Slettjökull, in N-Mýrdalsjökull, has decreased by 33 km2 (20%) corresponding to an average retreat of 1500 m over a 20 km long margin.

McKinzey, K.M., Orwin, J.F., and Bradwell, T. (2004) "Re-dating the moraines at Skálafellsjökull and Heinabergsjökull using different lichenometric methods: implications for the timing of the Icelandic Little Ice Age Maximum": Geografiske Annaler, v. **86A**: p. p.319-335.

Little Ice Age (LIA) moraines along the margins of Skálafellsjökull and Heinabergsjökull, two neighbouring outlet glaciers flowing from the Vatnajökull ice-cap, have been re-dated to test the reliability of different lichenometric approaches. During 2003, 12 000 lichens were measured on 40 moraine fragments at Skálafellsjökull and Heinabergsjökull to provide surface age proxies. The results are revealing. Depending on the chosen method of analysis, Skálafellsjökull either reached its LIA maximum in the early 19th century (population gradient) or the late 19th century (average of five largest lichens), *whereas the LIA maximum of Heinabergsjökull occurred by the mid-19th century (population gradient) or late-19th century (average of 5 largest lichens). Discrepancies (c. 80 years for Skálafellsjökull and c. 40 years for Heinabergsjökull) suggest that the previously cited AD 1887 LIA maxima for both glaciers should be reassessed. Dates predicted by the lichen population gradient method appear to be the most appropriate, as mounting evidence from other geochronological reconstructions and sea-ice records throughout Iceland tends to support an earlier LIA glacier maximum (late 18th to mid-19th century) and probably reflects changes in the North Atlantic Oscillation. These revised chronologies shed further light on the precise timing of the Icelandic LIA glacier maximum, whilst improving our understanding of glacier-climate interactions in the North Atlantic.*

McKinzey, K.M., Orwin, J.F., and Bradwell, T. (2004) "Re-dating the moraines at Skálafellsjökull and Heinabergsjökull using different lichenometric methods: implications for the timing of the Icelandic Little Ice Age Maximum": Geografiske Annaler, v. **86A**: p. p.319-335.

Little Ice Age (LIA) moraines along the margins of Skálafellsjökull and Heinabergsjökull, two neighbouring outlet glaciers flowing from the Vatnajökull ice-cap, have been re-dated to test the reliability of different lichenometric approaches. During 2003, 12 000 lichens were measured on 40 moraine fragments at Skálafellsjökull and Heinabergsjökull to provide surface age proxies. The results are revealing. Depending on the chosen method of analysis, Skálafellsjökull either reached its LIA maximum in the early 19th century (population gradient) or the late 19th century (average of five largest lichens), whereas the LIA maximum of Heinabergsjökull occurred by the mid-19th century (population gradient) or late-19th century (average of 5 largest lichens). Discrepancies (c. 80 years for Skálafellsjökull and c. 40 years for Heinabergsjökull) suggest that the previously cited AD 1887 LIA maxima for both glaciers should be reassessed. Dates predicted by the lichen population gradient method appear to be the most appropriate, as mounting evidence from other geochronological reconstructions and sea-ice records throughout Iceland tends to support an earlier LIA glacier maximum (late 18th to mid-19th century) and probably reflects changes in the North Atlantic Oscillation. These revised chronologies shed further light on the precise timing of the Icelandic LIA glacier maximum, whilst improving our understanding of glacier-climate interactions in the North Atlantic.

Norðdahl, H. (1991) "Climatic significance of glacier variations in Iceland and their potential value for climate reconstruction": Ice, v. **96**: p. 15.

Orwin, J.F., McKinzey, K.M., Stephens, M.A., and Dugmore, A.J. (submitted) "Mapping former ice margins using moraine lichen size distributions and the U2 statistic, southeast Iceland": Arctic, Antarctic and Alpine Researh.

Sigurðsson, O., and Jónsson, T. (1995) "Relation of glacier variations to climate changes in Iceland": Annals of Glaciology v. **21**: p. 263-270.

Sigurðsson, O., Jónsson, T., and Jóhannesson, T. (2007) "Relation between glacier front variations and summer temperature in Iceland since 1930": Annals of Glaciology, v. **46**.

Sigbjarnarson, G. (1969) Næmleiki jökla fyrir veðurfarsbreytingum., *in* Einarsson (ritstj.), M.Á., ed., Hafísinn. : Reykjavík, Almenna Bókaforlagið, p. bls. 346-363.

Sigurðsson, O. (2001) Jöklabreytingar á Islandi undanfarnar fjórar aldir, Vorráðstefna 2001: ágrið erinda og veggspjalda: Hótel Loftleiðum, Reykjavík, Jarðfræðifélag Íslands.

Sigurðsson, O., and Jónsson, T. (1995) "Relation of glacier variations to climate changes in Iceland": Annals of Glaciology v. **21**: p. 263-270.

Þórarinsson, S. (1969) Afleiðingar jöklabreytinga á Íslandi ef tímabil hafísára fer í hönd, Hafísinn: Reykjavík, A.B., p. 364-388; Kort, línurit.

— (1969) "The effect of glacier changes in Iceland resulting from increase in the frequency of drift ice years": Jökull, v. **19**: p. 103.

5.1.3 Aðrar heimildir um jöklabreytingar

Áskelsson, J. (1944) "Nútímajöklar": Náttúrufræðingurinn, v. **14. árg.**: p. 102.

Bárðarson, G.G. (1934) "Islands Gletscher. Beitrage zur Kenntnis der Gletscherbewegungen und Schwankungen auf Grund alter Quellenschriften und neuster Forschung": Societas Scientiarum Islandica, v. **Rit 16**: p. 1-60.

Björnsson, S. (1958) "Úr bréfum. Hrútárjökull og draumur Guðrúnar Bjarnadóttir ": Jökull v. **8**(bls. 36).

Evans, D.J.A., and Twigg, D.R. (2002) "The active temperate glacial landsystem: a model based on Breiðamerkurjökull and Fjallsjökull, Iceland": Quaternary Science Reviews, v. **21**(20-22): p. 2143-2177.

Accurate interpretations of ancient glaciated terrains rely heavily on our knowledge of process-form relationships in contemporary glacierized basins. A landsystems model for temperate, actively receding glaciers is presented based upon Breiðamerkurjökull and Fjallsjökull, Iceland. Historical documentation, maps and/or aerial photography documenting recession since 1903 provide a unique series of "snapshots" of the evolving glacial geomorphology at these snouts. This documentation is employed in association with sedimentological investigations to assess the evolution of sediment-landform assemblages at active temperate glacier margins, using the wealth of geomorphological and sedimentological information produced during the recent recession of Breðamerkurjokull and Fjallsjökull. Three depositional domains are recognized: (1) areas of extensive, low amplitude marginal dump, push and squeeze moraines derived largely from material on the glacier foreland and often recording

annual recession of active ice; (2) incised and terraced glacifluvial forms, such as recessional ice-contact fans and hochsandur fans, and simple and complex, anabranched eskers and small areas of pitted outwash; (3) subglacial landform assemblages of flutes, drumlins and overridden push moraines located between ice-marginal glacifluvial depo-centres. The lack of supraglacial sediment in active temperate glaciers like Breiðamerkurjökull and Fjallsjökull generally precludes the widespread development of chaotic hummocky moraine. The hummocky terrain previously termed "kame and kettle topography" has mostly evolved by melt-out into a complex network of anabranched eskers over the period 1945-1998 or actually comprises pitted or kettled outwash (sandar). The tills across the foreland were emplaced by subglacial deformation and lodgement, and comprise materials derived from pre-existing stratified sediments in addition to localized abrasion of rock surfaces and patches of lake sediments. Till sequences thicker than 2 m have been constructed by the sequential plastering of till layers onto stratified sediments and bedrock. Because this stacking is a sub-marginal process, it is suggested that complex till sequences similar to those observed at Breiðamerkurjökull/Fjallsjökull may be employed in the reconstruction of ancient glacier margins. Additionally, the geomorphology of the active, temperate landsystem at east Breiðamerkurjokull may contain subtle surge signatures, verifying the historical record of small surges by this part of the glacier. This illustrates the danger of employing landform-sediment associations from restricted study areas (e.g. parts of landsystems) as representative process-form models for glaciated terrains.

Guðmundsson, H.J. (1998) Breytingar á Kvíárjökli á Nútíma. , *in* (ritstj.):, G.S.A., ed., Kvískerjabók: rit til heiðurs systkinunum á Kvískerjum: Höfn í Hornafirði, Sýslusafn Austur-Skaftafellssýslu, p. bls. 49-55.

— (1998) Holocene glacier fluctuations and tephrochronology of the Öræfi district, Iceland [**PhD thesis**], University of Edinburgh, Scotland.

Jónsson, E. (2004) Í veröld jökla, sanda og vatna, *in* Björnsson, H., ed., Jöklaveröld, náttúra og mannlíf: Reykjavík, Skrudda, p. 11-86.

Marren, P.M. (2002) "Glacier margin fluctuations, Skaftafellsjökull, Iceland: implications for sandur evolution." Boreas, v. **Vol. 31**: p. 75-81.

Sharp, M.J., and Dugmore, A. (1985) "Holocene glacier fluctuations in eastern Iceland. " Zeitschrift fuer Gletscherkunde und Glazialgeologie, v. **21**: p. 341-349.

Stratigraphic investigations at two outlet glaciers of Vatnajökull: Skálafellsjökull (non-surging) and Eyjabakkajökull (surging). Follows pattern of glacier fluctuations from Holocene to Little Ice Age.

Sigbjarnarson, G. (1970) "On the recession of Vatnajökull. " Jökull, v. **20**: p. 50-61.

Sigbjarnason, G. (1969) "On the recession of Vatnajökull": Jökull, v. **19**: p. 102.

Snorrason, S. (1978) Breytingar á jaðri Fláajökuls og rennsli frá honum: Reykjavík, Raunvísindastofnun Háskólans, p. 12.

— (1979) Mýrajöklar og Vatnsdalur í A-Skaftafellssýslu. [**4. árs ritgerð**]: Reykjavík, Háskói Íslands.

— (1984) Mýrajöklar og Vatnsdalur (+ jarðfræðikort af svæðinu fyrir framan Skálafells-, Heinabergs- og Fláajökul), Háskólinn í Oslo.

Tómasson, H. (1987) "The history of mapping in Iceland, with special reference to glaciers. " Annals of Glaciology, v. **Vol. 8**: p. p. 4-7.

Williams, R.S.J., Hall, D.K., Sigurðsson, O., and Chien, J.Y.L. (1997) "Comparison of satellite-derived with ground-based measurements of the fluctuations of the margins of Vatnajökull, Iceland, 1973-1992 ": Annals of Glaciology v. **24**: p. 72-80.

Þórarinsson, S. (1939) "Vatnajökull; Scientific results of the Swedish-Icelandic investigations 1936-37-38. Chapter 9. The ice dammed lakes of Iceland with particular reference to their values as indicators of glacier oscillations": Geografiske Annaler, v. **21**(3-4): p. 216-242.

Discusses about 20 lakes and summarizes conclusions with regard to glacier fluctuations in historic times

— (1940) "Present Glacier Shrinkage and Eustatic Changes of Sea-Level": Geografiske Annaler, v. **22**: p. 131-159.

— (1943) "Vatnajökull; Scientific results of the Swedish-Icelandic investigations 1936-37-38. Chapt. 11. Oscillations of the Icelandic Glaciers in the last 250 years": Geografiska Annaler v. **25** (1-2): p. bls. 1-54.

Oscillations of the Iceland glaciers in the last 250 years. Detailed table and discussion

— (1956) "On the variations of Svínafellsjökull, Skaftafellsjökull and Kvíárjökull in Öræfi (Ágrip)." Jökull v. **6**: p. 1-15.

5.2 Jökulhlaup tengd eldvirkni

5.2.1 Grímsvötn, Gjálp, hlaup í Skeiðará

Áskelsson, J. (1959) "Skeiðarárhlaupið og umbrotin í Grímsvötnum": Jökull, v. **9**: p. 22-29.

Benediktsson, S., and Helgadóttir, S. (1997) Skeiðarárhlaup: Reykjavík, Náttúruverndarráð.

Björnsson, H. (1992) "Jökulhlaups in Iceland: prediction, characteristics and simulation": Annals of Glaciology, v. **16**: p. 95-106.

Jökulhlaups drain regularly from six subglacial geothermal areas in Iceland. From Grímsvötn in Vatnajökull, jökulhlaups have occurred at a 4-6 year interval since the 1940s with a peak discharge of 1,000 - 10,000 m3/s, 2 -3 weeks duration and total volumes of 0.5-3 km3. Prior to that, about one jökulhlaup occurred per decade with an estimated discharge of 5 km3 of water and a peak discharge of approximately 30,000 m3/s. Clarke½s (1982) modification of Nye's (1976) general model of discharge of jökulhlaups gives in many respects satisfactory simulations for jökulhlaups from Grímsvötn. The best fit is obtained for the Manning roughness coefficients n = 0.08-0.09 m-1/3 s and a constant lake temperature of 0.2 °C (which is the present lake temperature). The rapid ascent of the exceptional jökulhlaup in 1938, which accompanied a volcanic eruption, can only be simulated for a lake temperature of the order of 4 °C. Jökulhlaups originating at geothermal areas beneath ice cauldrons located 10-15 km northwest of Grímsvötn have a peak discharge of 200 - 1,500 m3/s in 1-3 days, the total volume is 50-350x106m3, and they recede slowly in 1-2 weeks. The form is in that respect a mirror image of the typical Grímsvötn hydrograph. The reservoir water temperature must be well above the melting point (10-20 °C) and the flowing water seems not to be confined to a tunnel but spread out beneath the glacier and later gradually collected back to conduits. Since the time of the settlement of Iceland (870 A.D.), at least 80 subglacial volcanic eruptions have been reported, many of them causing tremendous jökulhlaups with dramatic impact on inhabitated areas and landforms. The peak discharge of the largest floods (from Katla) has been estimated at the order of 100-300,000 m3/s, duration was 3 -5 days and the total volume of the order of 1 km3. It is now apparent that the potentially largest and most catastrophic jökulhlaups may be caused by eruptions in the voluminous ice-filled calderas in northern Vatnajökull (of Bárdarbunga and Kverkfjöll). They may be the source of prehistoric jökulhlaups, with estimated peak discharge of 400,000 m3/s. At present, jökulhlaups originate from some fifteen marginal ice-dammed lakes in Iceland. Typical values for peak discharges are 1,000 - 3,000 m3/s, duration 2-5 days and total volumes of 2,000 x 106 m3. Hydrographs for jökulhlaups from marginal lakes have a shape similar to those of the typical Grímsvötn jökulhlaup. Simulations give reasonable ascent of the hydrographs for constant lake temperature of about 1 °C but fail to show the recession. Some floods from marginal lakes, however, have reached their peaks exceptionally rapidly, in one day. That ascent could be simulated by drainage of lake water of 4-8 °C. An empirical power law relationship is obtained between peak discharge and total volume of the jökulhlaups from Grímsvötn; Qmax = K Vtb, where Qmax is measured in m3/s, Vt in 106 m3, K = 4.15 10-3 s-1 m-2.52 and b = 1.84. In general, the jökulhlaups (excepting those caused by eruptions) occur when the lake has risen to a critical level, but before a lake level required for simple flotation of the ice dam is reached. The difference between the hydrostatic water pressure maintained by the lake and the ice overburden pressure of the ice dam is of the order 2-6 bar.

— (1997) Grímsvatnahlaup fyrr og nú, *in* Haraldsson, H., ed., Vatnajökull : gos og hlaup 1996 : skýrsla unnin fyrir Vegagerðina af Raunvísindastofnun Háskólans og Orkustofnun: Reykjavík, Vegagerðin, p. 61-78.

— (2002) "Subglacial lakes and jökulhlaups in Iceland": Global and planetary change, v. **35**: p. 255-271.

Active volcanoes and hydrothermal systems underlie ice caps in Iceland. Glacier–volcano interactions produce meltwater that either drains toward the glacier margin or accumulates in subglacial lakes. Accumulated meltwater drains periodically in jökulhlaups from the subglacial lakes and occasionally during volcanic eruptions. The release of meltwater from glacial lakes can take place in two different mechanisms. Drainage can begin at pressures lower than the ice overburden in conduits that expand slowly due to melting of the ice walls by frictional and sensible heat in the water. Alternatively, the lake level rises until the ice dam is lifted and water pressure in excess of the ice overburden opens the waterways; the glacier is lifted along the flowpath to make space for the water. In this case, discharge rises faster than can be accommodated by melting of the conduits. Normally jökulhlaups do not lead to glacier surges but eruptions in ice-capped stratovolcanoes have caused rapid and extensive glacier sliding. Jökulhlaups from subglacial lakes may transport on the order of 107 tons of sediment per event but during violent volcanic eruptions, the sediment load has been 108 tons.

Björnsson, H., and Einarsson, P. (1990) "Volcanoes beneath Vatnajökull, Iceland: Evidence from radio echo-sounding earthquakes and jökulhlaups": Jökull, v. **40**: p. 147-168.

Integration of knowledge of subglacial topography, earthquake activity and jökulhlaups has contributed to more precise locations of the volcanic systems beneath Vatnajökull. Bárðarbunga is the centre of a volcanic system which includes the fissure swarms of Veiðivötn to the SW and Dyngjuháls to the NE. The Grímsvötn volcano is the centre of a system that comprises the Laki fissure swarm in the SW and extends for an unknown distance to the NE of the volcano. Þórðarhyrna is probably a separate central volcano within this system. The Kverkfjöll system can be traced 10 km to the SW of the Kverkfjöll volcano. It appears to be separated from the Grímsvötn volcano. The Askja fissure swarm extends beneath Dyngjujökull and can possibly be traced to the Grímsvötn volcano. Hamarinn and the ridge striking eastward from Hamarinn (Loki Ridge) are central volcanoes which together with the Fögrufjöll fissure swarm form a volcanic system. No support can be found in the topographic data for the existence of a central volcano near Breiðabunga. Volcanic activity in historical times has mainly been limited to the Grímsvötn and Bárðarbunga systems. Major rifting events have affected large sections of these volcanic systems but both have been remarkably quiet for the past decades. A few volcanic events are presumed to have occurred on the Hamarinn - Loki system and on the Askja fissure swarm beneath Dyngjujökull, but no event is known with certainty on the Kverkfjöll system. The rivers Skeiðará and Súla have the most frequent eruption-related jökulhlaups. They receive meltwater from the Grímsvötn caldera and the area to the SW of it, including Þórðarhyrna. Núpsvötn, Djúpá and Hverfisfljót drain the southwestern part of the Grímsvötn system, an area bounded by Þórðarhyrna, Geirvörtur, Hágöngur and Pálsfjall. Skaftá drains the Loki Ridge and the area west of Grímsvötn. Jökulhlaups in Kaldakvísl, and ultimately Þjórsá, must originate in the Bárðarbunga or the Hamarinn - Loki systems, and the only possible source for volcanic jökulhlaups in Skjálfandafljót is the northern part of the Bárðarbunga system. Jökulsá á Fjöllum may drain meltwater from activity in all the volcanic systems in northern Vatnajökull: Bárðarbunga, the Askja fissure swarm and Kverkfjöll. This includes the voluminous, ice-filled calderas of Bárðarbunga and Kverkfjöll. Activity in the northern part of the Grímsvötn system may cause floods in

Jökulsá á Fjöllum. Meltwater from volcanic activity on the SE flank of a ridge that strikes south from Kverkfjöll may drain to Jökulsá á Brú. Volcanic activity farther north on the E flanks of this ridge would cause floods in Kreppa.

Björnsson, H., and Hallgrímsson, M. (1976) "Mælingar í Grímsvötnum við Skeiðarárhlaup 1972 og 1976": Jökull, v. **26**: p. 91-92.

Björnsson, H., and Kristmannsdóttir, H. (1984) "The Grímsvötn geothermal area, Vatnajökull, Iceland (Jarðhitasvæðið í Grímsvötnum)": Jökull, v. **34**: p. 25-50.

Melting of ice at the Grímsvötn geothermal area has created a depression in the surface of the ice cap Vatnajökull and produced a subglacial lake from which jökulhlaups drain to Skeiðarársandur. The geothermal activity is also expressed by small cauldrons on the surface of the ice as well as by fumaroles on two nunataks that rise 300 m above the lake level. Vapour from the fumaroles yields little information about the deep reservoir fluid. The vapour seeps upwards from the water table and repeatedly condenses and evaporates on the way to the surface. The chemistry of the water in jökulhlaups, however, provides information about the fluid in the geothermal system. This information is not easy to interpret because of water-rock interaction in the lake. Silica solubility data and assumptions about the likely reservoir temperature, however, indicate that about 15% of the total mass in the lake is fluid discharged from the geothermal reservoir. This information about the geothermal mass fraction together with mass and energy balances for the lake enables one to calculate the masses of water and steam discharged from the geothermal reservoir as well as the mass of ice melted in the lake. The steam mass fraction os estimated to be 20-35% when the fluid enters the lake. From this, new estimates of the thermal power of the geothermal system are obtained. The total thermal power of the system is 4700-4900 MW, of which 2100-2300 MW are transported by steam and the rest by water.

Grímsvötn is one of few geothermal areas where active volcanism is observed and where there is a direct interaction between magma and geothermal water. Evidence of volcanic activity was found in the water chemistry of the jökulhlaup in December 1983. The high content of sulphate and the presence of iron indicated eruption of magma into the geothermal fluid.

Since the nineteen-fifties jökulhlaups have occurred regularly at 4-6 year intervals when the lake level has risen up to a critical level required for draining water from the bottom of the lake. However, jökulhlaups may occur at lower water levels. In 1983 a jökulhlaup was triggered at a water level 20-30 m lower than the critical level. This jökulhlaup may have been triggered by the opening of waterways into the lake along the slopes of Grímsfjall, where increased geothermal or volcanic activity has melted ice in places. An odour of hydrogen sulphide was detected for two months on Skeiðarársandur before the jökulhlaup commenced. Sulphurous odour for long periods may warrant a forecast of such premature jökulhlaups.

Björnsson, S. (1972) "Blinda í fé af völdum Skeiðarárhlaups": Jökull, v. **22**: p. 95.

— (1972) "Þankabrot um Skeiðará": Náttúrufræðingurinn, v. **42**(1-2): p. 36-43.

— (1998) "Skeiðará og Skeiðarársandur": Skaftfellingur, v. **12**: p. 69-83.

— (1999) "Eldgos 1861": Skaftfellingur, v. **13**: p. 55-58.

— (2002) "Jökulleir og Skeiðarárhlaup": Skaftfellingur v. **15**: p. 129-132.

— (2003) "Aldagamlar athuganir": Skaftfellingur, v. **16**: p. 71-76.

Brandsdóttir, B. (1984) "Seismic activity in Vatnajökull in 1900-1982 with special reference to Skeiðarárhlaups, Skaftárhlaups and Vatnajökull eruptions (Jarðskjálftar í Vatnajökli 1900-1982, tengsl þeirra við Skeiðarárhlaup, Skaftárhlaup og eldgos í jöklinum)": Jökull, v. **34**: p. 141-150.

Carey, S., Maria, A., and Sigurdsson, H. (2000) "Use of fractal analysis for discrimination of particles from primary and reworked jökulhlaup deposits in SE Iceland": Journal of Volcanology and Geothermal Research, v. **104**(1-4): p. 65-80.

The morphology of sideromelane particles from jökulhlaup deposits in southeastern Iceland has been studied by fractal analysis to assess post-depositional changes associated with reworking. Fractal dimensions of particle boundaries were calculated from data obtained by the caliper and dilation methods. Most particles exhibit multifractal relationships with a textural (D1) and structural (D2) fractal dimension. Particles from primary jökulhlaup deposits have significantly greater textural and structural fractal dimensions compared to reworked deposits. Differences in the fractal dimensions indicate that reworking in the littoral zone has reduced both the amount of fine scale features on particle surfaces and the complexity of the overall particle shapes. The caliper and dilation methods yield similar values of textural fractal dimension for each particle. For the same particles, the dilation method yields higher values of structural fractal dimension. Reworked particles used in this study can be effectively discriminated from primary particles using a combination of D1 and D2 fractal dimensions. The results indicate that fractal analysis provides a useful quantitative characterization of complex volcanic particles and can be utilized to examine aspects of particle origin, transport and deposition.

Cassidy, N.J., Russell, A.J., Marren, P.M., Fay, H., Ó., K., Rushmer, E.L., and van Dijk, T.A.G.P. (2003) GPR-derived architecture of November 1996 jökulhlaup deposits, Skeiðarársandur, Iceland. 2003, *in* Bristow, C.S., and Jol, H.M., eds., Ground Penetrating Radar in Sedimentation: Special Publication of the Geological Society no. 211, Geological Society of London, p. 153-166.

Einarsson, E.., and others (1987) Skaftafell og Öræfi : þættir um náttúru og sögu, Hið íslenska náttúrufræðifélag, 20 s.: myndir, kort p.

Eiríksson, J., and others (1994) Roadlog : Nordic geological excursion in Iceland : quaternary geology - glaciology Reykjavík, myndir, kort, línurit p.

Fay, H. (2002) Formation of ice block obstacle marks during the November 1996 glacier-outburst flood (jökulhlaup), Skeiðarársandur, southern Iceland, *in* Martini, P.I., Baker, V.R., and Garzon, G., eds., Flood and Megaflood processes and deposits.Special Publication of the International Association of Sedimentologists Volume **32**, p. 85-97.

Glacier outburst floodes or "jökulhlaups" commonly involve the transport of ice blocks released from glacier margins. Very few published studies have focussed on the effects of ice blocks on outwash plains during and following jökulhlaups. A volcanic eruption benaeth the Vatnajökull ice-cap in southern Iceland generated a jökulhlaup on 5 November 1996 that transported numerous ice blocks as large as 45 m in diameter on to Skeiðarársandur. The morphology and sedimentology of a series of large, coarse grained bedforms formed around large stranded ice blocks during the November 1996 jökulhlaup are examined in relation to flow conditions. Ice-block obstacle marks were formed both by scour during the flow and by in situ melting after the flood receded. Flow separation around ice blocks resulted in the lee of the blocks becoming a locus of rapid deposition and led to the formation of entirely aggradational obstacle shadows. Flow around ice blocks also resulted in the deposition of upstream-dipping strata in sets up to 4 m thick that are interpreted as antidune stoss sides. Evidence of deposition from traction carpets during both rising and waning stages of the flood was preserved around iced blocks. It is suggested that the 1996 jökulhlaup flow was predominently subcritical, but thet locally flow became supercritical around ice blocks

— (2002) Formation of kettle holes following a glacial outburst flood (jökulhlaup), Skeiðarársandur, southern Iceland, *in* Snorrason, Á., ed., The Extremes of the Extremes : Extraordinary Floods. Proceedings of a Symposium held at Reykjavik: International Association of Hydrological Sciences Publication 271, p. 205-210.

The 1996 jökulhlaup on Skeiðarársandur, southern Iceland, involved the transport of ice blocks released fronm the glacier margin. the morphology, sedimentology and spatial distribution of kettle holes and other ice-block-related features, which developed post-flood in this proglacial fluvial system, were examined. Four types of phenomena are described and explained: kettle chains orientated both parallel and transverse to the principal paleoflow direction, hummocky topography, steep-walled and inverse-conical kettle holes and conical sediment mounds

Flowers, G.E., Bjornsson, H., Palsson, F., and Clarke, G.K.C. (2004) "A coupled sheet-conduit mechanism for jökulhlaup propagation": Geophysical Research Letters, v. **31**(5).

The largest glacier outburst flood (jokulhlaup) ever recorded in Iceland occurred in 1996 and came from subglacial lake Grimsvotn in Vatnajokull ice cap. Among other noteworthy features, this flood was characterized by an unprecedentedly high lake level prior to flood initiation, extremely rapid linear rise in lake discharge, delay between the onset of lake drainage and floodwater arrival at the glacier terminus, formation of short-lived supraglacial fountains, and initially unchannelized outbursts of floodwater at the terminus. Observations suggest that the 1996 flood propagation mechanism was fundamentally different than that of previously observed floods from Grimsvotn. We advance a new model whereby floodwater initially propagates in a turbulent subglacial sheet, which feeds a nascent system of conduits. This model is able to explain key *observations made of the 1996 jokulhlaup and may shed light on other outburst floods that do not conform to the standard model.*

Fowler, A.C. (1999) "Breaking the seal at Grimsvotn, Iceland": Journal of Glaciology, v. **45**(151): p. 506-516.

Of several problems associated with theoretical explanations of the jökulhlaups which emerge from the outlet glacier Skeiðarárjökull of the ice cap Vatnajökull in southeast Iceland, the mechanism of flood initiation is one that has hitherto defied explanation. We provide, such an explanation based on a careful analysis of the classical Nye-Rothlisberger model; near the subglacial lake Grimsvötn, the hydraulic potential gradient is towards the lake, and there is therefore a catchment boundary under the ice, whose location depends on the subglacial meltwater drainage characteristics. As the conditions for a flood approach, we show that the water divide migrates towards the lake, while at the same time the lake pressure increases. When the hydraulic potential gradient towards the lake is low and the refilling rate is slow, the seal will "break" when the catchment boundary reaches the lake, while the lake level is still below flotation pressure, whereas if refilling is rapid, flotation can be achieved before a flood is initiated. This theory can thus explain why the seal is normally broken when the lake level at Grimsvotn is still some 60 m below flotation level. In addition, we are able to explain why the jokulhlaup following the 1996 eruption did not occur until flotation level was achieved, and we show how the cyclicity and magnitude of jökulhlaups can be explained within this theory.

Gíslason, S.R., Snorrason, A., Kristmannsdóttir, H.K., Sveinbjörnsdóttir, A.E., Torsander, P., Ólafsson, J., Castet, S., and Dupre, B. (2002) "Effects of volcanic eruptions on the CO_2 content of the atmosphere and the oceans: the 1996 eruption and flood within the Vatnajökull Glacier, Iceland": Chemical Geology, v. **190**(1-4): p. 181-205.

The October 1996 eruption within the Vatnajökull Glacier, Iceland, provides a unique opportunity to study the net effect of volcanic eruptions on atmospheric and oceanic CO_2. Volatile elements dissolved in the meltwater that enclosed the eruption site were eventually discharged into the ocean in a dramatic flood 35 days after the beginning of the eruption, enabling measurement of 50 dissolved element fluxes. The minimum concentration of exsolved CO_2 in the 1x1012 kg of erupted magma was 516 mg/kg, S was 98 mg/kg, Cl was 14 mg/kg, and F was 2 mg/kg. The pH of the meltwater at the eruption site ranged from about 3 to 8. Volatile and dissolved element release to the meltwater in less than 35 days amounted to more than one million tonnes, equal to 0.1% of the mass of erupted magma. The total dissolved solid concentration in the floodwater was close to 500 mg/kg, pH ranged from 6.88 to 7.95, and suspended solid concentration ranged from 1% to 10%. According to H, O, C and S isotopes, most of the water was meteoric whereas the C and S were of magmatic origin. Both C and S went through isotopic fractionation due to precipitation at the eruption site, creating "short cuts" in their global cycles. The dissolved fluxes of C, Ca, Na, Si, S and Mg were greatest ranging from 1.4x1010 to 1.4x109 mol. The dissolved C flux equaled 0.6 million tonnes of CO_2. The heavy metals Ni, Mn, Cu, Pb and Zn were relatively mobile during condensation and water-rock interactions at the eruption site. About half of the measured total carbon flood flux from the 1996 Vatnajokull eruption will be added to the long-term CO_2 budget of the oceans and the atmosphere. The other half will eventually precipitate with the Ca and Mg released. Thus, for eruptions on the ocean floor, one can expect a net long-term C release to the ocean of less than half that of

the exsolved gas. This is a considerably higher net C release than suggested for the oceanic crust by Staudigel et al. [Geochim. Cosmochim. Acta, 53 (1989) 3091]. In fact, they suggested a net loss of C. Therefore, magma degassed at the ocean floor contributes more C to the oceans and the atmosphere than magma degassed deep in the oceanic crust. The results of this study show that subglacial eruptions affecting the surface layer of the ocean where either Mn, Fe, Si or Cu are rate-determining for the growth of oceanic biomass have a potential for a transient net CO2 removal from the ocean and the atmosphere. For eruptions at high latitudes, timing is crucial for the effect of oceanic biota. Eruptions occurring in the wintertime when light is rate-determining for the growth of biota have much less potential for bringing about a transient net negative CO2 flux from the ocean atmosphere reservoir.

Gomez, B. (2001) Patterns of erosion and deposition in the proglacial zone associated with the 1996 jökulhlaup on Skeiðarársandur, *in* Jónsson, S.S., ed., Vorráðstefna 2001: ágrip erinda og veggspjalda: Hótel Loftleiðum, Reykjavík, Jarðfræðifélag Íslands, p. 81, línurit, teikn., töflur.

Gomez, B., Russell, A.J., Smith, L., and Knudsen, Ó. (2002) Erosion and deposition in the proglacial zone: the 1996 jökulhlaup on Skeiðarársandur, *in* Snorasson, A., Finsdottir, H.P., and Moss, M., eds., The Extremes of the Extremes: Extraordinary Floods: Proceedings of a symposium held at Reykjavík, Iceland. IAHS Publication Number 271 p. 217-221.

The 1996 jökulhlaup from Skeiðarárjökull Glacier, Iceland, had little impact on the proximal surface of Skeiðarársandur, though most channel change occurred in the proximal zone. Patterns of erosion and deposition were revealed by aerial photography, repeat-pass interferomerty and field survey. The jökulhlaup bypassed the proximal zone becuase meltwater ponded in an ice-marginal depression, which regulated the flow of water and calibre of sediment supplied to Skeiðarársandur, and most drainage was through a single primary outlet (the Gígjukvísl River). The geomorphic impact of jökulhlaups may vary between periods of glacier advance when a glacier and sandur are coupled and active aggradation occurs in the proximal zone, and periods of glacier retreat when the glacier is decoupled from the sandur. The style of sedimentation in rivers which route water and sediment directly on to the sandur will also differ from that in rivers buffered by ponding in the proglacial zone.

Gomez, B., Smith, L.C., Magilligan, F.J., Mertes, L.A.K., and Smith, N.D. (2000) "Glacier outburst floods and outwash plain development:Skeiðarársandur, Iceland": Terra Nova, v. **12**: p. 126-131.

Guðmundsson, M.T. (1989) "The Grímsvötn caldera, Vatnajökull: subglacial topography and structure of caldera infill": Jökull, v. **39**: p. 1-19.

Results of seismic reflection survey, undertaken in 1987, to determine structure, elevation and topography of floor of main caldera, to measure area and volume of subglacial lake and thus to assess flood potential, and also to obtain information on material deposited on lake floor by volcanic eruptions and sedimentation

— (1996) Ice-volcano interaction at the subglacial Grímsvötn volcano, Iceland, *in* Colbeck, S., ed., Glaciers, Ice Sheets and Volcanoes: A Symposium honouring Mark Meier: CCREL Special Report 96-27, p. 34-40.

For at least two centuries, volcanic activity in Grímsvötn has been characterized by frequent small eruptions within the composite Grímsvötn caldera and larger, less frequent, fissure eruptions outside the caldera. The caldera eruptions take place within a subglacial lake and rapidly melt the ice above the vents, forming openings in the ice shelf covering the lake. Mounds of hyaloclastites are piled up at the vents, attaining elevations similar to the lake level. Volume of ice melted during these eruptions is less than 0.1 km³. In contrast, the fissure eruption in 1938, which occurred to the north of the Grímsvötn caldera, melted 2 km³ of ice over several days as a subglacial hyaloclastite ridge with a volume of 0.3-0.5 km³ was formed. Simultaneously, meltwater was drained away in a jökulhlaup. In eruptions that break through the ice cover, it appears that the water level at the eruption sites controls the elevation of ridges and mounds formed. For eruptions that penetrate the ice cover outside the caldera, this water level seems to lie several hundred meters below the ice surface prior to eruption. Locally enhanced melting of ice at eruption sites suggest that thermal effects of individual eruptions last 5-20 years.

Gudmundsson, M.T., Björnsson, H., and Pálsson, F. (1995) "Changes in jökulhlaup sizes in Grímsvötn, Vatnajökull, Iceland, 1934-91, deduced from in-situ measurements of subglacial lake volume": Journal of Glaciology, v. **41** (138): p. 263-272.

A record of volumes of jökulhlaups from the subglacial Grimsvötn lake, Vatnajökull, Iceland, has been derived for the period 1934-91. The change in lake volume during jokulhlaups is estimated from the lake area, ice-cover thickness and the drop in lake level. The jökulhlaup volumes have decreased gradually during this period of low volcanic activity and declining geothermal power. The two Jokulhlaups in the 1930s each discharged about 4.5 km(3) (peak discharge 25-30 x 10(3) m(3) s(-1)). In the 1980s, jökulhlaup volumes were 0.6.-1.2 km(3) (peak discharge 2 x 10(3) m(3) s(-1)). The lake level required to trigger a jökulhlaup has risen as an ice dam east of the lake has thickened. Water flow in a jökulhlaup ceases when the base of a floating ice shelf covering Grimsvötn settles to about 1160 m a.s.l. Apparently, the jökulhlaups are cut off when the base of the ice shelf collapses on to a subglacial ridge bordering the lake on its eastern side. The decline in melting rates has resulted in a positive mass balance of the 160-170 km(2) Grimsvotn ice-drainage basin. Comparison of maps shows that the average positive mass-balance rate was 0.12 km(3) a(-1) (25% of the total accumulation) in the period 1946-87. A gradually increasing positive mass balance has prevailed since 1954, reaching 0.23 km(3) a(-1) in 1976-86 (48% of total accumulation).

Guðmundsson, M.T., and Högnadottir, Þ. (2007) "Volcanic systems and calderas in the Vatnajökull region, central Iceland: Constraints on crustal structure from gravity data": Journal of Geodynamics, v. **43**(1): p. 153-169.

A Bouguer anomaly map is presented of southern central Iceland, including the western part of Vatnajökull and adjacent areas. A complete Bouguer reduction for both ice surface and bedrock topography is carried out for the glaciated regions. Parts of the volcanic systems of Vonarskarð-Hágöngur, Barðarbunga-Veiðivötn, Grimsvötn-Laki, and to a lesser extent Kverkfjöll, show up as distinct features on the gravity map. The large central volcanoes with calderas: Vonarskarð, Barðarbunga, Kverkfjöll and Grimsvötn,

are associated with 15-20 mGal gravity highs caused by high density bodies in the uppermost 5 km of the crust. Each of these bodies is thought to be composed of several hundred km3 of gabbros that have probably accumulated over the lifetime of the volcano. The Skaftarkatlar subglacial geothermal areas are not associated with major anomalous bodies in the upper crust. The central volcanoes of Vonarskarð and Hagöngur belong to the same volcanic system; this also applies to Barðarbunga and Hamarinn, and Grimsvötn and Þórðarhyrna. None of the smaller of the two volcanoes sharing a system (Hagöngur, Hamarinn and Þórðarhyrna) is associated with distinct gravity anomalies and clear caldera structures have not been identified. However, ridges in the gravity field extend between each pair of central volcanoes, indicating that they are connected by dense dyke swarms. This suggests that when two central volcanoes share the same system, one becomes the main pathway for magma, forming a long-lived crustal magma chamber, a caldera and large volume basic intrusive bodies in the upper crust. Short residence times of magma in the crust beneath these centres favour essentially basaltic volcanism. In the case of the second, auxillary central volcano, magma supply is limited and occurs only sporadically. This setting may lead to longer residence times of magma in the smaller central volcanoes, favouring evolution of the magma and occasional eruption of rhyolites. The eastern margin of the Eastern Volcanic Zone is marked by a NE-SW lineation in the gravity field, probably caused by accumulation of low density, subglacially erupted volcanics within the volcanic zone. This lineation lies 5-10 km to the east of Grimsvötn.

Guðmundsson, M.T., Högnadóttir, Þ. and Langley, K. (2003) Jarðhiti, gosstöðvar og skilyrði til vatnssöfnunar í Grímsvötnum 2001-2002, RH-01-2003, Raunvísindastofnun Háskólans, p. 30.

Guðmundsson, M.T., Sigmundsson, F., and Björnsson, H. (1997) "Ice-volcano interaction of the 1996 Gjalp subglacial eruption, Vatnajokull, Iceland": Nature, v. **389**: p. 954-957.

Volcanic eruptions under glaciers can cause dangerous floods and lahars(1-3) and create hyaloclastite (fragmented glassy rock) mountains(4-8), But processes such as the rate of heat transfer between ice and magma, edifice formation, and the response of the surrounding glacier are poorly understood, because of the lack of data. Here we present observations from the fissure eruption at Vatnajokull ice cap, Iceland, in October 1996. In the 13 days of the eruption 3 km(3) of ice were melted and the erupted magma fragmented into glass forming a hyaloclastite ridge 6-7 km long and 200-300 m high under 500-750 m of ice. Meltwater of temperatures of 15-20 degrees C flowed along a narrow channel at the glacier bed into the Grimsvotn subglacial lake for five weeks, before draining in a sudden flood, or jokulhlaup. Subsidence and crevassing of the ice cap occurred over the eruptive fissure and the meltwater path, whereas elsewhere the glacier surface remained intact, suggesting that subglacial eruptions do not trigger widespread basal sliding in warm-based glaciers.

Guðmundsson, M.T., Sigmundsson, F., Björnsson, H., and Högnadóttir (2004) "The 1996 eruption at Gjálp, Vatnajökull ice cap, Iceland: efficiency of heat transfer, ice deformation and subglacial water pressure": Bulletin of Volcanology, v. **66**(1): p. 46-65.

The 13-day-long Gjálp eruption within the Vatnajökull ice cap in October 1996 provided important data on ice-volcano interaction in a thick temperate glacier. The eruption produced 0.8 km(3) of mainly volcanic glass with a basaltic icelandite composition *(equivalent to 0.45 km(3) of magma). Ice thickness above the 6-km-long volcanic fissure was initially 550-750 m. The eruption was mainly subglacial forming a 150-500 m high ridge; only 2-4% of the volcanic material was erupted subaerially. Monitoring of the formation of ice cauldrons above the vents provided data on ice melting, heat flux and indirectly on eruption rate. The heat flux was 5-6x10(5) W m(-2) in the first 4 days. This high heat flux can only be explained by fragmentation of magma into volcanic glass. The pattern of ice melting during and after the eruption indicates that the efficiency of instantaneous heat exchange between magma and ice at the eruption site was 50-60%. If this is characteristic for magma fragmentation in subglacial eruptions, volcanic material and meltwater will in most cases take up more space than the ice melted in the eruption. Water accumulation would therefore cause buildup of basal water pressure and lead to rapid release of the meltwater. Continuous drainage of meltwater is therefore the most likely scenario in subglacial eruptions under temperate glaciers. Deformation and fracturing of ice played a significant role in the eruption and modified the subglacial water pressure. It is found that water pressure at a vent under a subsiding cauldron is substantially less than it would be during static loading by the overlying ice, since the load is partly compensated for by shear forces in the rapidly deforming ice. In addition to intensive crevassing due to subsidence at Gjálp, a long and straight crevasse formed over the southernmost part of the volcanic fissure on the first day of the eruption. It is suggested that the feeder dyke may have overshot the bedrock-ice interface, caused high deformation rates and fractured the ice up to the surface. The crevasse later modified the flow of meltwater, explaining surface flow of water past the highest part of the edifice. The dominance of magma fragmentation in the Gjálp eruption suggests that initial ice thickness greater than 600-700 m is required if effusive eruption of pillow lava is to be the main style of activity, at least in similar eruptions of high initial magma discharge.*

Halldórsson, S.M. (1996) "Eldgos í Vatnajökli": Eystrahorn,**34. tbl. 14. árg.**(fimmtud. 3. okt. 1996): p. Forsíða.

Frásögn Sigurðar M. Halldórssonar með tilvitnunum í Pál Imsland

— (1996) "Verður hlaupið verra en 1938? " Eystrahorn,**36. tbl. 14. árg.**(fimmtud. 17. okt. 1996): p. 3.

Frásögn Sigurðar M. Halldórssonar með fléttuðu viðtali við Pál Imsland

Hannesson, P. (1958) Skeiðarárhlaupið 1945, Frá óbyggðum: Reykjavík, Bókaútgáfa Menningarsjóðs, p. 293-320.

Hannesson, S.Ö. (2005) "Minnisvarði um náttúruhamfarir": Glettingur, v. **15 (39-40. tölubl.)**(2-3): p. 18.

Haraldsson, H. (1997) Vatnajökull : gos og hlaup 1996 : skýrsla unnin fyrir Vegagerðina af Raunvísindastofnun Háskólans og Orkustofnun: Reykjavík, Vegagerðin, p. 184 s. : kort, línurit, töflur, uppdr.

Höskuldsson, A., and Sparks, R.S.J. (1997) "Thermodynamics and fluid dynamics of effusive subglacial eruptions": Bulletin of Volcanology, v. **59**(3): p. 219-230.

We consider the thermodynamic and fluid dynamic processes that occur during subglacial effusive eruptions. Subglacial eruptions typically generate catastrophic floods (jökulhlaups) due to melting of ice by lava and generation of a large water cavity. We consider the heat transfer from basaltic and rhyolitic lava eruptions to the ice for typical ranges of magma discharge and geometry of subglacial lavas in Iceland. Our analysis shows that the heat flux out of cooling lava is large enough to sustain vigorous natural convection in the surrounding meltwater. In subglacial eruptions the temperature difference driving convection is in the range 10-100 degrees C. Average temperature of the meltwater must exceed 4 degrees C and is usually substantially greater. We calculate melting rates of the walls of the ice cavity in the range 1-40 m/day, indicating that large subglacial lakes can form rapidly as observed in the 1918 eruption of Katla and the 1996 eruption of Gjalp fissure in Vatnajokull. The volume changes associated with subglacial eruptions can cause large pressure changes in the developing ice cavity. These pressure changes can be much larger than those associated with variation of bedrock and glacier surface topography. Previous models of water-cavity stability based on hydrostatic and equilibrium conditions may not be applicable to water cavities produced rapidly in volcanic eruptions. Energy released by cooling of basaltic lava at the temperature of 1200 degrees C results in a volume deficiency due to volume difference between ice and water, provided that heat exchange efficiency is greater than approximately 80%. A negative pressure change inhibits escape of water, allowing large cavities to build up, Rhyolitic eruptions and basaltic eruptions, with less than approximately 80% heat exchange efficiency, cause positive pressure changes promoting continual escape of meltwater. The pressure changes in the water cavity can cause surface deformation of the ice. Laboratory experiments were carried out to investigate the development of a water cavity by melting ice from a finite source area at its base, The results confirm that the water cavity develops by convective heat transfer.

Jóhannesson, T. (2002) The initiation of the 1996 jökulhlaup from Lake Grímsvötn, Vatnajökull, Iceland, *in* Snorrason, A., ed., The Extremes of the Extremes: Extraordinary Floods (Proceedings of a symposium held at Reykjavik, Iceland): International Association of Hydrological Sciences Publication 271.

The jökulhlaup from Lake Grímsvötn in Vatnajökull Ice Cap in1996 was initiated by a different physical mechanism to that assumed in traditional theories of jökulhlaups. The maximum discharge was reached only 16 h after the start of the flood at the terminus. Water outbursts, through a >300 m thick glacier near the terminus, indicate water pressures several bars in excess of ice overburden at the beginning of the flood. A deep ice canyonwas formed in the ice cap near Lake Grímsvötn extending along about 10% of the subglacial floodpath. Frozen sediments formed in crevasses and frazil ice on the surface of the flood waters indicate the flow of supercooled water in the terminus region. These observations can be interpreted such that the jökulhlaup was initiated by the movement of a localized pressure wave that travelled 50 km in 10 h from Lake Grímsvötn to the terminus, forming a subglacial pathway along the glacier bed. Shortly after this wave reached the terminus, the jökulhlaup was flowing at a high discharge through a tunnel which would have needed much a longer time to form by ice melting as assumed in existing theories of jökulhlaups. The observations also indicate that in current theories the rate of heat transfer from subglacial flood water to the overlying ice is greatly underestimated.

— (2002) "Propagation of a subglacial flood wave during the initiation of a jökulhlaup": Hydrological Sciences Journal-Journal Des Sciences Hydrologiques, v. **47**(3): p. 417-434.

Observations from the jokulhlaup from Grimsvötn in Vatnajökull, southeastern Iceland, in 1996 indicate that the jökulhlaup was initiated by the movement of a localised pressure wave that travelled 50 km in 10 h from Grimsvötn to the terminus, forming a subglacial pathway along the glacier bed. Shortly after this wave reached tire terminus, the jökulhlaup was flowing at a high discharge through a tunnel that would have needed much longer time to form by ice melting as assumed in existing theories of jokulhlaups. Frozen sediments formed in crevasses and frazil ice on the surface of the flood waters indicate the flow of supercooled water in the terminus region, demonstrating that the rate of heat transfer from subglacial flood water to the overlying ice is greatly underestimated in current theories.

Kaldal, I., and Vilmundardóttir, E.G. (1997) Hlaup á Skeiðarársandi haustið 1996. Könnun á farvegi Gígjukvíslar 13 nóvember 1996; greinargerð. , IK/EGV-9701 Orkustofnun.

— (1997) Könnun á farvegi Gígjukvíslar, Ráðstefna um eldgos í Vatnajökli 1996. Ágrip erinda og veggspjalda, Jarðfræðafélag Íslands, p. 36.

Kjaran, B. (1964) Bærinn í skjóli Lómagnúps, Auðnustundir: Reykjavík, Bókfellsútgáfan, p. 351 s., [8] mbl., [16] mbls. : teikn.

Inniheldur:
Gos í Öskju
Náttúran talar
Þeir, sem landið erfa
Skáld litanna
Í aftureldingu
Tveir Reykvíkingar
Gróður á gömlum akri
Litli víxlarinn af Skaga
Eyðibyggðir
Konungur fuglanna og þegnar hans
Vörn og sókn

Knudsen, O., Jóhannesson, H., Russell, A.J., and Haraldsson, H. (2001) "Changes in the Gígjukvísl river channel during the November 1996 jökulhlaup, Skeiðarársandur, Iceland." Jökull, v. **50**: p. 19-32.

Aerial photos taken in 1992 and 1997 enabled the production of maps of Skeiðarársandur before and after the November 1996 jökulhlaup. This paper presents pre- and post-jökulhlaup maps of the Gígjukvísl river channel, providing an excellent opportunity to examine geomorphological change resulting from the jökulhlaup. The Gígjukvísl channel system underwent spectacular transformation from a complex system of low capacity channels and proglacila lakes to a large high capacity channel, scaled to the November 1996 jökulhlaup flows. The overall size of the Gígjukvísl channel increased, *reducing flood flow resistance and decreasing future potential for the formation of backwater lakes. specific change within the Gígjukvísl channel, upstream of the Little Ice Age moraines, consists of bank erosion of up to 300 m at the main Gígjukvísl outlet and within channel deposition of between 6 and 12 m. Downstream of the Little Ice Age moraines channel change consists of bank erosion of 600 m and localised within-channel aggradation of 4 m. Comparison of 1992 and 1997 aerial photographs also provides a clear picture of the glacier snout retreat of 300 m and thinning of 50-60 m during this period. drastic change within the Gígjukvísl channel was brought about by the recent (post-1954) creation of a proglacial trench within the river system. Prior to the November 1996 jökulhlaup, the proximal Gígjukvísl river channel had never experience a high-magnitude jökulhlaup. Extensive bank erosion during the jökulhlaup drastically changed teh channel, so it is now well-adjusted to high-magnitude flood flows reducing the geomorphological impact of future jökulhlaups.*

Knudsen, Ó. (2001) Undirkælt vatn og ísmyndun undir sporðum skriðjökla í sunnanverðum Vatnajökli, Vorráðstefna 2001: ágrið erinda og veggspjalda: Hótel Loftleiðum, Reykjavík, Jarðfræðifélag Íslands.

Kristinsson, B. (1986) "Tvíhlaup á Skeiðarársandi 1986": Jökull, v. **36**: p. 56.

Kristinsson, B., Zophóníasson, S., Pálsson, S., and Kristmannsdóttir, H. (1986) Hlaup á Skeiðarársandi 1986, OS-86080/VOD-23 B: Reykjavík, National Energy Authority, p. 42.

Magilligan, F.J., Gomez, B., Mertes, L.A.K., Smith, L.C., Smith, N.D., Finnegan, D., and Garvin, J.B. (2002) "Geomorphic effectiveness, sandur development, and the pattern of landscape response during jökulhlaups: Skeiðarársandur, southeastern Iceland": Geomorphology, v. **44**(1-2): p. 95-113.

By contrast with other historical outburst floods on Skeiðarársandur, the 1996 jökulhlaup was unprecedented in its magnitude and duration, attaining a peak discharge of ~53,000 m3/s in 7 m3 of sediment, and along channel systems that remained connected to subglacial sediment supplies. This shift to a laterally dissimilar, channelized routing system creates a more varied depositional pattern that is not explicitly controlled by the concave longitudinal profile down-sandur. Laterally contiguous units, therefore, may vary greatly in age and sediment character, suggesting that current facies models inadequately characterize sediment transfers when the ice front is decoupled from its sandur. Water was routed onto the sandur in a highly organized fashion; and this jokulhlaup generated major geomorphic changes, including sandur incision in normally aggradational distal settings and eradication of proximal glacial landforms dating to ~A.D. 1892.

Maria, A., Carey, S., Sigurðsson, H., Kincaid, C., and Helgadóttir, G. (2000) "Source and dispersal of jökulhlaup sediments discharged to the sea following the 1996 Vatnajökull eruption": Geological Society of America Bulletin, v. **112**(10): p. 1507-1521.

The October 1996 Gjálp eruption beneath Vatnajökull glacier led to one of the largest jökulhlaups (glacial floods) in Iceland in the twentieth century. A catastrophic *discharge of meltwater and sediment swept across the Skeidararsandur flood plain to the sea. Tephra from the eruption consists of vesicular sideromelane shards with a basaltic andesite composition (53% SiO2, 3% MgO, 0.8% K2O). After the flood, sediment samples were collected from the hood plain and off the southeast coast of Iceland, where a major sediment plume had been created by the discharge. Compositions of glass shards from hood-plain and seafloor deposits do not match those of the Gjálp magma. Flood-plain samples consist primarily of blocky to poorly vesicular sideromelane clasts with compositions that are characteristic of Grimsvötn volcanic products (similar to 50% SiO2, 5.5% MgO, 0.4% K2O). Marine samples collected near the jökulhlaup outflow into the sea also consist primarily of blocky to poorly vesicular sideromelane clasts with compositions that are, for the most part, similar to products of the Grimsvötn volcanic center. Distal marine samples have more vesicular sideromelane clasts with compositions that are similar to products of the Katla volcanic center (e.g., 48% SiO2, 4.5% MgO, 0.8% K2O). Significant deposition to the seafloor was apparently limited to an area just offshore of the Skeiðarársandur. There is no indication that juvenile volcanic material from the Gjálp eruption was carried by the 1996 jökulhlaup onto the flood plain or into the ocean, Instead, the jökulhlaup carried primarily older volcaniclastic material eroded by the flood.*

Marren, P.M. (2002) "Fluvial-lacustrine interaction on Skeiðarársandur, Iceland: implications for sandur evolution": Sedimentary Geology, v. **149**(1-3): p. 43-58.

A complex assemblage of fluvial and lacustrine sediments is identified in a major section through proglacial sediments on Skeiðarársandur, south Iceland. High magnitude-low frequency events are identified in both the fluvial and lacustrine sediments. However, much of the sedimentary succession is composed of `normal' low magnitude-high frequency sediments. Retreat of Skeiðarárjökull following a surge event created a topographic basin occupied at various times by both fluvial and lacustrine depositional systems and also subjected to a high magnitude jökulhlaup. Previous studies have examined the processes and events occurring on Skeiðarárjákull in isolation. This paper improves the understanding of the way in which processes with varying magnitude and frequency regimes interact and contribute to the sedimentary record of proglacial environments.

— (2004) "Present-day sandurs are not representative of the geological record - Sedimentary Geology 152, 1-5 (2002)": Sedimentary Geology, v. **164**(3-4): p. 335-340.

— (2005) "Magnitude and frequency in proglacial rivers: a geomorphological and sedimentological perspective": Earth-Science Reviews, v. **Vol. 70**(3-4): p. 203-251.

Proglacial fluvial sedimentary systems receive water from a variety of sources and have variable discharges with a range of magnitudes and frequencies. Little attention has been paid to how these various magnitude and frequency regimes interact to produce a distinctive sedimentary record in modern and ancient proglacial environments. This paper reviews the concept of magnitude and frequency in relation to proglacial fluvial systems from a geomorphic and sedimentary perspective rather than a hydrological or statistical perspective. The nature of the meltwater inputs can be characterised as low-magnitude–high-frequency, primarily controlled by ablation inputs from the source glacier, or highmagnitude–low-frequency, primarily controlled by dexceptionalT inputs. The most important high magnitude–low-frequency inputs are catastrophic outburst *floods, often referred to by the term jökulhlaup (Icelandic for glacier-burst). Glacier surges are an additional form of cyclical variation impacting the proglacial environment, which briefly alter the volumes and patterns of meltwater input. The sedimentary consequences of low-magnitude–high-frequency discharges are related to frequent variations in stage, the greater directional variability that sediment will record, and the increased significance of channel confluence sedimentation. In contrast, the most significant characteristics of high-magnitude–low-frequency flooding include the presence of large flood bars and mid-channel jökulhlaupT bars, hyperconcentrated flows, large gravel dunes, and the formation of ice-block kettle hole structures and rip-up clasts. Glacier surges result in a redistribution of low-magnitude–high-frequency processes and products across the glacier margin, and small floods may occur at the surge termination. Criteria for distinguishing magnitude and frequency regimes in the proglacial environment are identified based on these major characteristics. Studies of Quaternary proglacial fluvial sediments are used to determine how the interaction of the various magnitude and frequency regimes might produce a distinctive sedimentary record. Consideration of sandur architecture and stratigraphy shows that the main controls on the sedimentary record of proglacial regions are the discharge magnitude and frequency regime, sediment supply, the pattern of glacier advance or retreat, and proglacial topography. A model of sandur development is suggested, which shows how discharge magnitude and frequency, in combination with sandur incision and aggradation (controlled by glacier advance and retreat) can control sandur stratigraphy.*

Molewski, P. (2005) REKONSTRUKCJA PROCESÓW GLACJALNYCH W WYBRANYCH STREFACH MARGINALNYCH LODOWCÓW ISLANDII - FORMY I OSADY. Reconstruction of glacial processes in the chosen marginal zones of the Icelandic glaciers - forms and deposits: Torun, Instytut Geografii UMK; Stowarzyszenie Geomorfologów Polskich, p. 148.

Ng, F., and Björnsson, H. (2003) "On the Clague-Mathews relation for jökulhlaups": Journal of Glaciology, v. **49**(165): p. 161-172.

In the empirical study of jokulhlaups, the peak discharge, Q(max),and water volume drained by the ice-dammed lake during the floods, V-t, appear to follow a power-law relation Q(max) = KVtb, where K are b are constants determined from field data. First identified by Clague and Mathews (1973), this relation is a useful reference for predicting flood magnitude, but its physical origin remains unclear. Here, we develop the theory that connects it to contemporary models for Simulating the flood hydrograph. We explain how the function Q(max) = f(V-t) arises from Nye's (1976) theory of time-dependent water flow in a subglacial channel coupled to a lake, and we describe how discharge volume data record the (monotonically increasing) form of this function so long as the lake is not emptied in the floods. The Grimsvötn jökulhlaups present an example where, because of partial draining of the lake, agreement between the model-derived f and data is excellent. It is documented that other lake systems drain completely, but we explain how the exponent b approximate to 2/3 observed for them collectively is due primarily to a scaling effect related to their size, modified by other factors such as the flood initiation process.

Oeland, G. (1997) "Iceland's trial by fire": National Geographic, v. **191**(no.5): p. 58-71.

Pálsson, S., and others (1999) Grímsvatnahlaupið fyrra 1996; greinargerð, unnið fyrir Vegagerðina, OS-99115: Reykjavík, Orkustofnun, Vatnamælingar, p. 26 s. : línurit, töflur.

Pálsson, S., Ingólfsson, P., and Tómasson, H. (1980) "Comparison of sediment load transport in the Skeiðarár jökulhlaups in 1972 and 1976 (Samanburður á aurburði í Skeiðarárhlaupum 1972 og 1976)": Jökull, v. **30**: p. 21-33.

Rist, S. (1955) "Skeiðarárhlaup 1954": Jökull, v. **5**: p. 30-36.

— (1976) "Grímsvatnahlaupið 1976. The jökulhlaup from Grímsvötn in 1976. (Abstract)": Jökull, v. **26**: p. 80-90.

Roberts, M.J., Russell, A.J., Tweed, F.S., and Knudsen, Ó. (2000) "Ice fracturing during jökulhlaups: implications for englacial floodwater routing and outlet development": Earth Surface Processes and Landforms, v. **25**: p. 1429-1446.

Theoretical studies of glacial outburst floods (jökulhlaups) assume that: (i) intraglacial floodwater is transported efficiently in isolated conduits; (ii) intraglacial conduit enlargement operates proportionally to increasing discharge; (iii) floodwater exits glaciers through pre-existing ice-marginal outlets; and (iv) the morphology and positioning of outlets remains fixed during flooding. Direct field observations, together with historical jökulhlaup accounts, confirm that these theoretical assumptions are not always correct. This paper presents new evidence for spatial and temporal changes in intraglacial floodwater routing during jökulhlaups; secondly, it identifies and explains the mechanisms controlling the position and morphology of supraglacial jökulhlaup outlets; and finally, it presents a conceptual model of the controls on supraglacial outbursts. Field observations are presented from two Icelandic glaciers, Skeiðarárjökull and Sólheimajökull. Video footage and aerial photographs, taken before, during and after the Skeiðarárjökull jökulhlaup and immediately after the Sólheimajökull jökulhlaup, reveal changes in floodwater routing and the positioning and morphology of outlets. Field observations confirm that glaciers cannot transmit floodwater as efficiently as previously assumed. Rapid increases in jökulhlaup discharge generate basal hydraulic pressures in excess of ice overburden. Under these circumstances, floodwater can be forced through the surface of glaciers, leading to the development of a range of supraglacial outlets. The rate of increase in hydraulic pressure strongly influences the type of supraglacial outlet that can develop. Steady increases in basal hydraulic pressure can retro-feed pre-existing englacial drainage, whereas transient increases in pressure can generate hydraulic fracturing. The position and morphology of supraglacial outlets provide important controls on the spatial and temporal impact of flooding. The development of supraglacial jökulhlaup outlets provides a new mechanism for rapid englacial debris entrainment.

— (2001) "Controls on englacial sediment deposition during the november 1996 jökulhlaup, Skeiðarárjökull, Iceland": Earth Surface Processes and Landforms, v. **26**: p. 935-952.

This paper presents sedimentary evidence for rapid englacial debris entrainment during jökulhlaups. Previous studies of jökulhlaup sedimentology have focused predominantly on proglacial impact, rather than depositional processes within glaciers. However,

observations of supraglacial floodwater outbursts suggest that englacial sediment emplacement is possible during jökulhlaups. The November 1996 jökulhlaup from Skeidarárjökull, Iceland presented one of the first opportunities to examine englacial flood deposits in relation to former supraglacial outlets. Using observations from Skeidarárjökull, this paper identifies and explains controls on the deposition of englacial flood sediments and presents a qualitative model for englacial jökulhlaup deposition. Englacial jökulhlaup deposits were contained within complex networks of upglacier-dipping fractures. Simultaneous englacial deposition of fines and boulder-sized sediment demonstrates that englacial fracture discharge had a high transport capacity. Fracture geometry was an important control on the architecture of englacial jökulhlaup deposits. The occurrence of pervasively frozen flood deposits within Skeidarárjökull is attributed to freeze-on by glaciohydraulic supercooling. Floodwater, flowing subglacially or through upglacier-dipping fractures, would have supercooled as it was raised to the surface faster than its pressure-melting point could increase as glaciostatic pressure decreased. Evidence for floodwater contact with the glacier bed is supported by the ubiquitous occurrence of sheared diamict rip-ups and intra-clasts of basal ice within jökulhlaup fractures, deposited englacially some 200–350 m above the bed of Skeidarárjökull. Evidence for fluidal supercooled sediment accretion is apparent within stratified sands, deposited englacially at exceptionally high angles of rest in the absence of post-depositional disturbance. Such primary sediment structures cannot be explained unless sediment is progressively accreted to opposing fracture walls. Ice retreat from areas of former supraglacial outbursts revealed distinct ridges characterized by localized upwellings of sediment-rich floodwater. These deposits are an important addition to current models of englacial sedimentation and demonstrate the potential for post-jökulhlaup landform development.

Roberts, M.J., Tweed, F.S., Russell, A.J., Knudsen, Ó., Lawson, D.E., Larson, G.J., Evenson, E.B., and Björnsson, H. (2002) "Glaciohydraulic supercooling in Iceland": Geology, v. **30**(no. 5): p. 439-442; 6 figures.

We present evidence of glaciohydraulic supercooling under jökulhlaup and ablationdominated conditions from two temperate Icelandic glaciers. Observations show that freezing of sediment-laden meltwater leads to intraglacial debris entrainment during normal and extreme hydrologic regimes. Intraglacial frazil ice propagation under normal ablation-dominated conditions can trap copious volumes of sediment, which forms anomalously thick sections of debris-rich ice. Glaciohydraulic supercooling plays an importantrole in intraglacial debris entrainment and should be given more attention in models of basal ice development. Extreme jökulhlau conditions can result in significant intraglacial sediment accretion by supercooling, which may explain the concentration of englacial sediments deposited in Heinrich layers in the North Atlantic during the last glaciation.

Rushmer, E.L. (2004) The role of hydrograph shape and sediment sorting in controlling jökulhlaup sedimentary successions [**Unpublished Ph.D. thesis**], Keele University, U.K.

Glacial outburst floods (jökulhlaups) play an important part in proglacial geomorphology and sedimentology. Research on the impact of floods has made assumptions by associating jökulhlaup sedimentary successions with distinctive hydrograph shapes and flow rheology. However, jökulhlaup hydrograph shape alone is thougt to have a significant impact on proglacial sedimentology. To date, little information exists on the role of hydrograph shape as a control an the sedimentological and geomorphological

impact on jökulhlaups. This paper illustrates how field interpretation of flood deposits can be related to specific hydrograph shapes, and outlines how flume experiments can be used to assess the extent to which hydrograph shape exerts a control on jökulhlaup sedimentology.

Russel, A.J., Knudsen, Ó., Maizels, J.K., and Marren, P.M. (1999) "Channel cross-section area changes and peak discharge calculations in the Gígjukvísl river during the November 1996 jökulhlaup, Skeiðarársandur, Iceland": <u>Jökull</u>, v. **47**: p. 45-58.

Russell, A.J. (2005) The geomorphological and sedimentary impact of jökulhlaups Skeiðarársandur, <u>Rekonstrukcja Procesow Glacjalnych W Wybranych Strefach Marginalnych Lodowcow Islandii - Formy I Osady Islandia (Reconstruction of glacial processes in the chosen marginal zones of the Icelandic Glaciers - forms and deposits), 14-28 sierpnia 2005</u> Torun, Poland, Instytut Geografii UMK, p. 73-96.

Russell, A.J., Gregory, A.G., Large, A.R.G., Fleisher, P.J., and Harris, T. (2007) "Tunnel channel formation during the November 1996 jökulhlaup, Skeiðarárjökull, Iceland": <u>Annals of Glaciology</u>, v. **45**.

Despite the ubiquity of tunnel channels and valleys within formerly glaciated areas, their origin remains enigmatic. Few modern analogues exist for event-related subglacial erosion. This paper presents evidence of subglacial meltwater erosion and tunnel channel formation during the November 1996 jökulhlaup, Skeiðarárjökull, Iceland. The jökulhlaup reached a peak discharge of 45,000 – 50,000 m 3 s -1 , with flood outbursts emanating from multiple outlets across the entire 23 km wide glacier snout. Subsequent retreat of the south-eastern margin of Skeiðarárjökull has revealed a tunnel channel excavated into the surrounding moraine sediment and ascending 11.5 m over a distance of 160 m from a larger trough to join the apex of an ice-contact fan formed in November 1996. The tunnel channel formed via hydro- mechanical erosion of 14,000 m 3 - 24,000 m 3 of unconsolidated glacier substrate, evidenced by copious rip-up clasts within the ice-contact fan. Flow reconstruction provides peak discharge estimates of 683 m 3 s -1. The tunnel channel orientation, oblique to local ice flow direction nd within a col, suggests that local jökulhlaup routing was controlled by (a) subglacial topography and (b)the presence of a nearby proglacial lake. We describe the first modern example of tunnel channel formation and illustrate the importance of pressurised subglacial jökulhlaup flow for tunnel channel formation.

Russell, A.J., Knight, P.G., and van Dijk, T.A.G.P. (2001) "Glacier surging as a control on the development of proglacial fluvial landforms and deposits, Skeiðarársandur, Iceland": <u>Global and Planetary Change</u>, v. **28**(1-4): p. 163-174.

Glacier-hydrological processes are one of the main factors controlling proglacial fluvial systems. It has been proposed that where jökulhlaups occur they play a dominant role in the evolution of proglacial outwash plains. However, extraordinary meltwater and sediment discharge associated with glacier surging can also play a crucial role in the proglacial system. The interplay of surge-related and jökulhlaup floods has been investigated at Skeiðarárjökull, a jökulhlaup type-site where surging is also known to occur, allowing the geomorphological and sedimentological effects of these events to be differentiated.

Skeiðarársandur contains a spectacular assemblage of landforms and deposits associated with the 1991 surge of Skeiðarárjökull. The impact of the 1991 surge was felt mainly on the western half of the glacier where the ice advanced up to 1 km between September and November. The surge limit is marked by a push-moraine complex up to 5 m in height and 10 m in breadth. Proglacial fluvial sediments were deposited as a series of outwash fans adjacent to the glacier, up to 400 m in diameter, as the glacier advanced during the surge. Glaciotectonic structures associated with ice pushing inter-finger with undisturbed proglacial fluvial fan sediments, constraining timing of deposition of proglacial fans to the period during and immediately following the glacier surge.

The study of landforms and sedimentary successions associated with the 1991 surge provides an excellent modern analogue for larger-scale push moraines and proglacial fans on Skeiðarársandur, which are related to similar processes. Surge-related outflows operating over timescales of months–years, together with jökulhlaup flows play a major role in the creation of distinctive proglacial fluvial landforms and deposits. Examination of the sedimentary and landform records of areas presently subject to surging will allow the development of models which can be used to differentiate glacier surging from rapid glacier response to abrupt climate change.

Russell, A.J., Knudsen, O., Fay, H., Marren, P.M., Heinz, J., and Tronicke, J. (2001) "Morphology and sedimentology of a giant supraglacial, ice-walled, jökulhlaup channel, Skeiðarárjokull, Iceland: implications for esker genesis": Global and Planetary Change, v. **28**(1-4): p. 193-216.

This paper examines the sedimentary infill of a spectacular, 500-m-long, 100-m-wide ice-walled supraglacial channel, excavated into the snout of Skeiðarárjokull, Iceland during the November 1996 jokulhlaup. The ice-walled channel developed in an area of the glacier, which was extensively fractured during the jokulhlaup. Sculpting of the ice-walled channel into the active snout of Skeiðarárjokull suggests that the presence of stagnating glacier ice is not a prerequisite for the development of ice-walled channels. The ice-walled channel occupied an inter-lobate location, which acted as a focus for meltwater during the November 1996 jokulhlaup. The geometry of the supraglacial ice-walled channel system acted as a major control on the morphology and sedimentology of jokulhlaup deposits, through the tremendous spatial variability of resultant flow conditions. Maximum calculated jokulhlaup powers and shear stresses for the supraglacial ice-walled channel reached 40,000 W m-2 and 5000 N m-2, respectively, with associated mean flow velocities between 7 and 11 m s-1.Within the main ice-walled channel, Ground Penetrating Radar and outcrop exposure provide evidence of an ~8-m-thick progradational and aggradational gravel macroform succession. The supraglacial ice-walled channel system is therefore analogous to a bedrock-confined fluvial system. This study provides a new analogue for the interpretation of ice-contact glaciofluvial deposits associated with former ice margins in Iceland and other areas subject to high magnitude discharges. Former supraglacial ice-walled channels resulting from tunnel collapse and ice margin break-up during high magnitude jokulhlaups will be associated with extensive coarse-grained, heavily kettled proglacial outwash surfaces. It is clear that the relationship between the characteristics of former ice-walled channels labeled as eskers and the prevailing glaciological and hydrological conditions needs to be modified in light of our knowledge of a modern flood-related large-scale supraglacial channel and its sedimentary infill. Such re-evaluation may provide a valuable new insight into former ice margin positions, modes of glacier retreat, and the role of high magnitude floods within the sedimentary record of former

proglacial areas. This study therefore improves our understanding of the meltwater magnitude and frequency regime of former glaciers.

Russell, A.J., and Knudsen, Ó. (1999) Controls on the sedimentology of November 1996 jökulhlaup deposits, Skeiðarársandur, Iceland, *in* Smith, N.D., and Rogers, J., eds., Fluvial Sedimentology VI: International Association of Sedimentologists Special Publication 28, p. 315-329.

— (1999) "An ice-contact rhythmite (turbidite) succession deposited during the November 1996 catastrophic outburst flood (jökulhlaup), Skeiðarárjökull, Iceland": Sedimentary Geology, v. **127**(1-2): p. 1-10.

— (2002) The effects of glacier outburst flood flow dynamics on ice-contact deposits: November 1996 jökulhlaup, Skeiðarársandur, Iceland, *in* Martini, I.P., Baker, V.R., and Garzon, G., eds., Flood and Megaflood Deposits:Recent and Ancient: Special Publication of the International Association of Sedimentologists 32, p. 67-83.

This study examines the extent to which observed large-scale stage variations are reflected in the proglacial landform and sedimentary record of the November 1996 jökulhlaup, Skeiðarárjökull, Iceland. Discrimination of rising from falling flood stage landforms and deposits is usually based upon the interpretation of the geomorphic and sedimentary record. Sedimentary successions in proglacial environments have been interpreted on the basis of vertical sedimentary characteristics which are then linked to the flood hydrograph. Most research has considered efflux within channels active on both rising and falling flow stage where the resultant morphology and sedimentology are the product of the temporal variability of both water and sediment flux. Spatial segregation of rising and falling stage proglacial outwash during the November 1996 jökulhlaup provided a superb opportunity to examine the role of flow stage in the creation and preservation of distinctive proglacial jökulhlaup landforms and deposits. Rising stage deposits contained finer, more poorly sorted sediment than found on falling stage successions and erosional surfaces. Rising stage deposits showed upward-coarsening successions, characteristic of progressive supply of coarser-grained sediment with stage increase, compatible with previous models of rising stage sedimentation. Some rising stage successions however, showed few signs of large-scale grading, and instead contained repeated cycles of sedimentation, recording individual sedimentation pulses. Distinctive upward-coarsening successions on a waning stage outwash fan were generated by sediment reworking and winnowing. The presence of an upward-coarsening succession alone is clearly not diagnostic of rising stage deposition. Conduits occupied by flows on both rising and falling flow stages were characterised by initial rising stage fan deposition followed by falling stage dissection and exhumation of ice blocks and rip-up clasts deposited on the rising flow stage. Rising stage deposits contained both single upward coarsening successions as well as successions consisting of stacked upward-coarsening and normally-graded units. Where waning stage flows were routed through a single conduit, high sediment efflux and aggradation rates were maintained late into the waning stage. Winnowing and sediment starvation resulted in progressive bed coarsening from matrix-supported gravels to clast-rich armour. This study illustrates the geomorphic and sedimentary significance of major within-jökulhlaup sediment reworking and ice-margin erosion over distances of 10^2-10^3 m. Ill-defined erosional, streamlined terraces reflect exhumation on the flood waning stage. This landform and sedimentary succession *could easily be confused with the product of fluvial depositional and erosional cycles operating over longer timescales associated with more sedate rates of glacier retreat within former proglacial areas.*

— (2002) The influence of channel flood history on the impact of the November 1996 jökulhlaup, Skeiðarársandur, Iceland., *in* Snorasson, A., Finsdottir, H.P., and Moss, M., eds., The Extremes of the Extremes: Extraordinary Floods. Proceedings of a symposium held at Reykjavik, Iceland, July 2000: IAHS Publication Number 271, p. 243-247.

Multiple channel occupation during the November 1996 jökulhlaup Skeiðarársandur, Iceland, provided an opportunity to assess the role of flood history in controlling the varied impact of a single large jökulhlaup. This paper considers the immediate geomorphological impact of the 1996 jökulhlaup in relation to the flood history of each major ice-proximal channel system draining Skeiðarárjökull. The jökulhlaup had greatest impact on the Gígjukvísl river channel, whilst the Skeiðará and Sæluhúsavatn channels were impacted to a lesser degree. The jökulhlaup had very little impact on the Háöldukvísl and Súla. Large jökulhlaup impact within the central portion of the glacier occurred because non-jökulhlaup flows had dominated the central portion of the glacier for many years. The impact of the 1996 jökulhlaup on individual channels is strongly influenced by each channels' flood history, which in turn is driven by differential rates of glacier margin retreat.

Russell, A.J., and Marren, P.M. (1999) Proglacial fluvial sedimentary sequences in Greenland and Iceland: a case study from active proglacial environments subject to jökulhlaups, *in* A.P.Jones, Tucker, M.E., and Hart, J.K., eds., The description and analysis of Quaternary stratigraphic field sections, Technical Guide 7: London, Quaternary Research Association, p. 171-208.

Sigbjarnarson, G. (1990) Vatnið og landið : ávörp , erindi og ágrip : vatnafræðiráðstefna haldin 22.-23. október 1987 í tilefni 40 ára afmælis Vatnamælinga og 20 ára afmælis Orkustofnunar : tileinkuð Sigurjóni Rist vatnamælingamanni sjötugum, Vatnafræðiráðstefna: Reykjavík : Orkustofnun, p. 307 s. : myndir, kort, línurit, töflur

Sigurðsson, O., Jónsson, P., Snorrason, Á., Víkingsson, S., Kaldal, I., and Pálsson, S. (2000) "The jökulhlaup on Skeiðarársandur in November 1996: event, discharge and sediment": Mars Polar Science.

Sigurðsson, S. (2004),,Lífið er enn dásamlegt", *in* Björnsson, H., ed., Jöklaveröld, náttúra og mannlíf: Reykjavík, Skrudda, p. 319-390.

Sigvaldason, G.E. (1965) "The Grímsvötn Thermal Area. Chemical Analysis of Jökulhlaup Water": Jökull, v. **15. árg.**: p. 125-128.

Smith, L.C., Alsdorf, D.E., Magilligan, F.J., Gomez, B., Mertes, L.A.K., Smith, N.D., and Garvin, J.B. (2000) "Estimation of erosion, deposition, and net volumetric change caused by the 1996 Skeiðarársandur jökulhlaup, Iceland, from synthetic aperture radar interferometry": Water Resources Research, v. **36**(6): p. 1583-1594.

Using repeat-pass satellite synthetic aperture radar interferometry, we develop a methodology to measure flood-induced erosion and deposition and apply it to a record 1996 glacier outburst flood (jökulhlaup) on Skeiðarársandur, Iceland. The procedures include (1) coregistration of backscatter intensity images to observe morphological differences; (2) mapping of interferometric phase correlation to identify preserved and modified surfaces; and (3) construction, correction, and differencing of pre-jökulhlaup and post-jökulhlaup topography. Procedures 1 and 2 are robust and should be widely applicable to other fluvial environments, while procedure 3 is complicated by uncertainties in phase measurement, baseline estimate, and atmospheric effects. After a correction procedure involving interpolation of digital elevation model elevation differences across low-correlation areas, we find similar to 4 m of elevation change are required to calculate volumes of erosion or deposition. This condition was satisfied for the 40 km(2) proglacial zone of Skeiðarársandur, where we estimate +38 x 10(6) m(3) of net sediment deposition along the ice margin, -25 x 10(6) m(3) of net erosion in channels downstream, and a total net balance of +13 x 10(6). These estimates are supported by field observations and survey data collected in 1997.

Smith, L.C., Sheng, Y., Magilligan, F.J., Smith, N.D., Gomez, B., Mertes, L.A.K., Krabill, W.B., and Garvin, J.B. (2006) "Geomorphic impact and rapid subsequent recovery from the 1996 Skeiðarársandur jökulhlaup, Iceland, measured with multi-year airborne lidar": Geomorphology, v. **75**(1-2): p. 65-75.

The November 1996 jökulhlaup that burst from the Vatnajökull ice cap onto Skeiðarársandur was the highest-magnitude flood ever measured on the largest active glacial outwash plain (sandur). Centimeter-scale elevation transects, measured from repeat-pass airborne laser altimetry missions flown in 1996 (pre-flood), 1997, and 2001, show that sediment deposition exceeded erosion across the central Skeiðarársandur and established an average net elevation gain of + 22 cm for the event. Net elevation gains of + 29 and + 24 cm occurred in braided channels of the Gigjukvísl and Skeiðará rivers, respectively. Nearly half of these gains, however, were removed within 4 years, and the two rivers contrast strongly in style of erosional/depositional impact and subsequent recovery. In the Gígjukvísl, the 1996 jökulhlaup caused massive sediment deposition (up to ~12 m) near the ice margin and intense "mega-forming" of braided channels and bars downstream. Post-jökulhlaup recovery (1997-2001) was characterized by rapid erosion (- 0.5 m) of ice-proximal sediments and their transport to downstream reaches, and eradication of the mega-forms. In contrast, the Skeiðará displays minimal post-jökulhlaup sediment erosion in its upstream reaches and little change in braided channel relief. This contrast between river systems is attributed to the presence of a previously studied ~2-km wide ice-marginal trench, caused by glacier retreat and lowering, which contained flows of the Gigjukvísl but not the Skeiðará prior to dispersal onto the outwash plain. Rapid removal of jökulhlaup deposits from this trench suggests that in terms of long-term evolution of the sandur, such features only delay downstream migration of jökulhlaup-derived sediment. These results, therefore, suggest that the net geomorphic impact of jokulhlaups on surface relief of Skeiðarársandur, while profound in the short term, may be eradicated within years to decades.

Snorrason, Á., Jónsson, P., Pálsson, S., Árnason, S., Sigurðsson, O., Víkingsson, S., Sigurðsson, Á., and Zóphóníasson, S. (1997) Hlaupið á Skeiðarársandi haustið 1996: Útbreiðsla, rennsli og aurburður, *in* Haraldsson, H., ed., Vatnajökull: Gos og Hlaup: Reykjavík: Reykjavík, Vegagerin, p. 79-137.

Snorrason, Á., Jónsson, P., Sigurðsson, O., Pálsson, S., Árnason, S., Víkingsson, S., and Kaldal, I. (2002) "November 1996 jökulhlaup on Skeiðarársandur outwash plain, Iceland": Special Publications of the International Association of Sedimentologists, v. **32**: p. 55-65.

Spring, U., and Hutter, K. (1981) "Numerical studies of Jökulhlaups": Cold Regions Science and Technology, v. **4**(3): p. 227-244.

The aim of this paper is to investigate Jökulhlaups: outbursts of ice-dammed lakes. The governing equations of unsteady water flow through straight, circular conduits, as derived by the authors in a previous paper, are compared with the equations of Nye, and for the steady state situation with Rothlisberger's theory. The dynamic theory is treated numerically by a finite-difference technique. Run-off simulations are illustrated for a model of the Grimsvötn Jökulhlaup, a periodic outburst of a subglacial lake beneath the Vatnajökull in Iceland. We study how various parameters, such as the friction coefficient of the conduit, and constants in the flow law of ice, influence the evolution of the outburst. In particular, we compute discharge hydrographs both incorporating and neglecting the rate of change of internal energy. It is shown that this term is not negligible and that the lake temperature, as a boundary condition, strongly influences the time-discharge relation and might explain the abrupt end of the outburst well before the lake has been emptied.

Stefansdottir, M.B., and Gislason, S.R. (2005) "The erosion and suspended matter/seawater interaction during and after the 1996 outburst flood from the Vatnajökull Glacier, Iceland": Earth and Planetary Science Letters, v. **237**(3-4): p. 433-452.

The Gjálp subglacial eruption 1996 within the Vatnajökull Glacier, Iceland triggered a catastrophic outburst flood, bringing at least 180 million tonnes of suspended solids to the sea in only 42 h. This amounts to 1% of the total annual global river suspended flux to the oceans. The specific BET-surface area of the suspended solids was measured to be 11.8-18.9 m2/g, translating to the average total BET-surface area of 2.8 x 10 9 km2, providing enormous potential for adsorption/desorption and precipitation/dissolution fluxes at the suspended solids-ocean water interface. Altered basalt glass was the major constituent of the suspended matter (80%), secondary minerals such as zeolites and calcite amounted to 11%, but only 5% was fresh volcanic glass. The suspended grains were generally rounded. The glass carried by the flood is different in chemical composition from the glass produced by the Gjálp eruption. The Gjalp material has higher FeOtotal / TiO2 and TiO2 / P2O5 ratios than the suspended glass in the flood waters. The majority of the flood samples match the composition of the volcanic system, down stream from the eruption site. The large amount of altered material in the flood and its chemical composition suggests erosion conforming to a 2 m deep, 1000 m wide and 50 000 m long channel in less than 42 h. The behaviour of 28 elements on the surface of the suspended solids exposed to seawater was quantified by experiments in the laboratory. The altered basaltic glass *dissolved in seawater, as recorded by the Si release from the glass. The dissolved concentrations of Na, Ca, Si, Ba, Cd, Co, Cu, Hg, Mn, Ni, and total dissolved inorganic N increased considerably when the suspended solids come into contact with the seawater, but the concentrations of Mg, K, S, Sr, Fe, Pb and Zn decreased. The experimental seawater solutions were supersaturated with respect to calcite, Mg-montmorillonite and amorphous iron-hydroxide. The rate of release (mol/m2/s) of Si, Mn, Ba, Co, Ni and Cd decreased continuously during the one week exposure to sweater. After one week, the logarithm of the dissolution rate of the altered basaltic glass was - 11.9 to - 11.6 (Si mole/m2/sec). Significantly lower than the steady-state rates for fresh basaltic glass at similar conditions. Calculated one day desorbed/dissolution suspended material fluxes are greater than the integrated dissolved flood fluxes for Mn, Ba, Ni, Co and Cd, but the Si dissolved food flux was greater than the one day desorbed/dissolved suspended material flux.*

Stefansdottir, M.B., and Gislason, S.R. (2006) "Suspended basaltic glass-seawater interactions": Journal of Geochemical Exploration, v. **88**(1-3): p. 332-335.

The objective of this study was to quantify by experiments the initial seawater-suspended basaltic glass interactions following the 1996 outburst flood from the Vatnajökull glacier, Iceland. The altered basaltic glass dissolved in seawater as recorded by the Si release from the glass. The dissolved concentrations of Na, Ca, Si, Ba, Cd, Co, Cu, Hg, Mn, Ni and total dissolved inorganic N increased with time but the concentrations of Mg, K, S, Sr, Fe, Pb and Zn decreased. Calculated 1 to 10 day fluxes for Si range from 38,000 tons/day to 70,000 tons/10 days. The fluxes for other major elements are more uncertain, but the positive flux (release from suspended matter to seawater) of Ca and Na, and negative flux of Mg, K and S are greater than the Si flux.

Stefánsdóttir, M.B., Gíslason, S.R., and Arnórsson, S. (1999) Flood from Grímsvötn subglacial caldera 1996 : composition of suspended matter, *in* Ármannsson, H., ed., 5th International Symposium on Geochemistry of the earth's surface: Reykjavík, Iceland, A.A. Balkema, Rotterdam, p. 539-542.

Stefánsson, R. (1983) "Skeiðarárhlaupið 1939 (The jökulhlaup in Skeiðará in 1939)": Jökull, v. **33**: p. 148.

Stefánsson Skaftafelli, R. (1982) "Skeiðarárhlaupin : margvíslegar afleiðingar þeirra": Skaftfellingur, v. **3**: p. 99-118.

Theódórsson, P. (1977) Tilraun til að mæla rennsli í Skeiðará með geislavirku jóði, RH-77-4: Reykjavík, Raunvísindastofnun Háskólans, p. 8; línurit, teikn., töflur.

Tómasson, H. (1974) "Grímsvatnahlaup 1972, mechanism and sediment discharge. Grímsvatnahlaupið 1972, orsakir, hegðun og aurburður (Ágrip)": Jökull, v. **24** p. 27-39.

Tómasson, H., and others (1974) Efnisflutningar í Skeiðarárhlaupi 1972, OS-ROD-7407: Reykjavík, Orkustofnun. Raforkudeild, p. Óreglul. bls.tal : myndir, línurit, töflur.

Tómasson, H., Pálsson, S., and Ingólfsson, P. (1980) "Comparison of sediment load in the Skeiðarár jökulhlaups in 1972 and 1976": Jökull, v. **30**: p. 21-33.

Tweed, F.S., Roberts, M.J., and Russell, A.J. (2005) "Hydrologic monitoring of supercooled discharge from Icelandic glaciers: hydrodynamic and sedimentary significance": Quaternary Science Reviews, v. **24**(22): p. 2308-2318.

Knowledge of how glaciers entrain sediment is central to understanding processes of glacier movement and products of glacial sediment deposition. Previous work has shown that if the total hydraulic potential of subglacial meltwater increases more rapidly than the resulting mechanical energy can be transformed into sensible heat, then supercooling and ice growth will result. This process causes frazil ice to grow onto adjacent glacier ice, which acts to trap sediment in flowing meltwater eventually producing sedimentary inclusions within glacier ice. Supercooling has been recognised as a sediment entrainment mechanism at glaciers in Alaska, and more recently at several temperate Icelandic glaciers. Here we present short-period temperature measurements and field evidence of glaciohydraulic supercooling from three Icelandic glaciers. Temperature measurements demonstrate that supercooling occurs over a range of hydrological conditions and that the process does not operate continuously at all instrumented sites. Measurements of supercooling during a small jökulhlaup are also presented. Progressive accretion of supercooled meltwater creates sediment-laden ice exposures adjacent to active artesian vents. Understanding controls on the efficacy and pervasiveness of hydraulic supercooling is important for decoding the sedimentary record of modern and ancient glaciers and ice sheets.

Tweed, F.S., and Russell, A.J. (1999) "Controls on the formation and sudden drainage of glacier-impounded lakes: implications for jökulhlaup characteristics ": Progress in Physical Geography, v. **23**(No. 1): p. 79-110.

Over the past few years there has been an increase in understanding of glacier-impounded or 'ice-dammed' lake behaviour. The spectacular jökulhlaup (catastrophic flood) from Grímsvötn, Iceland in November 1996 has both raised the profile of such events and emphasized the need for awareness of the processes involved. This review summarizes the extent of current knowledge of ice-dammed lakes, highlighting key developments and outlining areas of study still subject to difficulties. Controls on ice-dammed lake formation and persistence are identified, and cycles of jökulhlaup activity are related to glacier fluctuations. Ice-dammed lake drainage trigger mechanisms are reviewed and recent progress in the understanding of such mechanisms is emphasized. Controls on jökulhlaup routing and the development and character of jökulhlaup conduits are discussed and recent advances in jökulhlaup prediction, hydrograph modelling and peak discharge estimation are assessed. A process-based schematic model, drawing on published research, links ice-dammed lake occurrence and drainage to jökulhlaup characteristics. It is demonstrated that ice-dammed lake and ice-dam characteristics ultimately control seven key jökulhlaup attributes which determine the potential impact of jökulhlaups on both landscape and human activity in glaciated regions.

Wake, G.M. (1997) "After the flood ": Iceland review v. **35**(1): p. 32-35.

Waller, R.I., Russell, A.J., van Dijk, T.A.G.P., and Knudsen, O. (2001) "Jökulhlaup-related Ice Fracture and Supraglacial Water Release During the November 1996 Jökulhlaup, Skeiðarárjökull, Iceland": Geografiska Annaler, v. **83A**(1-2): p. 29-38.

During the initial stages of the November 1996 jökulhlaup at Skeiðarárjökull, Iceland, floodwaters burst onto the glacier surface via a series of fractures. This supraglacial drainage led to the formation of a number of distinct ice surface depressions, one of which is investigated in detail. The morphology and structural characteristics of this feature are described, as well as the sedimentology of an associated assemblage of debris-filled fractures. This work suggests that debris-charged subglacial floodwaters travelled up to the glacier surface, where supraglacial flow occurred initially via an extensive network of fractures, orientated parallel to the glacier margin. Supraglacial discharge became progressively more focused into a series of discrete outlets, leading to the mechanical erosion of a number of depressions on the glacier surface. The associated transfer of subglacially derived floodwaters to high levels within the glacier resulted in the rapid entrainment of large volumes of sediment which may influence the patterns, processes and products of ice-marginal sedimentation in the future.

Worsley, P. (1997) "The 1996 volcanically induced glacial mega-flood in Iceland-cause and consequence": Geology Today, v. **13**(6): p. 222-227.

— (1998) "Iceland: contrasting Skeidará mega-flood hydrographs": Geology Today v. **14**(3): p. 97-98.

Þórarinsson, S. (1954) "Athuganir á Skeiðarárhlaupi og Grímsvötnum 1954 (The jökulhlaup (glacier burst) from Grímsvötn in July 1954). Bráðabirgða-greinargerð": Jökull, v. **4**: p. 34-37.

— (1974) Vötnin stríð, saga Skeiðarárhlaupa og Grímsvatnagosa: Reykjavík, Bókaútgáfa Menningarsjóðs, 254 p.

— (1980) "Enn um Skeiðarárhlaup (An old letter on Skeiðarárhlaup)": Jökull, v. **30**: p. 74.

5.2.2 Hlaup úr Skaftárkötlum

Björnsson, H. (2002) "Subglacial lakes and jökulhlaups in Iceland": Global and planetary change, v. **35**: p. 255-271.

Active volcanoes and hydrothermal systems underlie ice caps in Iceland. Glacier–volcano interactions produce meltwater that either drains toward the glacier margin or accumulates in subglacial lakes. Accumulated meltwater drains periodically in jökulhlaups from the subglacial lakes and occasionally during volcanic eruptions. The release of meltwater from glacial lakes can take place in two different mechanisms. Drainage can begin at pressures lower than the ice overburden in conduits that expand slowly due to melting of the ice walls by frictional and sensible heat in the water. Alternatively, the lake level rises until the ice dam is lifted and water pressure in *excess of the ice overburden opens the waterways; the glacier is lifted along the flowpath to make space for the water. In this case, discharge rises faster than can be accommodated by melting of the conduits. Normally jökulhlaups do not lead to glacier surges but eruptions in ice-capped stratovolcanoes have caused rapid and extensive glacier sliding. Jökulhlaups from subglacial lakes may transport on the order of 107 tons of sediment per event but during violent volcanic eruptions, the sediment load has been 108 tons.*

Björnsson, H., and Einarsson, P. (1990) "Volcanoes beneath Vatnajökull, Iceland: Evidence from radio echo-sounding earthquakes and jökulhlaups": Jökull, v. **40**: p. 147-168.

Integration of knowledge of subglacial topography, earthquake activity and jökulhlaups has contributed to more precise locations of the volcanic systems beneath Vatnajökull. Bárðarbunga is the centre of a volcanic system which includes the fissure swarms of Veiðivötn to the SW and Dyngjuháls to the NE. The Grímsvötn volcano is the centre of a system that comprises the Laki fissure swarm in the SW and extends for an unknown distance to the NE of the volcano. Þórðarhyrna is probably a separate central volcano within this system. The Kverkfjöll system can be traced 10 km to the SW of the Kverkfjöll volcano. It appears to be separated from the Grímsvötn volcano. The Askja fissure swarm extends beneath Dyngjujökull and can possibly be traced to the Grímsvötn volcano. Hamarinn and the ridge striking eastward from Hamarinn (Loki Ridge) are central volcanoes which together with the Fögrufjöll fissure swarm form a volcanic system. No support can be found in the topographic data for the existence of a central volcano near Breiðabunga. Volcanic activity in historical times has mainly been limited to the Grímsvötn and Bárðarbunga systems. Major rifting events have affected large sections of these volcanic systems but both have been remarkably quiet for the past decades. A few volcanic events are presumed to have occurred on the Hamarinn - Loki system and on the Askja fissure swarm beneath Dyngjujökull, but no event is known with certainty on the Kverkfjöll system. The rivers Skeiðará and Súla have the most frequent eruption-related jökulhlaups. They receive meltwater from the Grímsvötn caldera and the area to the SW of it, including Þórðarhyrna. Núpsvötn, Djúpá and Hverfisfljót drain the southwestern part of the Grímsvötn system, an area bounded by Þórðarhyrna, Geirvörtur, Hágöngur and Pálsfjall. Skaftá drains the Loki Ridge and the area west of Grímsvötn. Jökulhlaups in Kaldakvísl, and ultimately Þjórsá, must originate in the Bárðarbunga or the Hamarinn - Loki systems, and the only possible source for volcanic jökulhlaups in Skjálfandafljót is the northern part of the Bárðarbunga system. Jökulsá á Fjöllum may drain meltwater from activity in all the volcanic systems in northern Vatnajökull: Bárðarbunga, the Askja fissure swarm and Kverkfjöll. This includes the voluminous, ice-filled calderas of Bárðarbunga and Kverkfjöll. Activity in the northern part of the Grímsvötn system may cause floods in Jökulsá á Fjöllum. Meltwater from volcanic activity on the SE flank of a ridge that strikes south from Kverkfjöll may drain to Jökulsá á Brú. Volcanic activity farther north on the E flanks of this ridge would cause floods in Kreppa.

Björnsson, H., Pálsson, F., and Guðmundsson, M.T. (1994) Mat á áhrifum framhlaups Síðujökuls 1993-1994 á afrennsli jökulhlaups frá Skaftárkötlum til Hverfisfljóts, RH-95-19: Reykjavík, Raunvísindastofnun Háskólans, p. 10.

Brandsdóttir, B. (1984) "Seismic activity in Vatnajökull in 1900-1982 with special reference to Skeiðarárhlaups, Skaftárhlaups and Vatnajökull eruptions (Jarðskjálftar í Vatnajökli

1900-1982, tengsl þeirra við Skeiðarárhlaup, Skaftárhlaup og eldgos í jöklinum)": Jökull, v. **34**: p. 141-150.

Gíslason, S.R., Eiríksdóttir, E.S., Sigfússon, B., Elefsen, S.Ó., and Harðardóttir, J. (2004) Efnasamsetning og rennsli Skaftár; í septemberhlaupi 2002, sumarrennsli 2003 og í septemberhlaupi 2003 RH-07-2004 Raunvísindastofnun Háskólans, p. 21 pp.

Gíslason, S.R., Ingvarsson, G.B., Eiríksdóttir, E.S., Sigfússon, B., Elefsen, S.Ó., Harðardóttir, J., Kristinsson, B., and Þorláksdóttir, S.B. (2005) Efnasamsetning og rennsli straumvatna á slóðum Skaftár 2002 til 2004, RH-12-2005, Raunvísindastofnun Háskólans, p. 54 pp.

Guðmundsson, M.T., and Högnadottir, ó. (2007) "Volcanic systems and calderas in the Vatnajökull region, central Iceland: Constraints on crustal structure from gravity data": Journal of Geodynamics, v. **43**(1): p. 153-169.

A Bouguer anomaly map is presented of southern central Iceland, including the western part of Vatnajökull and adjacent areas. A complete Bouguer reduction for both ice surface and bedrock topography is carried out for the glaciated regions. Parts of the volcanic systems of Vonarskarð-Hágöngur, Barðarbunga-Veiðivötn, Grimsvötn-Laki, and to a lesser extent Kverkfjöll, show up as distinct features on the gravity map. The large central volcanoes with calderas: Vonarskarð, Barðarbunga, Kverkfjöll and Grimsvötn, are associated with 15-20 mGal gravity highs caused by high density bodies in the uppermost 5 km of the crust. Each of these bodies is thought to be composed of several hundred km3 of gabbros that have probably accumulated over the lifetime of the volcano. The Skaftarkatlar subglacial geothermal areas are not associated with major anomalous bodies in the upper crust. The central volcanoes of Vonarskarð and Hagöngur belong to the same volcanic system; this also applies to Barðarbunga and Hamarinn, and Grimsvötn and Þórðarhyrna. None of the smaller of the two volcanoes sharing a system (Hagöngur, Hamarinn and Þórðarhyrna) is associated with distinct gravity anomalies and clear caldera structures have not been identified. However, ridges in the gravity field extend between each pair of central volcanoes, indicating that they are connected by dense dyke swarms. This suggests that when two central volcanoes share the same system, one becomes the main pathway for magma, forming a long-lived crustal magma chamber, a caldera and large volume basic intrusive bodies in the upper crust. Short residence times of magma in the crust beneath these centres favour essentially basaltic volcanism. In the case of the second, auxillary central volcano, magma supply is limited and occurs only sporadically. This setting may lead to longer residence times of magma in the smaller central volcanoes, favouring evolution of the magma and occasional eruption of rhyolites. The eastern margin of the Eastern Volcanic Zone is marked by a NE-SW lineation in the gravity field, probably caused by accumulation of low density, subglacially erupted volcanics within the volcanic zone. This lineation lies 5-10 km to the east of Grimsvötn.

Hardardóttir, J., Snorrason, Á., Zóphaníasson, S., and Pálsson, S. (2004) Sediment discharge in jökulhlaups in Skaftá river, South Iceland, *in* Beylich, A.A., Sæmundsson, Decaulne, A., and Sandberg, O., eds., Sedimentary source-to-sink-fluxes in cold environments: Sauðárkrókur, Náttúrustofa Norðurlands vestra, p. 104.

Jóhannesson, T., Knudsen, Ó., and Ástvaldsson, L. (1985) "Mæling á hitastigi hlaupvatns við jökuljaðar nálægt hámarki Skaftárhlaups sumarið 1984": Jökull, v. **35**: p. 110.

Kaldal, I. (2002) Skaftá, athugun á áfoki. Útbreiðsla Skaftárhlaupsins 1995, OS-2002/022, Orkustofnun, Rannsóknasvið

Kaldal, I., and Vilmundardóttir, E.G. (2000) Athugun á áfoki við Skaftá og Hverfisfljót. Stöðuyfirlit í mars 2000, OS-2000/029, Orkustofnun, Rannsóknasvið.

N.N. (1979) "Hlaup í Skaftá": Týli, tímarit um náttúrufræði og náttúruvernd, v. **9**(2): p. 57-58.

Old, G.H., Lawler, D.M., and Snorrason, A. (2005) "Discharge and suspended sediment dynamics during two jökulhlaups in the Skaftá river, Iceland": Earth Surface Processes and Landforms, v. **30**(11): p. 1441-1460.

This paper investigates the dynamics and significance of discharge and suspended sediment transport (SST) during two jökulhlaups (glacier outburst floods) in the Skaftá River, south Iceland. Jökulhlaups occur frequently in many glacial environments and are highly significant in the gemorphological evolution of river basins and coastal environments. However, direct high-resolution monitoring of jökulhlaups has rarely been accomplished and hardly ever at more than one station in a downstream sequence. Here we present detailed data on jökulhlaup discharge and water quality from an intensive monitoring and sampling programme at two sites in summer 1997 when two jökulhlaups occurred. Evidence is discussed that supports the origin of both jökulhlaups being subglacial reservoirs, produced over several months by subglacial geothermal activity. At the downstream site, Asa-Eldvatn, the larger jökulhlaup (1) had a peak discharge of 572 m(3) s(-1) and a peak suspended sediment flux of 4650 kg s(-1)(channel-edge value) or 4530 kg s(-1) (cross-sectional). These values compare to the non-jökulhlaup flow of 120 m(3) s(-1) and suspended sediment flux of 190 kg s(-1)(channel-edge) or 301 kg s(-1) (cross-sectional). Significantly, the jökulhlaups transported 18(.)8 per cent of the annual runoff and 53 per cent of the annual suspended sediment transport in 6(.)6 per cent of the year. Furthermore, water chemistry, suspended sediment and seismic data suggest that volcanic activity and geothermal boiling (possibly including steam explosions) may have occurred during Jökulhlaup 1. The research illustrates the value of integrating high-resolution, multi-point field monitoring of meteorological, hydrological, hydrochemical, geomorphological and seismological data for understanding the dynamics, significance and downstream translation of jökulhlaups.

Roberts, M.J., Tweed, F.S., Russell, A.J., Knudsen, Ó., Lawson, D.E., Larson, G.J., Evenson, E.B., and Björnsson, H. (2002) "Glaciohydraulic supercooling in Iceland": Geology, v. **30**(no. 5): p. 439-442; 6 figures.

We present evidence of glaciohydraulic supercooling under jökulhlaup and ablationdominated conditions from two temperate Icelandic glaciers. Observations show that freezing of sediment-laden meltwater leads to intraglacial debris entrainment during normal and extreme hydrologic regimes. Intraglacial frazil ice

propagation under normal ablation-dominated conditions can trap copious volumes of sediment, which forms anomalously thick sections of debris-rich ice. Glaciohydraulic supercooling plays an importantrole in intraglacial debris entrainment and should be given more attention in models of basal ice development. Extreme jökulhlaup conditions can result in significant intraglacial sediment accretion by supercooling, which may explain the concentration of englacial sediments deposited in Heinrich layers in the North Atlantic during the last glaciation.

Þórarinsson, S., and Rist, S. (1955) "Skaftárhlaup í september 1955 (Summary)": Jökull v. **5**: p. 37-40.

5.2.3 Bárðarbunga

Björnsson, H. (1992) "Jökulhlaups in Iceland: prediction, characteristics and simulation": Annals of Glaciology, v. **16**: p. 95-106.

Jökulhlaups drain regularly from six subglacial geothermal areas in Iceland. From Grímsvötn in Vatnajökull, jökulhlaups have occurred at a 4-6 year interval since the 1940s with a peak discharge of 1,000 - 10,000 m3/s, 2 -3 weeks duration and total volumes of 0.5-3 km3. Prior to that, about one jökulhlaup occurred per decade with an estimated discharge of 5 km3 of water and a peak discharge of approximately 30,000 m3/s. Clarke½s (1982) modification of Nye's (1976) general model of discharge of jökulhlaups gives in many respects satisfactory simulations for jökulhlaups from Grímsvötn. The best fit is obtained for the Manning roughness coefficients n = 0.08-0.09 m-1/3 s and a constant lake temperature of 0.2 °C (which is the present lake temperature). The rapid ascent of the exceptional jökulhlaup in 1938, which accompanied a volcanic eruption, can only be simulated for a lake temperature of the order of 4 °C. Jökulhlaups originating at geothermal areas beneath ice cauldrons located 10-15 km northwest of Grímsvötn have a peak discharge of 200 - 1,500 m3/s in 1-3 days, the total volume is 50-350x106m3, and they recede slowly in 1-2 weeks. The form is in that respect a mirror image of the typical Grímsvötn hydrograph. The reservoir water temperature must be well above the melting point (10-20 °C) and the flowing water seems not to be confined to a tunnel but spread out beneath the glacier and later gradually collected back to conduits. Since the time of the settlement of Iceland (870 A.D.), at least 80 subglacial volcanic eruptions have been reported, many of them causing tremendous jökulhlaups with dramatic impact on inhabitated areas and landforms. The peak discharge of the largest floods (from Katla) has been estimated at the order of 100-300,000 m3/s, duration was 3 -5 days and the total volume of the order of 1 km3. It is now apparent that the potentially largest and most catastrophic jökulhlaups may be caused by eruptions in the voluminous ice-filled calderas in northern Vatnajökull (of Bárdarbunga and Kverkfjöll). They may be the source of prehistoric jökulhlaups, with estimated peak discharge of 400,000 m3/s. At present, jökulhlaups originate from some fifteen marginal ice-dammed lakes in Iceland. Typical values for peak discharges are 1,000 - 3,000 m3/s, duration 2-5 days and total volumes of 2,000 x 106 m3. Hydrographs for jökulhlaups from marginal lakes have a shape similar to those of the typical Grímsvötn jökulhlaup. Simulations give reasonable ascent of the hydrographs for constant lake temperature of about 1 °C but fail to show the recession. Some floods from marginal lakes, however, have reached their peaks exceptionally rapidly, in one day. That ascent could be simulated by drainage of lake water of 4-8 °C. An empirical power law relationship is obtained between peak discharge and total volume of the jökulhlaups from Grímsvötn; Qmax =

K Vtb, where Qmax is measured in m3/s, Vt in 106 m3, K = 4.15 10-3 s-1 m-2.52 and b = 1.84. In general, the jökulhlaups (excepting those caused by eruptions) occur when the lake has risen to a critical level, but before a lake level required for simple flotation of the ice dam is reached. The difference between the hydrostatic water pressure maintained by the lake and the ice overburden pressure of the ice dam is of the order 2-6 bar.

Björnsson, H., and Einarsson, P. (1990) "Volcanoes beneath Vatnajökull, Iceland: Evidence from radio echo-sounding earthquakes and jökulhlaups": Jökull, v. **40**: p. 147-168.

Integration of knowledge of subglacial topography, earthquake activity and jökulhlaups has contributed to more precise locations of the volcanic systems beneath Vatnajökull. Bárðarbunga is the centre of a volcanic system which includes the fissure swarms of Veiðivötn to the SW and Dyngjuháls to the NE. The Grímsvötn volcano is the centre of a system that comprises the Laki fissure swarm in the SW and extends for an unknown distance to the NE of the volcano. Þórðarhyrna is probably a separate central volcano within this system. The Kverkfjöll system can be traced 10 km to the SW of the Kverkfjöll volcano. It appears to be separated from the Grímsvötn volcano. The Askja fissure swarm extends beneath Dyngjujökull and can possibly be traced to the Grímsvötn volcano. Hamarinn and the ridge striking eastward from Hamarinn (Loki Ridge) are central volcanoes which together with the Fögrufjöll fissure swarm form a volcanic system. No support can be found in the topographic data for the existence of a central volcano near Breiðabunga. Volcanic activity in historical times has mainly been limited to the Grímsvötn and Bárðarbunga systems. Major rifting events have affected large sections of these volcanic systems but both have been remarkably quiet for the past decades. A few volcanic events are presumed to have occurred on the Hamarinn - Loki system and on the Askja fissure swarm beneath Dyngjujökull, but no event is known with certainty on the Kverkfjöll system. The rivers Skeiðará and Súla have the most frequent eruption-related jökulhlaups. They receive meltwater from the Grímsvötn caldera and the area to the SW of it, including Þórðarhyrna. Núpsvötn, Djúpá and Hverfisfljót drain the southwestern part of the Grímsvötn system, an area bounded by Þórðarhyrna, Geirvörtur, Hágöngur and Pálsfjall. Skaftá drains the Loki Ridge and the area west of Grímsvötn. Jökulhlaups in Kaldakvísl, and ultimately Þjórsá, must originate in the Bárðarbunga or the Hamarinn - Loki systems, and the only possible source for volcanic jökulhlaups in Skjálfandafljót is the northern part of the Bárðarbunga system. Jökulsá á Fjöllum may drain meltwater from activity in all the volcanic systems in northern Vatnajökull: Bárðarbunga, the Askja fissure swarm and Kverkfjöll. This includes the voluminous, ice-filled calderas of Bárðarbunga and Kverkfjöll. Activity in the northern part of the Grímsvötn system may cause floods in Jökulsá á Fjöllum. Meltwater from volcanic activity on the SE flank of a ridge that strikes south from Kverkfjöll may drain to Jökulsá á Brú. Volcanic activity farther north on the E flanks of this ridge would cause floods in Kreppa.

Freysteinsson, S. (1972) "Jökulhlaup í Köldukvísl": Jökull, v. **22**: p. 83-88.

Guðmundsson, A.T., and (1996) Volcanoes in Iceland : 10.000 years of volcanic history: Reykjavík, Vaka-Helgafell, 136 s. : myndir, teikn., kort, töflur p.

Guðmundsson, M.T., and Högnadottir, ó. (2007) "Volcanic systems and calderas in the Vatnajökull region, central Iceland: Constraints on crustal structure from gravity data": Journal of Geodynamics, v. **43**(1): p. 153-169.

A Bouguer anomaly map is presented of southern central Iceland, including the western part of Vatnajökull and adjacent areas. A complete Bouguer reduction for both ice surface and bedrock topography is carried out for the glaciated regions. Parts of the volcanic systems of Vonarskarð-Hágöngur, Barðarbunga-Veiðivötn, Grimsvötn-Laki, and to a lesser extent Kverkfjöll, show up as distinct features on the gravity map. The large central volcanoes with calderas: Vonarskarð, Barðarbunga, Kverkfjöll and Grimsvötn, are associated with 15-20 mGal gravity highs caused by high density bodies in the uppermost 5 km of the crust. Each of these bodies is thought to be composed of several hundred km3 of gabbros that have probably accumulated over the lifetime of the volcano. The Skaftarkatlar subglacial geothermal areas are not associated with major anomalous bodies in the upper crust. The central volcanoes of Vonarskarð and Hagöngur belong to the same volcanic system; this also applies to Barðarbunga and Hamarinn, and Grimsvötn and Þórðarhyrna. None of the smaller of the two volcanoes sharing a system (Hagöngur, Hamarinn and Þórðarhyrna) is associated with distinct gravity anomalies and clear caldera structures have not been identified. However, ridges in the gravity field extend between each pair of central volcanoes, indicating that they are connected by dense dyke swarms. This suggests that when two central volcanoes share the same system, one becomes the main pathway for magma, forming a long-lived crustal magma chamber, a caldera and large volume basic intrusive bodies in the upper crust. Short residence times of magma in the crust beneath these centres favour essentially basaltic volcanism. In the case of the second, auxillary central volcano, magma supply is limited and occurs only sporadically. This setting may lead to longer residence times of magma in the smaller central volcanoes, favouring evolution of the magma and occasional eruption of rhyolites. The eastern margin of the Eastern Volcanic Zone is marked by a NE-SW lineation in the gravity field, probably caused by accumulation of low density, subglacially erupted volcanics within the volcanic zone. This lineation lies 5-10 km to the east of Grimsvötn.

5.2.4 Þórðarhyrna

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5.2.5 Kverkfjöll, hlaup í Jökulsá á Fjöllum

Björnsson, H. (1992) "Jökulhlaups in Iceland: prediction, characteristics and simulation": Annals of Glaciology, v. **16**: p. 95-106.

Jökulhlaups drain regularly from six subglacial geothermal areas in Iceland. From Grímsvötn in Vatnajökull, jökulhlaups have occurred at a 4-6 year interval since the 1940s with a peak discharge of 1,000 - 10,000 m3/s, 2 -3 weeks duration and total volumes of 0.5-3 km3. Prior to that, about one jökulhlaup occurred per decade with an estimated discharge of 5 km3 of water and a peak discharge of approximately 30,000 m3/s. Clarke½s (1982) modification of Nye's (1976) general model of discharge of jökulhlaups gives in many respects satisfactory simulations for jökulhlaups from Grímsvötn. The best fit is obtained for the Manning roughness coefficients n = 0.08-0.09 m-1/3 s and a constant lake temperature of 0.2 °C (which is the present lake temperature). The rapid ascent of the exceptional jökulhlaup in 1938, which accompanied a volcanic eruption, can only be simulated for a lake temperature of the order of 4 °C. Jökulhlaups originating at geothermal areas beneath ice cauldrons located 10-15 km northwest of Grímsvötn have a peak discharge of 200 - 1,500 m3/s in 1-3 days, the total volume is 50-350x106m3, and they recede slowly in 1-2 weeks. The form is in that respect a mirror image of the typical Grímsvötn hydrograph. The reservoir water temperature must be well above the melting point (10-20 °C) and the flowing water seems not to be confined to a tunnel but spread out beneath the glacier and later gradually collected back to conduits. Since the time of the settlement of Iceland (870 A.D.), at least 80 subglacial volcanic eruptions have been reported, many of them causing tremendous jökulhlaups with dramatic impact on inhabitated areas and landforms. The peak discharge of the largest floods (from Katla) has been estimated at the order of 100-300,000 m3/s, duration was 3 -5 days and the total volume of the order of 1 km3. It is now apparent that the potentially largest and most catastrophic jökulhlaups may be caused by eruptions in the voluminous ice-filled calderas in northern Vatnajökull (of Bárdarbunga and Kverkfjöll). They may be the source of prehistoric jökulhlaups, with estimated peak discharge of 400,000 m3/s. At present, jökulhlaups originate from some fifteen marginal ice-dammed lakes in Iceland. Typical values for peak discharges are 1,000 - 3,000 m3/s, duration 2-5 days and total volumes of 2,000 x 106 m3. Hydrographs for jökulhlaups from marginal lakes have a shape similar to those of the typical Grímsvötn jökulhlaup. Simulations give reasonable ascent of the hydrographs for constant lake temperature of about 1 °C but fail to show the recession. Some floods from marginal lakes, however, have reached their peaks exceptionally rapidly, in one day. That ascent could be simulated by drainage of lake water of 4-8 °C. An empirical power law relationship is obtained between peak discharge and total volume of the jökulhlaups from Grímsvötn; Qmax = K Vtb, where Qmax is measured in m3/s, Vt in 106 m3, K = 4.15 10-3 s-1 m-2.52 and b = 1.84. In general, the jökulhlaups (excepting those caused by eruptions) occur when the lake has risen to a critical level, but before a lake level required for simple flotation of the ice dam is reached. The difference between the hydrostatic water pressure maintained by the lake and the ice overburden pressure of the ice dam is of the order 2-6 bar.

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Carrivick, J.L. (2004) Palaeohydraulics of a glacier outburst flood (jökulhlaup) from Kverkfjöll, Iceland, *in* Beylich, A.A., Sæmundsson, Decaulne, A., and Sandberg, O., eds., Sedimentary source-to-sink-fluxes in cold environments: Sauðárkrókur, Náttúrustofa Norðurlands vestra, p. 104.

— (2006) "Application of 2D hydrodynamic modelling to high-magnitude outburst floods: An example from Kverkfjöll, Iceland": Journal of Hydrology, v. **321**(1-4): p. 187-199.

High-magnitude outburst floods cause rapid landscape change and are a hazard to life, property and infrastructure. However, high-magnitude fluvial processes and mechanisms of erosion, transport and deposition are very poorly understood, and remain largely unquantified. This poor understanding is partly because of the inherent difficulty of directly measuring high-magnitude outburst floods, but also because of the limitations and assumptions of 1D models and other palaeohydrological methods, which reconstructions of high-magnitude floods have to date relied upon. This study therefore applies a 2D hydrodynamic model; SOBEK, to reconstructing a high-magnitude outburst flood. This method offers the first calculations of high-magnitude fluvial flow characteristics within an anastomosing network of simultaneously inundated channels, including; sheet or unconfined flow, simultaneous channel and sheet flow, flow around islands, hydraulic jumps, multi-directional flow including *backwater areas, hydraulic ponding and multiple points of flood initiation. 2D-modelling of outburst floods clearly has the potential to revolutionise understanding of high-magnitude spatial and temporal hydraulics and high-magnitude flow phenomena, geomorphological and sedimentological processes, and hence rapid fluvial landscape change. This potential for new understanding is because of the now wide availability of high-resolution DEM data for large and often inaccessible areas, and the availability of remotely-sensed data that can parameterise outburst flood sources, such as glacial lakes, for example. Additionally, hydraulic models and computing power are now sufficient to cope with large (5,000,000 grid cells) areas of inundation and large (100,000 m3 s-1) peak discharges.*

— (2007 (in press)) "Modelling transient hydrodynamics and rapid landscape change due to a high-magnitude outburst flood: an example from Kverkfjöll volcano, Iceland": Annals of Glaciology, v. **45**.

— (Submitted) "Hydrodynamics and geomorphic work of jökulhlaups (glacial outburst floods) from Kverkfjöll volcano, Iceland": Hydrological Processes.

— (Submitted) Impacts and characteristics of jökulhlaups from Kverkfjöll, Iceland [**PhD thesis**], University of Keele.

Carrivick, J.L., Pringle, J.K., Russell, A.J., and Cassidy, N.J. (2007 (In press)) "Architecture and stratigraphy of high-magnitude outburst flood sedimentation within a bedrock valley system": Journal of Environmental and Engineering Geophysics.

Jökulhlaups and lahars are both types of high-magnitude outburst flood that commonly comprise a glacial meltwater and volcaniclastic sediment mix, and have discharges that are typically several orders of magnitude greater than perennial flows. Both types thus constitute a serious threat to life, property and infrastructure but are too powerful and too short-lived for direct measurements of flow characteristics to be made. Consequently a variety of indirect methods have been used to reconstruct flow properties, processes and mechanisms. Unfortunately, a lack of observations of sedimentary architecture, geometry and stratigraphic relationships, are hampering our ability to discriminate fluvial magnitude-frequency regimes and styles of deposition, particularly within rapidly-varied flows. This paper therefore uses Ground Penetrating Radar (GPR) to obtain quantitative data on subsurface sedimentary character of high-magnitude outburst flood sediments, including geometry, architecture and stratigraphy, from a bedrock-valley system in north-central Iceland. Basement pillow lava and subaerial lava flows are distinguished based upon a chaotic, and hummocky signature, and thickness, lack of coherent internal structure, and upper rough surface as evidenced by concentration of hyperbole point sources, respectively. Unconsolidated sedimentary units are interpreted due to the presence of coherent internal structures of a horizontal and sub horizontal nature. Deposition produced spatially diverse sediments due to rapidly-varied flow conditions. Observations include prograding and backfilling architecture, intercalated slope material and fluvial sediments, and multiphase deposition of sediments. Specifically, outburst flood sediments were initially deposited by traction load of coarse-grained material on prograding bedforms, and subsequently by drop-out from suspension of finer-grained material. The latter phase produces laterally extensive tabular sedimentary *architectures that in-fill pre-existing topography and mask the complexity of bedrock forms beneath. Existing qualitative concepts of high-magnitude fluvial deposition within a topographically confined bedrock channel are therefore now refined with quantitative data on sediment architecture and thus flow regimes.*

Carrivick, J.L., Russell, A.J., and Tweed, F.S. (2004) "Geomorphological evidence for jökulhlaups from Kverkfjöll volcano, Iceland": <u>Geomorphology</u> v. **63**: p. 81-102.

Jökulhlaups (glacial outburst floods) are known to have drained along the Jökulsá á Fjöllum river in Iceland during the Holocene. However, little is known about their number, age, source, and flow characteristics. This paper provides detailed geomorphological evidence for jökulhlaups that have routed from the Kverkfjöll ice margin and hence into the Jökulsá á Fjöllum. Erosional evidence of jökulhlaups from Kverkfjöll includes gorges, cataracts, spillways, subaerial lava steps, and valley-wide scoured surfaces. Depositional evidence includes wash limits, boulder bars, cataract-fill mounds, terraces, slackwater deposits, and outwash fans. Some of these landforms have been documented previously in association with jökulhlaups. However, subaerial lava surfaces that have been scoured of the upper clinker, gorges within pillow–hyaloclastite ridges, gorges between pillow–hyaloclastite ridges and subaerial lava flows, subaerial lava lobe steps, cataract-fill mounds, and boulder run-ups are previously undocumented in the literature. These landforms may therefore be diagnostic of jökulhlaups within an active volcanic rifting landscape. The nature and spatial distribution of these landforms and their stratigraphic association with other landforms suggest that there have been at least two jökulhlaups through Kverkfjallarani. The Biskupsfell eruption occurred between these two jo¨kulhlaups. Kverkfjallarani jökulhlaups were very strongly influenced by topography, geology, and interevent processes that together determined the quantity and nature of sediment availability. Such controls have resulted in jökulhlaups that were probably fluidal, turbulent, and supercritical over large areas of the anastomosing channel bed. Kverkfjallarani jökulhlaups would have had highly variable hydraulic properties, both spatially and temporally. The knowledge of flow characteristics that can be gained from jökulhlaup impacts has implications for recognising jökulhlaups in the rock record and for hazard analysis and mitigation within similar landscapes and upon other glaciated volcanoes.

— (2004) Glacier outburst floods (jökulhlaups) from Kverkfjöll, Iceland:flood routeways, flow characteristics and sedimentary impacts, *in* Beylich, A.A., Sæmundsson, Decaulne, A., and Sandberg, O., eds., <u>Sedimentary source-to-sink-fluxes in cold environments</u>: Sauðárkrókur, Náttúrustofa Norðurlands vestra, p. 104.

Carrivick, J.L., Russell, A.J., Tweed, F.S., and Twigg, D. (2004) "Palaeohydrology and sedimentary impacts of jokulhlaups from Kverkfjoll, Iceland": <u>Sedimentary Geology</u>, v. **172**(1-2): p. 19-40.

Jokulhlaups (glacial outburst floods) occur frequently within Iceland and within most glaciated regions of the world. The largest jokulhlaups known to have occurred within Iceland drained from the northern margin of the Vatnajokull and along the Jokulsa a Fjollum during the Holocene. However, little is known about the number, age and flow characteristics of the Jokulsa a Fjollum jokulhlaups. One source of meltwater into the Jokulsa a Fjollum is Kverkfjoll, a glaciated stratovolcano. This paper provides detailed sedimentological evidence demonstrating that jokulhlaups have routed through

Kverkfjallarani and hence from Kverkfjoll. Sedimentological evidence of jokulhlaups includes valley-fill deposits and slack water deposits. Lithofacies, which are indicative of high-magnitude fluvial sedimentation, show that these deposits cannot be the result of nonjokulhlaup processes. The situation and nature of the sediments permit palaeoflow reconstructions. Fine-grained deposits within slack water deposits mark a break in jokulhlaup deposition and suggest that at least three jokulhlaups have drained through Hraundalur, the predominant valley within Kverkfjallarani. Evidence of lava overrunning `wet' jokulhlaup deposits indicates that jokulhlaups occurred in close association with volcanic eruptions in the Biskupsfell fissure. The largest jokulhlaup was initially hyperconcentrated and subsequently became more fluid. Slope-area reconstructions indicate that the largest jokulhlaup had a probable average peak discharge of 45,000-50,000 m3 s-1; however, the peak discharge attenuated by 25-30% in just 25 km. These observations quantify the number, rheology, hydraulics and chronology of jokulhlaups from Kverkfjoll and hence within the Jokulsa a Fjollum. This study presents a model of jokulhlaup impacts and characteristics from glaciated volcanoes and/or within volcanic rifting zones.

Carrivick, J.L., and TWIGG, D.R.T. (2004) "Jökulhlaup-influenced Topography and Geomorphology at Kverkfjöll, Iceland": Journal of Maps p. 17-27.

High magnitude jökulhlaups (glacial outburst floods) are known to have drained along the Jökulsá á Fjöllum river from the northern margin of Vatnajökull, Iceland during the Holocene. However, little is known of the number, age, source and flow characteristics of these jökulhlaups. Ongoing research therefore seeks to quantitatively analyse jökulhlaups from Kverkfjöll, which is a discrete source of meltwater into the Jökulsá á Fjöllum. To this end a high-resolution digital elevation model was produced and extensive geomorphological mapping and sedimentary analyswere accomplished in the field.The digital elevation model was produced by processing digitally scanned aerial photographs with the ERDAS Imagine Orthobase software. Processing incorporated twenty-nine ground control points, which were surveyed with a differential global positioning system. Ground control points allow photographic distortion to be remove and the elevation model to be located on the Earth's surface. A DEM with 10m horizontal resolution was resampled from a 5m horizontal resolution extraction. The DEM has sub-metre vertical accuracy. The DEM is substantially more detailed than presently available topographic maps an is therefore of interest for a whole range of recreational and scientific purposes. This research has identified geomorphological surfaces that distinguish at least three jökulhlaups from Kverkfjöll during the Holocene. These jökulhlaups routed into the Jökulsá á Fjöllum. Ongoing research has also sought to examine flow characteristics of jökulhlaups through Kverkfjallarani and to compare calculations of spatial and temporal hydraulics to maps of geomorphological and sedimentological jökulhlaup products.

Cassidy, N.J., Russell, A.J., Pringle, J.K., and Carrivick, J.L. (2004) GPR-Derived Architecture of Large-Scale Icelandic Jökulhlaup Deposits, North-East Iceland, Tenth International Conference on Ground Penetrating Radar: Delft, The Netherlands, .

Jökulhlaups (glacial outburst floods) occur frequently throughout Iceland and across most of the glaciated regions of the world. The largest of these jökulhlaups are known to have occurred along the northern margin of the Vatnajökull Icecap and drained down the Jökulsá á Fjöllum river during the Holocene. Unfortunately, little is known about the number, frequency, age and flow characteristics of the Jökulsá á Fjöllum jökulhlaups and the relationship between their deposit architectures and the underlying volcanic

lavas. During the summer of 2003, a total of over 20 km of GPR data was collected from a variety of jökulhlaup outwash sediments across the Jökulsá á Fjöllum flood plain. GPR results and corresponding facies interpretations are presented for the outwash deposits at two locations: Kverkfjöll, (approximately 20 Km from the jökulhlaup source) and Möðrudalur (approximately 100 Km downstream from the glacial margin). By combining the GPR data with ground surveying, photogrammetry and detailed sedimentary outcrop evidence, this study adds new perspectives to the sedimentary analysis of high-magnitude jökulhlaup events and their large-scale bars and bedforms. The results indicate that sedimentary architectures are controlled by the topographic nature of the underling lavas and the flow conditions in each region. By analysing the GPR derived facies in detail, it is also possible to identify different phases of jökulhlaup deposition. This information is vital for the assessment of jökulhlaup magnitudes, frequencies, and pathways and can be used for the prediction of future jökulhlaup impacts.

Einarsson, T. (1976) "Tilgáta um orsök hamfarahlaupsins í Jökulsá á Fjöllum og um jarðvísindalega þýðingu þessa mikla hlaups": Jökull, v. **26**: p. 61-64.

Guðmundsson, M.T., and Högnadottir, Þ. (2007) "Volcanic systems and calderas in the Vatnajökull region, central Iceland: Constraints on crustal structure from gravity data": Journal of Geodynamics, v. **43**(1): p. 153-169.

A Bouguer anomaly map is presented of southern central Iceland, including the western part of Vatnajökull and adjacent areas. A complete Bouguer reduction for both ice surface and bedrock topography is carried out for the glaciated regions. Parts of the volcanic systems of Vonarskarð-Hágöngur, Barðarbunga-Veiðivötn, Grimsvötn-Laki, and to a lesser extent Kverkfjöll, show up as distinct features on the gravity map. The large central volcanoes with calderas: Vonarskarð, Barðarbunga, Kverkfjöll and Grimsvötn, are associated with 15-20 mGal gravity highs caused by high density bodies in the uppermost 5 km of the crust. Each of these bodies is thought to be composed of several hundred km3 of gabbros that have probably accumulated over the lifetime of the volcano. The Skaftarkatlar subglacial geothermal areas are not associated with major anomalous bodies in the upper crust. The central volcanoes of Vonarskarð and Hagöngur belong to the same volcanic system; this also applies to Barðarbunga and Hamarinn, and Grimsvötn and Þórðarhyrna. None of the smaller of the two volcanoes sharing a system (Hagöngur, Hamarinn and Þórðarhyrna) is associated with distinct gravity anomalies and clear caldera structures have not been identified. However, ridges in the gravity field extend between each pair of central volcanoes, indicating that they are connected by dense dyke swarms. This suggests that when two central volcanoes share the same system, one becomes the main pathway for magma, forming a long-lived crustal magma chamber, a caldera and large volume basic intrusive bodies in the upper crust. Short residence times of magma in the crust beneath these centres favour essentially basaltic volcanism. In the case of the second, auxillary central volcano, magma supply is limited and occurs only sporadically. This setting may lead to longer residence times of magma in the smaller central volcanoes, favouring evolution of the magma and occasional eruption of rhyolites. The eastern margin of the Eastern Volcanic Zone is marked by a NE-SW lineation in the gravity field, probably caused by accumulation of low density, subglacially erupted volcanics within the volcanic zone. This lineation lies 5-10 km to the east of Grimsvötn.

Höskuldsson, Á., Sparks, R.S.J., and Carroll, M.R. (2006) "Constraints on the dynamics of subglacial basalt eruptions from geological and geochemical observations at Kverkfjöll, NE-Iceland": Bulletin of Volcanology, v. **68**(7-8): p. 689-701.

The Kverkfjöll area, NE Iceland is characterised by subglacial basalt pillow lavas erupted under thick ice during the last major glaciation in Iceland. The water contents of slightly vesiculated glassy rims of pillows in six localities range from 0.85 +/- 0.03 to 1.04 +/- 0.03 wt%. The water content measurements allow the ice thickness to be estimated at between 1.2 and 1.6 km, with the range reflecting the uncertainty in the CO2 and water contents of the melt. The upper estimates agree with other observations and models that the ice thickness in the centre of Iceland was 1.5-2.0 km at the time of the last glacial maximum. Many of the pillows in the Kverkfjöll area are characterised by vesiculated cores (40-60% vesicles) surrounded by a thick outer zone of moderately vesicular basalt (15-20% vesicles). The core contains similar to 1 mm diameter spherical vesicles distributed uniformly. This observation suggests a sudden decompression and vesiculation of the still molten core followed by rapid cooling. The cores are attributed to a jökulhlaup in which melt water created by the eruption is suddenly released reducing the environmental pressure. Mass balance and solubility relationships for water allow a pressure decrease to be calculated from the observed change of vesicularity of between 4.4 and 4.7 MPa depressurization equivalent to a drop in the water level in the range 440-470 m. Consideration of the thickness of solid crust around the molten cores at the time of the jökulhlaup indicates an interval of 1-3 days between pillow emplacement and the jökulhlaup. Upper limits for ice melting rates of order 10(-3) m/s are indicated. This interpretation suggests that jökulhlaups can reactivate eruptions.

Rushmer, E.L. (2006) "Sedimentological and geomorphological impacts of the Jökulhlaup (glacial outburst flood) in January 2002 at Kverkfjöll, Northern Iceland": Geografiska Annaler Series a-Physical Geography, v. **88A**(1): p. 43-53.

Jökulhlaups (glacial outburst floods) are common hazards in many glaciated environments. However, research on the controls on the sedimentological and geomorphological impact of jökulhlaups is rare. Developing a more comprehensive understanding of flood impacts may be useful for hazard identification, prediction and mitigation. This study determines the controls on the sedimentological and geomorphological impact of a jökulhlaup in January 2002 at Kverkfjoll, northern Iceland. This jökulhlaup, caused by geothermal activity, reached a peak discharge of 490 m(3)s(-1) as recorded at a permanent gauging station 40 km downstream from the glacier snout. However, reconstructed peak discharges in the proximal part of the jökulhlaup channel near the glacier snout indicate a peak discharge of 2590 m(3)s(-1). The jokulhlaup hydrograph was characterized by a rapid rising stage and a more gradual falling stage. As a result, sedimentary and geomorphological impacts included poorly sorted, structureless, matrix-supported deposits; massive sand units; clast-supported units; ice-proximal cobbles, rip-up clasts and kettle-holes; and steep-sided kettle-holes. These features are proposed to be characteristic of rapid rising stage deposition. Additionally, large-scale gravel bars and bedload sheets prograded and migrated during the rapid rising stage. The development of these bedforms was facilitated by high bedload transport rates, due to high discharge acceleration rates during the rapid rising stage. During the more prolonged falling stage, there was sufficient time for sediment incision and erosion to occur, exhuming cobbles, ice blocks and rip-up clasts, and creating well-defined terrace surfaces. This study provides a clearer understanding of hydrological and sedimentological processes and mechanisms operating during jökulhlaups, and *helps to identify flood hazards more accurately, which is fundamental for hazard management and minimizing risk.*

5.2.6 Hlaup í Jökulsá á Fjöllum, ekki skilgreint úr hvaða eldstöð

Alho, P. (2003) "Land cover characteristics in NE Iceland with special reference to jökulhlaup geomorphology": Geografiska Annaler Series a-Physical Geography, v. **85A**(3-4): p. 213-227.

Subglacial eruptions in Vatnajökull have accounted for several jökulhlaups (glacial outburst floods) in the Northern Volcanic Zone (NVZ). These events and aeolian processes have had a considerable impact on the landscape evolution of the area. Most of this area is occupied by barren land cover; the northern margin of the barren land cover is advancing northwards, burying vegetation under wind-blown sediment. This paper presents a land-cover classification based on a supervised Landsat TM image classification with pre-processing and extensive field observations. Four land cover categories were identified: (a) lava cover (34.8%); (b) barren sediment cover (39.0%); (c) vegetation (25.1%); and (d) water and snow (1.1%). The mapping of sand transport routes demonstrates that a major aeolian sand transportation pathway is situated in the western part of the study area. The sedimentary formation elongated towards the northeast is evidence of active and continuous aeolian sand transportation towards the north. Interpretation of the satellite image suggests that four main areas are affected by jokulhlaups along the Jökulsa á Fjöllum: Ásbyrgi, Grímsstaðir, Herðubreið-Möðrudalur, and the Dyngjujökull sandur. In addition, jökulhlaup-related sediment cover (8%) in the study area, together with erosional features, are evidence of a severe and extensive jökulhlaup-induced process of land degradation.

Alho, P., Russell, A.J., Carrivick, J.L., and Kayhko, J. (2005) "Reconstruction of the largest Holocene jökulhlaup within Jökulsá á Fjöllum, NE Iceland": Quaternary Science Reviews, v. **24**(22): p. 2319-2334.

Glacial outburst floods (jökulhlaups) have a significant role for landscape evolution in NE Iceland. A number of jökulhlaups have routed from the northern margin of Vatnajökull during the Holocene. In this study, reconstruction of the largest Holocene jökulhlaup along Jökulsá á Fjöllum, NE Iceland was undertaken using the HEC-RAS hydraulic modelling and HEC-GeoRAS flood mapping techniques with a Digital Elevation Model (DEM) derived from ERS-InSAR data and field-based wash limit evidence. The largest jökulhlaup produced extensive erosional and depositional landforms across an inundated area of ~1390 km2 and is calculated to have had a peak discharge of 0.9x106 m3 s-1. Power per unit area within this jökulhlaup varied from 6 to 46,000 W m-2. Jökulhlaup hydraulics are related to geomorphogical evidence at three key sites: in Vaðalda, Upptyppingar and Möðrudalur sub-areas in order to explain the abrupt spatial variation of the flood characteristics on a regional scale and to relate erosional and depositional features to spatial variations in jökulhlaup hydraulics. These process-form relationships of the largest jökulhlaup along the Jökulsá á Fjöllum are compared with large outburst floods elsewhere. The largest Jökulsá á Fjöllum jökulhlaup had a factor of ~20 times smaller discharge and ~a factor of 20 times lower power per unit area than Altai palaeoflood--the largest known flood on the Earth.

Alho, P., Russell, A.J., J.L., C., and Käyhkö, J. (2005) "Large-scale impacts and characteristics of giant Holocene jökulhlaups within the Jökulsá á Fjöllum river, NE Iceland": Quaternary Science Reviews, v. **24**.

Glacial outburst floods (jökulhlaups) have a significant role for landscape evolution in NE Iceland. A number of jökulhlaups have routed from the northern margin of Vatnajökull during the Holocene. In this study, reconstruction of the largest Holocene jökulhlaup along Jökulsá á Fjöllum, NE Iceland was undertaken using the HEC-RAS hydraulic modelling and HEC-GeoRAS flood mapping techniques with a Digital Elevation Model (DEM) derived from ERS-InSAR data and field-based wash limit evidence. The largest jökulhlaup produced extensive erosional and depositional landforms across an inundated area of 1390 km2 and is calculated to have had a peak discharge of 0.9×106 m3 s−1. Power per unit area within this jökulhlaup varied from 6 to 46,000 W m−2. Jökulhlaup hydraulics are related to geomorphogical evidence at three key sites: in Vaðalda, Upptyppingar and Möðrudalur sub-areas in order to explain the abrupt spatial variation of the flood characteristics on a regional scale and to relate erosional and depositional features to spatial variations in jökulhlaup hydraulics. These process-form relationships of the largest jökulhlaup along the Jökulsá á Fjöllum are compared with large outburst floods elsewhere. The largest Jökulsá á Fjöllum jökulhlaup had a factor of 20 times smaller discharge and a factor of 20 times lower power per unit area than Altai palaeoflood—the largest known flood on the Earth.

Elíasson, S. (1978) "Molar um Jökulsárhlaup og Ásbyrgi": Náttúrufræðingurinn, v. **47**(3-4): p. 160-177.

— (1980) "Jarðsaga Jökulsárgljúfra": Lesörk Náttúruverndarráðs, v. **6**.

Ísaksson, S.P. (1985) "Stórhlaup í Jökulsá á Fjöllum á fyrri hluta 18. aldar": Náttúrufræðingurinn, v. **54**(3-4): p. 165-191.

Kirkbride, M.P., Dugmore, A.J., and Brazier, V. (2006) "Radiocarbon dating of mid-Holocene megaflood deposits in the Jökulsá á Fjöllum, north Iceland": The Holocene, v. **16**(4): p. 605 - 609.

Two megafloods in the canyon of the Jökulsá á Fjöllum, the major northern routeway for glaciovolcanic floods from Vatnajökull, have been closely dated by 14C AMS dates from Betula macrofossils within peat immediately below beds of flood-deposited sand. Ages of c. 4415 and c. 4065 yr BP (5020 and 4610 cal. yr BP) are consistent with the presence of the Hekla 4 tephra (c. 3830 yr BP) resting on the upper surface of the younger flood sand. These sediments are correlated across the Jökulsá a Fjöllum canyon with the upper flood sands in a stack recording around 16 flood events. Deposits on both sides of the canyon were trimmed by the last megaflood after the Hekla 3 tephra fall at c. 2900 yr BP, and the highest Holocene flood stages were at the culmination of a series peaking at c. 3500 yr BP. These floods have wider palaeoclimatic significance because they require the formation of large subglacial reservoirs below Vatnajökull. Therefore, the dated floods indicate that a large composite ice cap covered volcanoes in the southeastern highlands through the early and middle Holocene, and that flood routeways largely switched to the south after c. 3500 yr BP.

Knudsen, Ó., and Russell, A.J. (2002) Jökulhlaup deposits at Ásbyrgi, northern Iceland: sedimentology and implications or flow type. Proceedings of a symposium held July 2000 at Reykjavik, Iceland, *in* Snorrason, A., Finsdottir, H.P., and Moss, M.E., eds., The Extremes of the Extremes: An International Symposium on Extraordinary Floods: IAHS Publication Number 271: , p. 107-112.

Most research into the impact of Icelandic jökulhlaups has concentrated on large relatively unconfined outwash plains in the south of Iceland. By contrast, here is only a limited picture of the magnitude, rheology, geomorphic impact and sedimentology of floods draining to the north from Vatnajökull glacier. This paper presents sedimentary evidence of jökulhlaup deposits at Ásbyrgi. The sedimentary succession consists of large-scale sandy trough cross-bedded units capped by a boulder-rich unit. These deposits are interpreted as the product of a hyperconcentrated flow. The location of the pit and the boulder surface suggests these flows emanated from the present river course of the Jökulsá á Fjöllum. The last period of jökulhlaup activity within the Jökulsá á Fjöllum was in the early-mid eighteenth century when a series of jökulhlaups inundated the lowlands north of Ásbyrgi. The fact that the historical floods within the Jökulsá á Fjöllum were hyperconcentrated suggests that these floods may have had a subglacial volcanic origin.

Russell, A., Knudsen, O., Tweed, F., Marren, P.M., Rice, J.W., Roberts, M., Waitt, R.B., and Rushmer, L. (2001) Giant jökulhlaup from the northern margin of Vatnajökull ice cap, Vorráðstefna 2001: ágrip erinda og veggspjalda: Hótel Loftleiðum, Reykjavík, Jarðfræðifélag Íslands.

Russell, A.J., Kayhkö, J., Tweed, F.S., Alho, P., Carrivick, J.L., Marren, P.M., Cassidy, N.J., Rushmer, E.L., Mountney, N.P., and Pringle, J. (2004) Jökulhlaups impacts within the Jökulsá á Fjöllum system, NE Iceland: implications for sediment transfer, *in* Beylich, A.A., Sæmundsson, Decaulne, A., and Sandberg, O., eds., Sedimentary source-to-sink-fluxes in cold environments: Sauðárkrókur, Náttúrustofa Norðurlands vestra, p. 104.

Tómasson, H. (1973) "Hamfarahlaup í Jökulsá á Fjöllum": Náttúrufræðingurinn, v. **43**(1-2): p. 12-34.

Þórarinsson, S. (1950) "Jökulhlaup og eldgos á jökulvatnasvæði Jökulsár á Fjöllum": Náttúrufræðingurinn, v. **20**(3): p. 113-133.

— (1950) "Leiðrétting við "Jökulhlaup og eldgos." 20. árg. bls. 113-133": Náttúrufræðingurinn, v. **20**(4): p. 191.

5.2.7 Öræfajökull

Bingham, R.G. (1998) An assessment of rare, large magnitude (catastrophic) events in landscape evolution: a study of jökulhlaups in Öræfi, south-east Iceland. , University of Edinburgh.

Argument continues today over the relative significance of rare, large magnitude (a.k.a. catastrophic) events in landscape evolution. This project develops the debate by examination of the proglacial foregrounds of Falljökull and Kotárjökull, Öræfi, south-east Iceland. 'Catastrophic' jökulhlaups (large-scale glacier floods) inundated these neighbouring foregrounds in the years 1362 and 1727 as a result of sudden drainages of the Öræfajökull caldera during Plinian-style volcanic eruptions. The proglacial landscapes today preserve much of the geomorphology created by these jökulhlaups, but they have also experienced 'gradual' modification due to glacial and fluvial activity. The proglacial foregrounds of Falljökull and Kotárjökull are mapped geomorphologically, thus showing in more detail than has previously been published the courses followed by the 1362 and 1727 jökulhlaups. The distribution of the landforms produced by the jökulhlaups is explained using an analogue from the Skeidarársandur 1996 jökulhlaup studied by Russell and Knudsen (in press). In front of Falljökull, modification to the landscape since the 1727 jökulhlaup has mostly been directly related to glacier movement. Moraines left behind by glacier retreat are dated using lichenometry, basing the dating on an age/size relationship produced by Thompson and Jones (1986). Since 1727, Falljökull advanced until the late 19th century, and then retreated until the early 1970s. In front of Kotárjökull, modification to the landscape since the 1727 jökulhlaup may mostly be a result of fluvial action. Thompson and Jones (1986) believed that a sequence of river terraces had been cut over many years following 1727 due to gradual fluvial downcutting, but it is possible that the terraces were formed catastrophically during the jökulhlaup. These terraces were surveyed and mapped. Lichenometric dating was found to be impossible to carry out on the terraces owing to a thick moss cover. This means that the lichen dates recorded by Thompson and Jones (1986) may not reflect the true date of exposure of the terraces but merely when they were last free of moss. The results suggest that the Kotárjökull foreground preserves better the catastrophic landscape created by the jökulhlaups, whilst the Falljökull foreground has been modified to a greater degree by gradual land-forming processes. The unconfined nature of Falljökull's snout compared with the confined location of Kotárjökull's snout may have played a major role in producing these contrasting outcomes.

Björnsson Kvískerjum, F. (1996) "Hvenær hófst byggð í Öræfum eftir gosið á 14. öld": Skaftfellingur v. **11**: p. 78-85.

Björnsson, S. (1951) "Jökulhlaup 10. nóv. 1598": Náttúrufræðingurinn, v. **21**(3): p. 121-122.

— (1993) "Hvað gerðist við Kvíárjökull í lok ísaldar": Náttúrufræðingurinn v. **62**(1-2): p. bls. 21-33.

Einarsson, E., and others (1987) Skaftafell og Öræfi : þættir um náttúru og sögu, Hið íslenska náttúrufræðifélag, 20 s.: myndir, kort p.

Eiríksson, J., and others (1994) Roadlog : Nordic geological excursion in Iceland : quaternary geology - glaciology Reykjavík, myndir, kort, línurit p.

Hálfdánarson, E. (1918-1920) Frásögn síra Einars Hálfdánarsonar um hlaupið í Öræfajökli 1727, Blanda: fróðleikur gamall og nýr Volume **1.b.**: Reykjavík, Sögufélag, p. 54-59.

Imsland, P. (1987) Öræfajökull - brot úr jarðfræði og sögu eldfjallsins, Ferð í Öræfi 9. - 12. júlí 1987: Reykjavík, Hið íslenska náttúrufræðifélag, p. 14-15.

— (1988) Öræfajökull - brot úr jarðfræði og sögu eldfjallsins, Skaftafell og Öræfi, þættir um náttúru og sögu: Reykjavík, Hið íslenska Náttúrufræðifélag, p. 13-14.

— (2005) "Öræfajökull : brot úr jarðfræði og sögu eldfjallsins": Glettingur, v. **15 (39-40. tölubl.)**(2-3): p. 59-60.

— (2006) "Öræfajökull - brot úr jarðfræði og sögu eldfjallsins": Glettingur, v. **15. árg.**(2.-3. hefti): p. 39-40.

Stevenson, J.A., McGarvie, D.W., Smellie, J.L., and Gilbert, J.S. (2006) "Subglacial and ice-contact volcanism at the Öræfajökull stratovolcano, Iceland ": Bulletin of Volcanology, v. **68**(7-8): p. 737-752.

Eruptions of Öræfajökull have produced mafic and silicic magmas, and have taken place in both glacial and interglacial periods. The geology of the volcano records the differing response of magmas of contrasting composition to interaction with ice of variable thickness and gives insight into the development of a long-lived ice-covered stratovolcano. Vatnafjall, a ridge on the southeast flank of Öræfajökull, is the first area of the volcano to have been mapped in detail and the geological map is presented here alongside descriptions of each erupted unit. The oldest units comprise pillow lavas, hyaloclastite and jointed lava flows that were formed during subglacial basaltic eruptions involving abundant meltwater. The products of a subsequent explosive, initially phreatomagmatic, subglacial rhyolite eruption were confined by ice to form a tephra pile over 200 m thick that was intruded by dense rhyolite magma towards the end of the eruption. Confinement by ice caused a later trachydacite lava flow to form buttresses and a steep pillar. Whilst some of the meltwater produced infiltrated the lava (to generate red and black glassy breccias and cause localised steam explosions), it is likely that much of it drained down the steep topography. The most recently-erupted units are subaerial basaltic lava flows, the oldest of which were erupted during an interglacial period and have subsequently been partially eroded and scoured by advancing ice. Ice has been important in shaping the edifice by confining eruptive products to form constructional features and by later eroding parts of them to form deep valleys. Reconstructions of volcano-ice interaction allowed the local

thickness of the glacier at the time of each eruption to be estimated, and demonstrates that the upper surface of the ice has varied in elevation by over ~700 m.

Þorsteinsson, P. (1992) "Rauðalækur í Héraði milli sanda": Skaftfellingur, v. **8**: p. 140-158.

Þórarinsson, S. (1957) "Hérað milli sanda og eyðing þess": Andvari, v. **82. árg.**: p. 35-47.

— (1958) "The Öræfajökull eruption of 1362": Acta Nat. Isl. , v. **II** (2): p. 1-99.

— (1959) Der Öræfajökull und die Landschaft Öræfi. , Miscellaneous papers, Volume **22**: Bonn, Museum of Natural History.Department of Geology and Geography, p. 124.-138.

5.2.8 Esjufjöll

Björnsson, S. (1977) "Hlaupið í Jökulsá á Breiðamerkursandi árið 1927 (The jökulhlaup in Jökulsá on Breiðamerkursandur in 1927) ": Jökull, v. **27. árg.**: p. bls. 94-95.

— (1978) "Hlaupið í Jökulsá á Breiðamerkursandi árið 1927. Athugasemd": Jökull, v. **28**: p. 90.

5.2.9 Katla, með tilvitnunum í hlaup úr eldstöðvum í Vatnajökli

Björnsson, H. (1992) "Jökulhlaups in Iceland: prediction, characteristics and simulation": Annals of Glaciology, v. **16**: p. 95-106. **(aðallega um jökulhlaup úr Vatnajökli)**

Jökulhlaups drain regularly from six subglacial geothermal areas in Iceland. From Grímsvötn in Vatnajökull, jökulhlaups have occurred at a 4-6 year interval since the 1940s with a peak discharge of 1,000 - 10,000 m3/s, 2 -3 weeks duration and total volumes of 0.5-3 km3. Prior to that, about one jökulhlaup occurred per decade with an estimated discharge of 5 km3 of water and a peak discharge of approximately 30,000 m3/s. Clarke½s (1982) modification of Nye's (1976) general model of discharge of jökulhlaups gives in many respects satisfactory simulations for jökulhlaups from Grímsvötn. The best fit is obtained for the Manning roughness coefficients n = 0.08-0.09 m-1/3 s and a constant lake temperature of 0.2 °C (which is the present lake temperature). The rapid ascent of the exceptional jökulhlaup in 1938, which accompanied a volcanic eruption, can only be simulated for a lake temperature of the order of 4 °C. Jökulhlaups originating at geothermal areas beneath ice cauldrons located 10-15 km northwest of Grímsvötn have a peak discharge of 200 - 1,500 m3/s in 1-3 days, the total volume is 50-350x106m3, and they recede slowly in 1-2 weeks. The form is in that respect a mirror image of the typical Grímsvötn hydrograph. The reservoir water temperature must be well above the melting point (10-20 °C) and the flowing water seems not to be confined to a tunnel but spread out beneath the glacier and later gradually collected back to conduits. Since the time of the settlement of Iceland (870 A.D.), at least 80 subglacial volcanic eruptions have been reported, many of them causing tremendous jökulhlaups with dramatic impact on inhabitated areas

and landforms. The peak discharge of the largest floods (from Katla) has been estimated at the order of 100-300,000 m3/s, duration was 3 -5 days and the total volume of the order of 1 km3. It is now apparent that the potentially largest and most catastrophic jökulhlaups may be caused by eruptions in the voluminous ice-filled calderas in northern Vatnajökull (of Bárdarbunga and Kverkfjöll). They may be the source of prehistoric jökulhlaups, with estimated peak discharge of 400,000 m3/s. At present, jökulhlaups originate from some fifteen marginal ice-dammed lakes in Iceland. Typical values for peak discharges are 1,000 - 3,000 m3/s, duration 2-5 days and total volumes of 2,000 x 106 m3. Hydrographs for jökulhlaups from marginal lakes have a shape similar to those of the typical Grímsvötn jökulhlaup. Simulations give reasonable ascent of the hydrographs for constant lake temperature of about 1 °C but fail to show the recession. Some floods from marginal lakes, however, have reached their peaks exceptionally rapidly, in one day. That ascent could be simulated by drainage of lake water of 4-8 °C. An empirical power law relationship is obtained between peak discharge and total volume of the jökulhlaups from Grímsvötn; Qmax = K Vtb, where Qmax is measured in m3/s, Vt in 106 m3, K = 4.15 10-3 s-1 m-2.52 and b = 1.84. In general, the jökulhlaups (excepting those caused by eruptions) occur when the lake has risen to a critical level, but before a lake level required for simple flotation of the ice dam is reached. The difference between the hydrostatic water pressure maintained by the lake and the ice overburden pressure of the ice dam is of the order 2-6 bar.

Björnsson, H., Pálsson, F., and Guðmundsson, M.T. (2000) "Surface and bedrock topography of the Mýrdalsjökull ice cap, Iceland: The Katla caldera, eruption sites and routes of jökulhlaups": Jökull, v. **49**: p. 29-46.

Elíasson, J., Kjaran, S.P., Holm, S.L., Guðmundsson, M.T., and Larsen, G. (In Press) "Large hazardous floods as translatory waves": Environmental Modelling & Software, v. **Corrected Proof**.

The theory for non-stationary flow in translatory waves is developed for an inclined plane in a prismatic channel and a funneling channel. The existence of translatory waves traveling over dry land or superimposed on constant flow is established, and the dependance on the initial flow value is discussed. Inherent instabilities of the wave tail are discussed. Data from a CFD simulation of a jökulhlaup (volcanic glacial burst) down the Markarfljót valley in Iceland are shown, and the similarities to the translatory wave established. Geological evidence of such large floods exists, and it is concluded that some historical floods like Katla 1918 have most likely been of this type. It is concluded that in simulation and hazard assessment of great floods, the translatory flow theory has an advantage over estimates based on Manning and alike methods, since the often subjective determination of the Manning n is avoided.

Höskuldsson, A., and Sparks, R.S.J. (1997) "Thermodynamics and fluid dynamics of effusive subglacial eruptions": Bulletin of Volcanology, v. **59**(3): p. 219-230.

We consider the thermodynamic and fluid dynamic processes that occur during subglacial effusive eruptions. Subglacial eruptions typically generate catastrophic floods (jökulhlaups) due to melting of ice by lava and generation of a large water cavity. We consider the heat transfer from basaltic and rhyolitic lava eruptions to the ice for typical ranges of magma discharge and geometry of subglacial lavas in Iceland. Our analysis shows that the heat flux out of cooling lava is large enough to sustain vigorous natural

convection in the surrounding meltwater. In subglacial eruptions the temperature difference driving convection is in the range 10-100 degrees C. Average temperature of the meltwater must exceed 4 degrees C and is usually substantially greater. We calculate melting rates of the walls of the ice cavity in the range 1-40 m/day, indicating that large subglacial lakes can form rapidly as observed in the 1918 eruption of Katla and the 1996 eruption of Gjálp fissure in Vatnajökull. The volume changes associated with subglacial eruptions can cause large pressure changes in the developing ice cavity. These pressure changes can be much larger than those associated with variation of bedrock and glacier surface topography. Previous models of water-cavity stability based on hydrostatic and equilibrium conditions may not be applicable to water cavities produced rapidly in volcanic eruptions. Energy released by cooling of basaltic lava at the temperature of 1200 degrees C results in a volume deficiency due to volume difference between ice and water, provided that heat exchange efficiency is greater than approximately 80%. A negative pressure change inhibits escape of water, allowing large cavities to build up, Rhyolitic eruptions and basaltic eruptions, with less than approximately 80% heat exchange efficiency, cause positive pressure changes promoting continual escape of meltwater. The pressure changes in the water cavity can cause surface deformation of the ice. Laboratory experiments were carried out to investigate the development of a water cavity by melting ice from a finite source area at its base, The results confirm that the water cavity develops by convective heat transfer.

Lacasse, C., Sigurdsson, H., Carey, S., Paterne, M., and Guichard, F. (1996) "North Atlantic deep-sea sedimentation of Late Quaternary tephra from the Iceland hotspot": Marine Geology, v. **129**(3-4): p. 207-235.

Piston cores recovered from the North Atlantic were used to study the sedimentation of Holocene and Pleistocene volcanic ash in the Irminger and Iceland Basins. Ash Zones 1 (≈ 11,100 yr B.P.), 2 (≈ 55,000 yr B.P.) and 3 (≈ 305,000 yr B.P.) were identified from their major element glass composition. The silicic and alkalic Ash Zones 1 and 2 originate from the Southeastern Volcanic Zone of Iceland, where they correlate with the Sólheimar ignimbrite from Katla volcano and the Thórsmörk ignimbrite from Tindfjallajökull volcano, respectively. The low-alkali composition of silicic Ash Zone 3 indicates a source from one of the silicic centers in the active rift system. Ash Zones 2 and 3 occur in the Irminger Basin as dispersed glass shards over a depth interval of several tens of centimeters. Their compositional and granulometric characteristics reflect an initial fallout on pack-ice north of Iceland, followed by ice-rafting sedimentation in the Denmark Strait, prior to bioturbation. δ18O stratigraphy of foraminifera in the cores indicates that the ash zones were deposited during a cold interval, at the time when seas north of Iceland were ice-covered. Sedimentary features indicate that turbidity currents were also involved in the dispersal of Ash Zones 1 and 2 south of Iceland. The initiation of these gravity currents from the shelf can be attributed to either glacier bursts (jökulhlaups) carrying tephra, or the entrance of pyroclastic flows into the ocean.

Maria, A., Carey, S., Sigurðsson, H., Kincaid, C., and Helgadóttir, G. (2000) "Source and dispersal of jökulhlaup sediments discharged to the sea following the 1996 Vatnajökull eruption": Geological Society of America Bulletin, v. **112**(10): p. 1507-1521.**(aðallega um jökulhlaup úr Gjálp)**

The October 1996 Gjálp eruption beneath Vatnajökull glacier led to one of the largest jökulhlaups (glacial floods) in Iceland in the twentieth century. A catastrophic *discharge of meltwater and sediment swept across the Skeidararsandur flood plain to the sea. Tephra from the eruption consists of vesicular sideromelane shards with a basaltic andesite composition (53% SiO2, 3% MgO, 0.8% K2O). After the flood, sediment samples were collected from the hood plain and off the southeast coast of Iceland, where a major sediment plume had been created by the discharge. Compositions of glass shards from hood-plain and seafloor deposits do not match those of the Gjálp magma. Flood-plain samples consist primarily of blocky to poorly vesicular sideromelane clasts with compositions that are characteristic of Grimsvötn volcanic products (similar to 50% SiO2, 5.5% MgO, 0.4% K2O). Marine samples collected near the jökulhlaup outflow into the sea also consist primarily of blocky to poorly vesicular sideromelane clasts with compositions that are, for the most part, similar to products of the Grimsvötn volcanic center. Distal marine samples have more vesicular sideromelane clasts with compositions that are similar to products of the Katla volcanic center (e.g., 48% SiO2, 4.5% MgO, 0.8% K2O). Significant deposition to the seafloor was apparently limited to an area just offshore of the Skeiðarársandur. There is no indication that juvenile volcanic material from the Gjálp eruption was carried by the 1996 jökulhlaup onto the flood plain or into the ocean, Instead, the jökulhlaup carried primarily older volcaniclastic material eroded by the flood.*

Smith, K.T., and Dugmore, A.J. (2006) "Jökulhlaups circa Landnám: Mid- to late first millennium AD floods in South Iceland and their implications for landscapes of settlement": Geografiska Annaler Series a-Physical Geography, v. **88A**(2): p. 165-176.

This paper presents geomorphological and sedimentological evidence for three large-scale floods to the west of the ice-capped volcano Katla around the time of Norse settlement or Landnám (AD 870-930). These glacial outburst floods (jökulhlaups), the most recent prehistoric events in a series of Holocene floods in the Markarfljót valley, are securely dated by tephrochronology and radiocarbon dating to between c. AD 500 and c. AD 900. The environmental impact of these events would have been extensive, affecting both the highlands and about 40-50 km(2) of the coastal lowlands where about 15 of the 400 or so landnam farms in Iceland were sited. An awareness of environmental conditions and landscape stability around the time of the Norse colonisation of Iceland is important to understand the earliest settlement patterns because of the different constraints and opportunities that they represent.

5.2.10 Annað, eða almennt um jökulhlaup tengd eldvirkni, ekki skilgreint úr hvaða eldstöð

Barzini, G.N., and Ball, R.C. (1993) "Landscape Evolution in Flood - a Mathematical-Model": Journal of Physics a-Mathematical and General, v. **26**(23): p. 6777-6787.

We present analytical and numerical studies for the evolution of a landscape in flood. Our model is based on the assumption that the local fluxes of both water and sediment depend only (and simply) on the gradient of the water surface and local depth of flood. Nonlinear differential equations for water conservation dictate the distribution of flood-water. The divergence of the sediment flux then determines the net rise (deposition) or fall (erosion) of the underlying landscape. We present linear stability analysis for an initially planar slope, with uniform water flow: the dominant instability is the development of corrugations at an angle oblique to the flow direction. Numerical results are presented for the long time evolution of a system with periodic boundary conditions, and no net gain or loss of either water or sediment. The resulting *landscape resembles that of a braided river bed, and analysis of the contours shows quantitative agreement with the experimental power law distribution of island sizes for the Zaire and Rakaia river systems and the outwash drainage system at Vatnajökull.*

Björnsson, H. (2002) "Subglacial lakes and jökulhlaups in Iceland": Global and planetary change, v. **35**: p. 255-271.

Active volcanoes and hydrothermal systems underlie ice caps in Iceland. Glacier–volcano interactions produce meltwater that either drains toward the glacier margin or accumulates in subglacial lakes. Accumulated meltwater drains periodically in jökulhlaups from the subglacial lakes and occasionally during volcanic eruptions. The release of meltwater from glacial lakes can take place in two different mechanisms. Drainage can begin at pressures lower than the ice overburden in conduits that expand slowly due to melting of the ice walls by frictional and sensible heat in the water. Alternatively, the lake level rises until the ice dam is lifted and water pressure in excess of the ice overburden opens the waterways; the glacier is lifted along the flowpath to make space for the water. In this case, discharge rises faster than can be accommodated by melting of the conduits. Normally jökulhlaups do not lead to glacier surges but eruptions in ice-capped stratovolcanoes have caused rapid and extensive glacier sliding. Jökulhlaups from subglacial lakes may transport on the order of 107 tons of sediment per event but during violent volcanic eruptions, the sediment load has been 108 tons.

— (2004) Glacial Floods, *in* Owens, P., and Slaymaker, O., eds., Mountain Geomorphology, Arnold Publishers.

Björnsson, H., and Einarsson, P. (1990) "Volcanoes beneath Vatnajökull, Iceland: Evidence from radio echo-sounding earthquakes and jökulhlaups": Jökull, v. **40**: p. 147-168.

Integration of knowledge of subglacial topography, earthquake activity and jökulhlaups has contributed to more precise locations of the volcanic systems beneath Vatnajökull. Bárðarbunga is the centre of a volcanic system which includes the fissure swarms of Veiðivötn to the SW and Dyngjuháls to the NE. The Grímsvötn volcano is the centre of a system that comprises the Laki fissure swarm in the SW and extends for an unknown distance to the NE of the volcano. Þórðarhyrna is probably a separate central volcano within this system. The Kverkfjöll system can be traced 10 km to the SW of the Kverkfjöll volcano. It appears to be separated from the Grímsvötn volcano. The Askja fissure swarm extends beneath Dyngjujökull and can possibly be traced to the Grímsvötn volcano. Hamarinn and the ridge striking eastward from Hamarinn (Loki Ridge) are central volcanoes which together with the Fögrufjöll fissure swarm form a volcanic system. No support can be found in the topographic data for the existence of a central volcano near Breiðabunga. Volcanic activity in historical times has mainly been limited to the Grímsvötn and Bárðarbunga systems. Major rifting events have affected large sections of these volcanic systems but both have been remarkably quiet for the past decades. A few volcanic events are presumed to have occurred on the Hamarinn - Loki system and on the Askja fissure swarm beneath Dyngjujökull, but no event is known with certainty on the Kverkfjöll system. The rivers Skeiðará and Súla have the most frequent eruption-related jökulhlaups. They receive meltwater from the Grímsvötn caldera and the area to the SW of it, including Þórðarhyrna. Núpsvötn, Djúpá and Hverfisfljót drain the southwestern part of the Grímsvötn system, an area bounded by Þórðarhyrna, Geirvörtur, Hágöngur and Pálsfjall. Skaftá drains the Loki

Ridge and the area west of Grímsvötn. Jökulhlaups in Kaldakvísl, and ultimately Þjórsá, must originate in the Bárðarbunga or the Hamarinn - Loki systems, and the only possible source for volcanic jökulhlaups in Skjálfandafljót is the northern part of the Bárðarbunga system. Jökulsá á Fjöllum may drain meltwater from activity in all the volcanic systems in northern Vatnajökull: Bárðarbunga, the Askja fissure swarm and Kverkfjöll. This includes the voluminous, ice-filled calderas of Bárðarbunga and Kverkfjöll. Activity in the northern part of the Grímsvötn system may cause floods in Jökulsá á Fjöllum. Meltwater from volcanic activity on the SE flank of a ridge that strikes south from Kverkfjöll may drain to Jökulsá á Brú. Volcanic activity farther north on the E flanks of this ridge would cause floods in Kreppa.

Caseldine, C.J., Russell, A.J., Knudsen, Ó., and Harðardóttir, J. (2005) <u>Iceland Modern Processes and Past Environments</u>, Elsevier.

Iceland provides an unique stage on which to study the natural environment, both past and present, and it is understanding both aspects of reconstructing the past and observing and interpreting the present that form the focus of the contributions to this volume. The papers are all written by active researchers and incorporate both reviews and new data. Although concentrating largely on the recent Quaternary timescale a wide range of topics is explored including subglacial volcanism, onshore and offshore evidence for the Last Glacial Maximum and subsequent deglaciation, current glacial characteristics including jökulhlaups and glacial landsystems, soil development, Holocene ecosystem change, current oceanography, impacts of volcanic sulphur loading, chemical weathering and the CO2 budget and documentary evidence for historical climate.

Contents

Preface. 1. Iceland. modern processes, past environments: an introduction (C. Caseldine et al.). 2. Late Quaternary marine sediment studies of the Icelandic shelf-palaeoceanography, land/ice sheet/ocean interactions and deglaciation: a review (J.T. Andrews). 3. Relative sea level change in Iceland: new aspects of the Weichselian deglaciation of Iceland (H. Norddahl and H. Petursson). 4. Recent developments in oceanographic research in Icelandic waters (S. Jonsson, H. Valdimarsson). 5. The glacier-marginal landsystems of Iceland (D.J.A. Evans). 6. Subglacial volcanic activity in Iceland (M.T. Gudmundsson). 7. Icelandic jökulhlaup impacts (A.J. Russell et al.). 8. Environmental and climatic effects from atmospheric SO2 mass-loading by Icelandic flood lava eruptions (P. Pordarson). 9. Holocene glacier history (M. Wastl, J. Stotter). 10. Variations of termini of glaciers in Iceland in recent centuries and their connection with climate (O. Sigurdsson). 11. Local knowledge and travellers' tales: a selection of climatic observations in Iceland (A. Ogilvie). 12. Chemical weathering, chemical denudation and the CO2 budget for Iceland (S.R. Gislason). 13. Icelandic soils (O. Arnalds). 14. The Holocene vegetation history of Iceland, state-of-the-art and future research (M. Hallsdottir, C. Caseldine).

Fay, H. (2002) <u>The role of ice blocks in the creation of distinctive proglacial landscapes during and following glacial outburst floods (jökulhlaups)</u> [**Unpublished PhD Thesis**], University of Keele.

Helland, H. (1883) "Om Vulkaner i og under Jökler på Island og om Jökulhlaup": <u>Nordisk Tidskrift</u>, v. **6**: p. 368-387.

Jonsson, S., Adam, N., and Bjornsson, H. (1998) "Effects of subglacial geothermal activity observed by satellite radar interferometry": Geophysical Research Letters, v. **25**(7): p. 1059-1062.

We use one day Synthetic Aperture Radar (SAR) interferograms from data of the Earth Remote Sensing Satellites ERS-1 and ERS-2 to study ice how and uplift of two surface depressions within the Vatnajokull ice cap, Iceland. The ice cauldrons are created by melting at subglacial geothermal areas. Meltwater accumulates in a reservoir under the cauldrons over 2 to 3 years until it drains in a jökulhlaup under the ice dam surrounding the reservoir. The ice surface in the depressions drops down by several tens of meters during these draining events but rises again, as ice flows into the depressions, until a jökulhlaup occurs again. Using SAR interferograms we quantify an uplift rate of about 2 to 18 cm/day within the jokulhlaup cycle varying with the surface slope of the depressions. The uplift rate is high during the first months after a jökulhlaup when the cauldron is relatively deep with steep slopes, but the uplift rate decreases as the cauldron is gradually filled. A simple axisymmetric model simulating the ice-flow into one of the depressions describes quantitatively the filling rate of the cauldron and qualitatively the shape of the ice flow field. The best-fit model has an ice flow law parameter Ao that is about one order of magnitude lower than typically estimated for temperate glaciers.

Larsen, G., and Guðmundsson, M.T. (1997) Gos í eldstöðvum undir Vatnajökli eftir 1200 AD., *in* Haraldsson, H., ed., Vatnajökull. Gos og hlaup 1996: Reykjavík, Vegagerðin, p. 23-36.

Maizels, J.K. (1991) The origin and evolution of Holocene sandur deposits in areas of jökulhlaup drainage, Iceland, *in* Maizels, J.K., and Caseldine, C., eds., Environmental Change in Iceland: Past and Present, Kluwer Academic Publishers, p. 267-302.

— (1997) "Jökulhlaup deposits in proglacial areas": Quaternary Science Reviews, v. **16**: p. 793-819.

Marren, P.M. (2002) Criteria for distinguishing high magnitude flood events in the proglacial fluvial sedimentary record, The Extremes of the Extremes: Extraordinary Floods: IAHS Publ. no. 271: Proceedings of a symposium held at Reykjavik, Iceland, July 2000, p. 237-241.

Recognizing high magnitude or extreme floods in the sedimentary record is important if estimates of their geomorphic and sedimentary significance over long time scales (i.e. 102–103 years) are to be made. Standard regime or palaeocompetence based palaeohydraulic approaches present one set of solutions to this problem. An alternative is to examine the sedimentary record to determine the dominant depositional processes in any particular environment. Specifically, it is important to assess the role of high magnitude floods within the sedimentary record. This paper presents a set of criteria, based on flow rheology, sediment structures, clast orientation and sediment architecture and geometry, which are designed to critically determine the magnitude–frequency regime of fluvial sediments. The criteria were derived from literature on the sedimentary impact of high magnitude floods and from fieldwork in southeast Iceland.

— (2004) "Present-day sandurs are not representative of the geological record - Sedimentary Geology 152, 1-5 (2002)": Sedimentary Geology, v. **164**(3-4): p. 335-340.

Rist, S. (1970) "Annáll um jökulhlaup": Jökull v. **20**: p. 88-89.

— (1973) "Jökulhlaupaannáll 1971, 1972 og 1973 (Summary. Jökulhlaups in the years 1971, 1972 and 1973)": Jökull, v. **23**: p. 55-60.

— (1976) "Jökulhlaupaannáll 1974, 1975 og 1976. Jökulhlaups in the years 1974, 1975 and 1976." Jökull, v. **26**: p. 75-79.

— (1981) "Jökulhlaupaannáll 1977, 1978, 1979 og 1980 (Chronicle of jökulhlaups)": Jökull, v. **31**: p. 31-35.

— (1984) "Jökulhlaupaannáll. Report of jökulhlaups in 1981, 1982 and 1983": Jökull, v. **34**: p. 165-172.

Roberts, M.J. (2002) Controls on Supraglacial Outlet Development during Glacial Outburst Floods [**Unpublished Ph.D. thesis**], Staffordshire University, U.K.

— (2005) "Jökulhlaups: A reassessment of floodwater flow through glaciers": Reviews of Geophysics, v. **43**(1).

[1] In glaciated catchments, glacier-generated floods (jökulhlaups) put human activity at risk with large, sporadic jökulhlaups accounting for most flood-related fatalities and damage to infrastructure. In studies of jökulhlaup hydrodynamics the view predominates that floodwater travels within a distinct conduit eroded into the underside of a glacier. However, some jökulhlaups produce subglacial responses wholly inconsistent with the conventional theory of drainage. By focusing on Icelandic jökulhlaups this article reassesses how floodwater flows through glaciers. It is argued that two physically separable classes of jökulhlaup exist and that not all jökulhlaups are an upward extrapolation of processes inherent in events of lesser magnitude and smaller scale. The hydraulic coupling of multiple, nonlinear components to the flood circuit of a glacier can induce extreme responses, including pressure impulses in subglacial drainage. Representing such complexity in mathematical form should be the basis for upcoming research, as future modeling results may help to determine the glaciological processes behind Heinrich events. Moreover, such an approach would lead to more accurate, predictive models of jökulhlaup timing and intensity.

Roberts, M.J., Russell, A.J., Tweed, F.S., and Knudsen, Ó. (2000) "Ice fracturing during jökulhlaups: implications for englacial floodwater routing and outlet development": Earth Surface Processes and Landforms, v. **25**: p. 1429-1446.

Theoretical studies of glacial outburst floods (jökulhlaups) assume that: (i) intraglacial floodwater is transported efficiently in isolated conduits; (ii) intraglacial conduit enlargement operates proportionally to increasing discharge; (iii) floodwater exits glaciers through pre-existing ice-marginal outlets; and (iv) the morphology and positioning of outlets remains fixed during flooding. Direct field observations, together with historical jökulhlaup accounts, confirm that these theoretical assumptions are not always correct. This paper presents new evidence for spatial and temporal changes in intraglacial floodwater routing during jökulhlaups; secondly, it identifies and explains the mechanisms controlling the position and morphology of supraglacial jökulhlaup outlets; and finally, it presents a conceptual model of the controls on supraglacial outbursts. Field observations are presented from two Icelandic glaciers, Skeiðarárjökull and Sólheimajökull. Video footage and aerial photographs, taken before, during and after the Skeiðarárjökull jökulhlaup and immediately after the Sólheimajökull jökulhlaup, reveal changes in floodwater routing and the positioning and morphology of outlets. Field observations confirm that glaciers cannot transmit floodwater as efficiently as previously assumed. Rapid increases in jökulhlaup discharge generate basal hydraulic pressures in excess of ice overburden. Under these circumstances, floodwater can be forced through the surface of glaciers, leading to the development of a range of supraglacial outlets. The rate of increase in hydraulic pressure strongly influences the type of supraglacial outlet that can develop. Steady increases in basal hydraulic pressure can retro-feed pre-existing englacial drainage, whereas transient increases in pressure can generate hydraulic fracturing. The position and morphology of supraglacial outlets provide important controls on the spatial and temporal impact of flooding. The development of supraglacial jökulhlaup outlets provides a new mechanism for rapid englacial debris entrainment.

— (2000) "Rapid sediment entrainment and englacial deposition during jökulhlaups": Journal of Glaciology v. **46**: p. 349-351.

Englacial water flow is a commonly invoked hypothesis to account for the presence of water-worked sediment at high elevations within glaciers (e.g. Kirkbride and Spedding, 1996; Naslund and Hassinen, 1996; Glasser and others, 1999). However, subscribers to this hypothesis lack evidence for sediment entrainment by englacial water flow. Here we present direct field evidence for supraglacial outbursts and rapid englacial fluvial sediment deposition during two recent Icelandic jökulhlaups. Both of these jökulhlaups generated basal water pressures in excess of ice overburden, which fractured overlying ice, allowing sediment to be fluvially emplaced at high elevations within each glacier. Although these jökulhlaups were hydrologically extreme, similar short-term rates of increase in basal hydraulic pressure may be generated during lower-magnitude hydrological events. The recent Icelandic jökulhlaups therefore provide us with a direct insight into rapid sediment entrainment and englacial deposition, a process that could be applied to other high-water-pressure events.

— (2002) Controls on the Development of Supraglacial Floodwater Outlets during Jökulhlaups *in* Snorrason, A., Finsdottir, H.P., and Moss, M., eds., The Extremes of the Extremes. Proceedings of a symposium held July 2000 at Reykjavik, Iceland: International Association of Hydrological Sciences Red Book Publication 271, p. 71-76.

Recent field observations have revealed that jökulhlaups with a near-instantaneous rise to peak discharge can generate temporary hydraulic pressures capable of forcing floodwater through the surface of glaciers. This paper identifies and explains the

controls on the development of supraglacial jökulhlaup outlets. Field evidence is presented from two recent Icelandic jökulhlaups, which produced multiple supraglacial outbursts. Subglacial hydraulic pressure increase is identified as the principal control on supraglacial outlet development during jokulhlaups. A near-instantaneous rise to peak subglacial water pressure can produce supraglacial outbursts by hydrofracturing. Pressure increases below the hydrofracturing threshold, but above ice overburden pressure, can back-feed pre-existing drainage, resulting in outbursts from moulins and crevasses. Hydrofracture outbursts can route water to areas of the glacier not normally inundated by floods, and can control the spatial distribution of ice block release.

Roberts, M.J., Tweed, F.S., Russell, A.J., Knudsen, O., and Harris, T.D. (2003) "Hydrologic and geomorphic effects of temporary ice-dammed lake formation during jökulhlaups": Earth Surface Processes and Landforms, v. **28**(7): p. 723-737.

Glacial outburst floods (jökulhlaups) occur frequently in glaciated environments, and the resultant flooding causes geomorphic change and, in some instances, damage to local infrastructure. During some jökulhlaups, floodwater is stored temporarily in ice-marginal locations. In July 1999, a linearly rising jökulhlaup burst from Sólheimajökull, Iceland. During this remarkable event, subglacial floodwater pooled transiently in two relict ice-dammed lake basins, before draining suddenly back into Sólheimajökull. The significance of such rapid formation and attendant drainage of temporary ice-dammed lakes during jökulhlaups has not been addressed. Consequently, this paper: (i) assesses the hydrologic and geomorphic effects of temporary ice-dammed lake formation caused by lake-basin 'retro-filling'; and (ii) discusses the impact and significance of transient retro-filling under jökulhlaup conditions. Pre- and post-flood fieldwork at Sólheimajökull enabled the impact and significance of lake-basin retro-filling to be assessed. Field evidence demonstrates that the July 1999 jokulhlaup had an unusually rapid rise to peak discharge, resulting in subglacial floodwater being purged to ice-marginal locations. The propensity for temporary retro-filling was controlled by rapid expulsion of floodwater from Sólheimajökull, coincident with locations suitable for floodwater storage. Floodwater inundated both ice-marginal lake basins, permitting significant volumes of sediment deposition. Coarse-grained deltas prograding from the ice margin and boulders perched on scoured bedrock provide geomorphic records of sudden retro-filling. The depositional characteristics of take-basin deposits at Sólheimajökull are similar to jökulhlaup sediments documented in proglacial settings elsewhere; however, their depositional setting and association with ice-marginal landforms is distinctive. Findings suggest that temporary ice-dammed lake formation and drainage has the capacity to alter the shape of the flood hydrograph, especially if drainage of a temporary lake is superimposed on the original jökulhlaup. Deposits associated with take-basin retro-filling have a long-term preservation potential that could help to identify temporary ice-dammed lake formation in modern and ancient glacial environments.

Runólfsson, S. (2004) Landkostir og landbætur í Austur-Skaftafellssýslu, *in* Björnsson, H., ed., Jöklaveröld, náttúra og mannlíf: Reykjavík, Skrudda, p. 165-200.

Rushmer, E.L. (2004) The role of hydrograph shape and sediment sorting in controlling jökulhlaup sedimentary successions [**Unpublished Ph.D. thesis**], Keele University, U.K.

Glacial outburst floods (jökulhlaups) play an important part in proglacial geomorphology and sedimentology. Research on the impact of floods has made assumptions by associating jökulhlaup sedimentary successions with distinctive hydrograph shapes and flow rheology. However, jökulhlaup hydrograph shape alone is thougt to have a significant impact on proglacial sedimentology. To date, little information exists on the role of hydrograph shape as a control an the sedimentological and geomorphological impact on jökulhlaups. This paper illustrates how field interpretation of flood deposits can be related to specific hydrograph shapes, and outlines how flume experiments can be used to assess the extent to which hydrograph shape exerts a control on jökulhlaup sedimentology.

Russell, A.J., Fay, H., Harris, T.D., Roberts, M.J., and Tweed, F.S. (Submitted) "Preservation of jökulhlaups within subglacial sediments": Quaternary Science Reviews.

Russell, A.J., Fay, H., Marren, P.M., Tweed, F.S., and Knudsen, Ó. (2005) Icelandic jökulhlaup impacts, *in* Caseldine, C.J., Russell, A.J., Knudsen, Ó., and Harðardóttir, eds., Iceland: Modern Processes and Past Environments, Elsevier Book, p. 153-203.

Russell, A.J., and Marren, P.M. (1999) Proglacial fluvial sedimentary sequences in Greenland and Iceland: a case study from active proglacial environments subject to jökulhlaups, *in* A.P.Jones, Tucker, M.E., and Hart, J.K., eds., The description and analysis of Quaternary stratigraphic field sections, Technical Guide 7: London, Quaternary Research Association, p. 171-208.

Russell, A.J., Roberts, M., Fay, H., Harris, T.D., Tweed, F.S., and Marren, P.M. (2004) Jökulhlaups as agents of glacial sediment transfer, *in* Beylich, A.A., Sæmundsson, Decaulne, A., and Sandberg, O., eds., Sedimentary source-to-sink-fluxes in cold environments: Sauðárkrókur, Náttúrustofa Norðurlands vestra, p. 104.

Russell, A.J., Roberts, M.J., Fay, H., Marren, P.M., Cassidy, N.J., Tweed, F.S., and Harris, T. (2006) "Icelandic jokulhlaup impacts: Implications for ice-sheet hydrology, sediment transfer and geomorphology": Geomorphology, v. **75**(1-2): p. 33-64.

Glaciers and ice sheets erode, entrain, and deposit massive quantities of debris. Fluxes of subglacial meltwater exert a fundamental control on ice dynamics and sediment transport budgets. Within many glacial systems outburst floods (jökulhlaups) constitute high magnitude, high frequency fluxes of meltwater relative to normal ablation controlled discharge. This paper presents a synthesis of research on recent Icelandic jökulhlaups and their geomorphological and sedimentary impact. We identify jökulhlaup impacts within subglacial, englacial and proglacial settings and discuss their wider significance for ice sheet hydrology, sediment transfer and geomorphology. Because jökulhlaups erode, deposit, and re-work sediment simultaneously, they usually cause significant glaciological and sedimentological impacts. Jökulhlaups that propagate as subglacial flood waves often produce widespread hydromechanical disruption at the glacier base. Recent Icelandic jökulhlaups have been recognised as highly efficient agents of reworking subglacial sediment and glacial sediment entrainment. Models of jökulhlaup impact, therefore, need to encompass the sub- and englacial environment in addition to the proglacial zone where research has

traditionally been focussed. Most jökulhlaups transport sediment to proglacial sandar, and often directly to oceans where preservation potential of the impact is greater. Proglacial jökulhlaup deposits form distinctive sedimentary assemblages, coupled with suites of high-energy erosional landforms. This study of modem jökulhlaup processes and sedimentary products may be useful for the interpretation of meltwater processes associated with Quaternary ice sheets.

Tryggvason, E. (1960) "Earthquakes, jökulhlaups and subglacial eruptions": Jökull, v. **10**: p. 18-22.

Tweed, F., Russell, A.J., and Knudsen, Ó. (1999) "Iceland awaits the big one": Geographical Journal, v. **71**(12): p. 11.

Tweed, F.S., Roberts, M.J., and Russell, A.J. (2005) "Hydrologic monitoring of supercooled discharge from Icelandic glaciers: hydrodynamic and sedimentary significance": Quaternary Science Reviews, v. **24**(22): p. 2308-2318.

Knowledge of how glaciers entrain sediment is central to understanding processes of glacier movement and products of glacial sediment deposition. Previous work has shown that if the total hydraulic potential of subglacial meltwater increases more rapidly than the resulting mechanical energy can be transformed into sensible heat, then supercooling and ice growth will result. This process causes frazil ice to grow onto adjacent glacier ice, which acts to trap sediment in flowing meltwater eventually producing sedimentary inclusions within glacier ice. Supercooling has been recognised as a sediment entrainment mechanism at glaciers in Alaska, and more recently at several temperate Icelandic glaciers. Here we present short-period temperature measurements and field evidence of glaciohydraulic supercooling from three Icelandic glaciers. Temperature measurements demonstrate that supercooling occurs over a range of hydrological conditions and that the process does not operate continuously at all instrumented sites. Measurements of supercooling during a small jökulhlaup are also presented. Progressive accretion of supercooled meltwater creates sediment-laden ice exposures adjacent to active artesian vents. Understanding controls on the efficacy and pervasiveness of hydraulic supercooling is important for decoding the sedimentary record of modern and ancient glaciers and ice sheets.

van Loon, A.J. (2004) "From speculation to model: the challenge of launching new ideas in the earth sciences": Earth-Science Reviews, v. **65**(3-4): p. 305-313.

Some geological phenomena are explained by geological processes that have never been witnessed. There may also be processes that leave (or have left) no traces at all, or the traces of which have not been recognized as such. Yet, science requires that ideas about such 'secret' processes are communicated with the earth-science community. If such ideas are launched without providing a possible method to check their correctness, they are commonly called speculations. If potential methods for validation are presented, some earth scientists call them hypotheses. These are considered more valuable than speculations, although experiments to support such hypotheses cannot always be carried out in a satisfactory way. If an apparently logical order of causes and consequences is presented, accompanied by physical or mathematical data to support the supposed sequence of events, the term 'model' is commonly applied. Models are considered superior to hypotheses, although the *validity of models is often questionable. It is shown that speculations, hypotheses and models do not differ fundamentally from each other, so that there is no reason for the scientific community to treat them in different ways. The commonly negative attitude towards speculations is not justified and hampers scientific progress. An example of a hypothesis on a process never observed is presented to indicate how small-if existing at all-the margins are between models, hypotheses and speculations. It is concluded that both hypotheses and speculations may trigger research that will deepen insight into complex earth-scientific relationships..*

5.3.Jökulhlaup úr þverdal

5.3.1 Grænalón

Arason, H. (1957) Hlaup úr Grænalóni í Fljótshverfi 1898 *in* Hannesson, P., and Eyþórsson, J., eds., Hrakningar og heiðarvegir Volume **4.b.**: Akureyri, Norðri, p. 189-191

Björnsson, H., and Pálsson, F. (1989) "Rúmmál Grænalóns og breytingar á stærð og tíðni jökulhlaup": Jökull, v. **39**: p. 90-95.

Eiríksson, J., and others (1994) Roadlog : Nordic geological excursion in Iceland : quaternary geology - glaciology Reykjavík, myndir, kort, línurit p.

Eyþórsson, J. (1950) "Hlaupið úr Grænalóni í september 1949": Náttúrufræðingurinn, v. **20**(3.h.): p. 141-142.

Jóhannesson, H. (1982) "Fróðleiksmolar um Grænalón og nágrenni": Náttúrufræðingurinn, v. **52**(1.-4.h.): p. 86-101.

Rist, S. (1951) "Grænalón": Náttúrufræðingurinn, v. **21. árg.**(4. hefti): p. 184-186.

Roberts, M.J., Pálsson, F., Gudmundsson, M.T., Björnsson, H., and Tweed, F.S. (2005) "Ice-water interactions during floods from Grænalón glacier-dammed lake, Iceland": Annals of Glaciology, v. **40**(1): p. 133-138.

This paper explores changing ice–water interactions during jökulhlaups from Grænalón, a 5 × 108 m3 subaerial lake dammed by Skeiðarárjökull, Iceland. Unstable drainage of Graenalón since the early 20th century has resulted in 45 jökulhlaups whose hydrologic character has varied enormously. Geomorphic observations and geophysical measurements from the inlet and outlet zones of the subglacial floodwater tract constrained the hydromechanical factors governing ice–water interactions at Grænalón. To date, three distinct drainage regimes have occurred in response to the changing surface elevation of Grænalón. Shifts from one drainage regime to another involved pronounced changes in jökulhlaup magnitude, timing and cyclicity. Present hydraulic conditions for lake drainage differ from the classical view of a pressure-

coupled lake draining directly beneath an ice dam. Instead, lowamplitude drawdown occurs at regular, frequent intervals when hydrostatic pressure in a shallow, rock–ice trench enables water to flow beneath a sagging ice barrier. Floodwater exits Skeiðarárjökull in a supercooled state due to rapid hydraulic displacement from an overdeepened subglacial basin.

Þórarinsson, S. (1969) Afleiðingar jöklabreytinga á Íslandi ef tímabil hafísára fer í hönd, Hafísinn: Reykjavík, A.B., p. 364-388; Kort, línurit.

5.3.2 Vatnsdalur

Árnason, G.S. (2001) "Áhrifavaldurinn Vatnajökull: þættir um menningu og mannlíf í skjóli konungs evrópskra jökla": Skaftfellingur, v. **14**: p. 97-108.

Benediktsson, G. (1944) Hinn gamli Adam í oss : ritgerðir Reykjavík, Víkurútgáfan.

— (1954) Hinn gamli Adam í oss : ritgerðir Reykjavík, Víkingsútgáfan.

— (1977) Í flaumi lífsins fljóta : bernsku- og æskuminningar: Reykjavík, Örn og Örlygur.

— (1978) Að leikslokum : áhugaefni og ástríður: Reykjavík, Örn og Örlygur.

Benediktsson, K. (1999) "Þegar ég var 17. ára": Skaftfellingur, v. **13. árg.** : p. bls. 67.

Bennett, M.R., Huddart, D., and McCormick, T. (2000) "The glaciolacustrine landform-sediment assemblage at Heinabergsjökull, Iceland": Geografiska annaler, v. **Vol. 82A**(Nr. 1): p. p.1-16.

Landform–sediment assemblages associated with two ice-dammed lakes, one active and one fossil, at Heinabergsjökull in southeast Iceland are described. The current ice-dammed lake (Vatnsdalur) is dominated by a large aggradational terrace, as well as an excellent suite of shorelines. The second fossil ice-dammed lake dates from the Neoglacial maximum of Heinabergsjökull (c. 1887) and drained during the late 1920s. This lake is associated with a suite of shorelines and ice-marginal glaciolacustrine fans. The sedimentology of one of these fans is described. Between 50 and 70% of the sediment succession is dominated by ice-rafted sediment, although rhythmites, matrix-rich gravels, sands and graded sand–silt couplets are also present. A range of intra-formational, soft-sediment deformation structures are present, consistent with liquefaction and deformation associated with loading, current shear, and iceberg calving. The landform–sediment assemblages described from Heinabergsjökull provide important data for the interpretation of Pleistocene ice-dammed lakes.

Guttormsson, H. (1993) Við rætur Vatnajökuls:byggðir, fjöll og skriðjöklar: Reykjavík.

Jónsson, E. (2004) Í veröld jökla, sanda og vatna, *in* Björnsson, H., ed., Jöklaveröld, náttúra og mannlíf: Reykjavík, Skrudda, p. 11-86.

Kristjánsdóttir, U. (1988) Byggðin varin-änni veitt, *in* Þorkelsson, G.B., and Jónsson, E., eds., Jódýnur-hestar og mannlíf í Austur-Skaftafellssýslu: Akureyri., Bókaforlag Odds Björnssonar.

— (1993) "Hólmsá": Skaftfellingur v. **9**: p. bls. 69-82

— (2000) "Vatnsdalur og Vatnsdalshlaup": Skaftfellingur v. **13**: p. bls.81-90.

Ólafsdóttir, R., and Þórhallsdóttir, J.K. (2004) "Varnir og sóknir : saga varnaraðgerða heimamanna og Vegagerðarinnar við Hólmsá á Mýrum frá lokum litlu ísaldarinnar": Skaftfellingur, v. **17**: p. 37-50; myndir, kort, línurit, tafla.

Runólfsson, S. (2004) Landkostir og landbætur í Austur-Skaftafellssýslu, *in* Björnsson, H., ed., Jöklaveröld, náttúra og mannlíf: Reykjavík, Skrudda, p. 165-200.

Sigurjónsson, B. (2004) "Mýrasveit og Mýramenn á þriðja og fjórða áratug tuttugustu aldar ": Skaftfellingur, v. **17**: p. 125-140.

Snorrason, S. (1979) Mýrajöklar og Vatnsdalur í A-Skaftafellssýslu. [**4. árs ritgerð**]: Reykjavík, Háskói Íslands.

— (1984) Mýrajöklar og Vatnsdalur (+ jarðfræðikort af svæðinu fyrir framan Skálafells-, Heinabergs- og Fláajökul), Háskólinn í Oslo.

Þórarinsson, S. (1969) Afleiðingar jöklabreytinga á Íslandi ef tímabil hafísára fer í hönd, Hafísinn: Reykjavík, A.B., p. 364-388; Kort, línurit.

Þórhallsdóttir, J.K. (2004) Flóðahætta á Mýrum í Austur-Skaftafellssýslu : orsakir, áhrif og varnaraðgerðir [**BSc thesis**]: Reykjavík, Háskóli Íslands.

5.3.3 Lón í Breiðamerkurfjall

Björnsson, F. (1962) "Fjallsárhlaupið 1962 og athuganir á lóninu í Breiðamerkurfjalli. (The glacier burst in Fjallsá 1962)": Jökull, v. **12**: p. 42-43.

5.3.4 Jaðarlón við Brúarjökul

Björnsson, H., and Eydal, G.P. (1999) Jökulhlaup í Kverká og Kreppu frá jaðarlónum við Brúarjökul, Science Institute of the University of Iceland, p. 5.

5.3.5 Annað, eða almennt um jökulhlaup úr þverdal

Björnsson, H. (2004) Glacial Floods, *in* Owens, P., and Slaymaker, O., eds., Mountain Geomorphology, Arnold Publishers.

— (2004) Glacial lake outburst floods in mountain environments, *in* Owens, P.N., and Slaymaker, O., eds., Mountain Geomorphology, Hodder & Stoughton Educational., p. 313.

5.4 Framhlaup (surge)

5.4.1 Skeiðarárjökull

Björnsson, H. (1998) "Hydrological characteristics of the drainage system beneath a surging glacier": Nature, v. **395**: p. 771-774.

A unique combination of natural circumstances allows us to assess current theories about water flow beneath glaciers. Outburst floods from the subglacial lake, Grímsvötn, have taken place before, during and subsequent to surging of Skeiðarárjökull, the glacier beneath which they drain. The observable drainage patterns associated with these floods show the different nature of the basal water conduit system of the glacier during surge and non-surge phases. During surge, basal water is dispersed slowly across the bed in a distributed drainage system; but when the glacier is not surging, water is transported rapidly through a system of tunnels.

Fischer, A., Rott, H., and Björnsson, H. (2003) "Observation of recent surges of Vatnajokull, Iceland, by means of ERS SAR interferometry": Annals of Glaciology, v. **37**: p. 69-76.

Recent surges of two outlet glaciers of the Vatnajökull ice cap, Iceland, were observed using European Remote-sensing Satellite (ERS) synthetic aperture radar (SAR) tandem interferograms from 12 different dates between December 1995 and January 2000. ERS SAR interferometry provided new information on the temporal and spatial variations in surface velocity during surges, after fieldwork became impossible. The area affected by the surge and therefore by increased basal sliding was delineated. The migration of flow divides on the ice cap during a surge was described. At Sylgjujökull, a western outlet glacier covering an area of 175 km(2), the fully developed surge and its abating phase were studied. Over a period of > 2 years after December 1995, the ice motion decreased steadily, with initially the highest velocities and subsequently the most pronounced decrease in velocity at the glacier terminus. The surge of Dyngjujökull, a northern outlet glacier covering an area of 1040 km(2), reached its maximum in 1999/2000. Slow acceleration over an area of about 200 km(2) was first observed between March 1996 and January 1997. The interferogram

from January 1999 shows a well-developed surge area, covering 210 km(2). This area more than doubled by January 2000, with maximum velocities reaching > 7 m d(-1). Between January 1997 and January 2000, the flow divide between Dyngju- and Skeiðarárjökull shifted 16 km to the south. The investigations indicate that a surge cycle on these glaciers spans several years, with slowly increasing motion over an extended area in the beginning, and more pronounced velocity changes during the active surge phase lasting 1-2 years.

Russell, A.J., Knight, P.G., and van Dijk, T.A.G.P. (2001) "Glacier surging as a control on the development of proglacial fluvial landforms and deposits, Skeiðarársandur, Iceland": Global and Planetary Change, v. **28**(1-4): p. 163-174.

Glacier-hydrological processes are one of the main factors controlling proglacial fluvial systems. It has been proposed that where jökulhlaups occur they play a dominant role in the evolution of proglacial outwash plains. However, extraordinary meltwater and sediment discharge associated with glacier surging can also play a crucial role in the proglacial system. The interplay of surge-related and jökulhlaup floods has been investigated at Skeiðarárjökull, a jökulhlaup type-site where surging is also known to occur, allowing the geomorphological and sedimentological effects of these events to be differentiated.

Skeiðarársandur contains a spectacular assemblage of landforms and deposits associated with the 1991 surge of Skeiðarárjökull. The impact of the 1991 surge was felt mainly on the western half of the glacier where the ice advanced up to 1 km between September and November. The surge limit is marked by a push-moraine complex up to 5 m in height and 10 m in breadth. Proglacial fluvial sediments were deposited as a series of outwash fans adjacent to the glacier, up to 400 m in diameter, as the glacier advanced during the surge. Glaciotectonic structures associated with ice pushing inter-finger with undisturbed proglacial fluvial fan sediments, constraining timing of deposition of proglacial fans to the period during and immediately following the glacier surge.

The study of landforms and sedimentary successions associated with the 1991 surge provides an excellent modern analogue for larger-scale push moraines and proglacial fans on Skeiðarársandur, which are related to similar processes. Surge-related outflows operating over timescales of months–years, together with jökulhlaup flows play a major role in the creation of distinctive proglacial fluvial landforms and deposits. Examination of the sedimentary and landform records of areas presently subject to surging will allow the development of models which can be used to differentiate glacier surging from rapid glacier response to abrupt climate change.

Sigurðsson, O. (1992) "Framhlaup Skeiðarárjökuls 1991": Glettingur, v. **2** (2): p. 25.

van Dijk, T.A.G.P., and Sigurðsson, O. (2002) Surge-related floods at Skeiðarárjökull Glacier, Iceland: implications for ice-marginal outwash deposits, *in* Snorrason, A., Finnsdóttir, H.P., and Moss, M.E., eds., The Extremes of the Extremes: Extraordinary Floods. IAHS Special Publications Vol. 271, International Association of Hydrological Sciences, Wallingford, p. 193-198.

5.4.2 Breiðamerkurjökull

Boulton, G., and Zatsepin, S. (2006) "Hydraulic impacts of glacier advance over a sediment bed": Journal of Glaciology, v. **52**(179): p. 497 - 527.

A sedimentary sequence of till overlying a gravel aquifer was instrumented with waterpressure transducers prior to a small, anticipated surge of the margin of the glacier Breiðamerkurjökull in Iceland. The records of water pressure at each transducer site show a well-defined temporal sequence of hydraulic regimes that reflect the changing recharge of surface-derived meltwater, the pressure drop along the drainage pathway and the pattern of ice loading. The poroelastic and water-pressure response of glacially overridden sediments to the recharge rate is determined in the frequency domain through an analytic solution. This permits the in situ conductivity, compressibility and consolidation states of subglacial sediments to be derived, and reveals aquifer-scale compressibility that produces an important water-pressure wave associated with the advancing glacier. The model is then used to explore how varying conductivity/compressibility, largely determined by granulometry, can determine drainage states and instabilities that may have a large impact on glacier/ice-sheet dynamics, and how the drainage time of surface water to the bed can determine the frequency response of subglacial groundwater regimes and their influence on subglacial sediment stability. Mismatches between model predictions and specific events in water-pressure records are used to infer processes that are not incorporated in the model: hydrofracturing that changes the hydraulic properties of subglacial sediments; the impact on groundwater pressure of subglacial channel formation; upwelling beyond the glacier margin; and rapid variations in the state of consolidation. The poroelastic model also suggests how seismic methods can be developed further to monitor hydraulic conditions at the base of an ice sheet or glacier.

5.4.3 Eyjabakkajökull

Sharp, M. (1985) ""Crevasse-fill" ridges - a landform type characteristic of surging glaciers?" Geografiska Annaler, v. **67A**(3-4): p. 213-220, illus., diags., map.

Investigation of origin of morainic ridges produced by surging glacier, undertaken at Eyjabakkajökull which drains north-eastern part of Vatnajökull

Sharp, M.J., and Dugmore, A. (1985) "Holocene glacier fluctuations in eastern Iceland. " Zeitschrift fuer Gletscherkunde und Glazialgeologie, v. **21**: p. 341-349.

Stratigraphic investigations at two outlet glaciers of Vatnajökull: Skálafellsjökull (non-surging) and Eyjabakkajökull (surging). Follows pattern of glacier fluctuations from Holocene to Little Ice Age.

5.4.4 Brúarjökull

Björnsson, H., Pálsson, F., Guðmundsson, S., and Eydal, G.P. (2001) Áhrif Hálslóns á Brúarjökul, RH-04-2001: Reykjavík, Raunvísindastofnun Háskólans, p. 26.

Eyþórsson, J. (1963) "Brúarjökull hlaupinn (A sudden advance of Brúarjökull) ": Jökull, v. **13**: p. 19-21.

— (1964) "Brúarjökulsleiðangur 1964 (An expedition to Brúarjökull 1964) ": Jökull, v. **14**: p. 104-107.

Guðmundsson, M.T., Högnadóttir, and Björnsson, H. (1996) Brúarjökull - framhlaupið 1963-1964 og áhrif þess á rennsli Jökulsár á Brú, RH-11-96: Reykjavík, Raunvísindastofnun Háskólans.

Hoppe, G. (1995) "Brúarjökull": Glettingur, v. **5**(2): p. 38-41.

Kaldal, I., Víkingsson, S., and Sigurðsson, O. (2001) "Framhlaup Brúarjökuls á sögulegum tíma": Glettingur v. **11** (2-3): p. 26-30.

Kjaer, K.H., Larsen, E., van der Meer, J., Ingólfsson, Ó., Kruger, J., Benediktsson, I.Ö., Knudsen, C.G., and Schomacker, A. (2006) "Subglacial decoupling at the sediment/bedrock interface: a new mechanism for rapid flowing ice": Quaternary Science Reviews, v. **25**(21-22): p. 2704-2712.

On millennial or even centennial time scales, the activity of rapid flowing ice can affect climate variability and global sea level through release of meltwater into the ocean and positive feedback loops to the climate system. At the surge-type glacier Brúarjökull, an outlet of the Vatnajökull ice cap, eastern Iceland, extremely rapid ice flow was sustained by overpressurized water causing decoupling beneath a thick sediment sequence that was coupled to the glacier. This newly discovered mechanism has far reaching consequences for our understanding of fast-flowing ice and its integration with sediment discharge and meltwater release.

Kjerúlf, o. (1962) "Vatnajökull hlaupinn (Brúarjökull 1980)": Jökull, v. **12**: p. 47-48.

Knudsen, O. (1995) "Concertina eskers, Brúarjökull, Iceland: An indicator of surge-type glacier behaviour": Quaternary Science Reviews, v. **14**(5): p. 487-493.

Brúarjökull is a surging outlet lobe of Vatnajökull in SE Iceland. Geological evidence indicates that during quiescent phases, water drainage takes place in ice-walled and ice-roofed channels. As the glacier retreats, the courses of these channels are represented by eskers. Eskers which were englacial prior to surges become deformed during a surge. The deformation of eskers reflects strong longitudinal compression of the ice in the terminal zone. The wavelength of one of the compressed eskers indicates that ice in a 4 km wide margin was compressed by 50% of its original length. Compressed, or concertina eskers, date from the 1963-1964 and the 1890 surges of Brúarjökull. They have not been found from the 1810 surge, indicating that they may not survive if overrun by subsequent surges.

Knudsen, O., and Marren, P.M. (2002) "Sedimentation in a volcanically dammed valley, Brúarjökull, northeast Iceland": Quaternary Science Reviews, v. **21**(14-15): p. 1677-1692.

Sedimentation in upper Jokuldalur, northeast Iceland reveals a complex deglaciation history for the area. Subglacial eruption of an en-echelon ridge of pillow lavas and tuffs dammed the valley. The retreat of Brúarjökull to within the volcanic dam allowed a proglacial lake to form. Extensive retreat between surges of Brúarjökull may have resulted in the lake infilling and draining several times. The present infill reflects progressive glacier retreat, punctuated by stillstands and deposition of discrete wedges of coarse grained, ice-contact subaqueous fans. The valley infilled with sediment to within 10 m of the uppermost shoreline before progressive lowering of the outlet drained the lake. Breaching of the volcanic dam has since led to the incision of up to 85 m of sediment, deep into the underlying bedrock to create a spectacular gorge. This study documents how proglacial sedimentation can be controlled by glacier surge behaviour and the pattern of quiescent phase retreat.

Nelson, A.E., Willis, I.C., and Cofaigh, C.Ó. (2005) "Till genesis and glacier motion inferred from sedimentological evidence associated with the surge-type glacier, Brúarjökull, Iceland": Annals of Glaciology, v. **42**(1): p. 14-22.

A study employing macro- and micro-sedimentological techniques was conducted at three sites with recently deglaciated sediments in the proglacial area of Brúarjökull, a surge-type outlet glacier of the Vatnajökull ice cap, Iceland. Tills at these sites were likely deposited and deformed during the 1963/64 surge. At the height of the last surge, these sediments were beneath 90-120 m of ice, and associated basal shear stresses would have been 24-32 kPa. Tills associated with the surge at these sites formed by a combination of subglacial sediment deformation and lodgement and are thus regarded as 'hybrid tills'. The tills show evidence of both ductile and brittle deformation. Discontinuous clay lenses within the tills, indicating local ice-bed decoupling and sliding, imply that subglacial water pressures were spatially and temporally variable during the surge. The thickness of the subglacial deforming-till layer was 50-90 cm.

Rist, S. (1990) Ár og vötn í einstökum landshlutum: Austurland, *in* Rist, S., ed., Vatns er þörf: Reykjavík, Menningarsjóður, p. 141-148.

— (1990) Vatns er þörf: Reykjavík, Menningarsjóður, 248 s. : myndir, kort, línurit, töflur, uppdr.

Schomacker, A., Kruger, J., and Kjaer, K.H. (2006) "Ice-cored drumlins at the surge-type glacier Brúarjökull, Iceland: a transitional-state landform": Journal of Quaternary Science, v. **21**(1): p. 85-93.

This paper presents data on a glacial landform that, to Our knowledge, has not previously been described in the literature: the ice-cored drumlin. The study area is the forefield of the surge-type glacier Brúarjökull at the northeastern margin of the Vatnajökull ice cap, Fast Iceland. Based on sedimentological field investigations and aerial photograph interpretation, a qualitative model for the formation of ice-cored drumlins is proposed. The drumlin core consists of stagnant glacier ice from a previous advance and bubbly ice formed by snowdrifts, which were incorporated during the most recent *advance-the 1963-64 surge. This advance deposited a mantle of basal till and streamlined the ice-cored moraines. Till deformation and deposition on the drumlin ice-core is facilitated by a substratum of low-permeability ice-cored moraines.*

Þórarinsson, S. (1969) "Glacier surges in Iceland, with special reference to surges of Brúarjökli": Canadian Journal of Earth Sciences, v. **6**(no. 4): p. 875-882.

5.4.5 Dyngjujökull

Aðalgeirsdóttir, G., Björnsson, H., Pálsson, F., and Magnússon, E. (2005) "Analyses of a surging outlet glacier of Vatnajökull ice cap, Iceland." Annals of Glaciology, v. **Vol. 42**(1): p. 23-28.

Many of the large outlet glaciers of Vatnajökull ice cap, Iceland, have a history of regular surges. The mass transport during surges can be up to 25% of the total ice flux. This is a considerable amount that affects the whole ice cap, the location of the ice divides, the flow field and the size and shape of the ice cap. Data from the surging outlet Dyngjujökull, on the northern side of Vatnajökull, which surged during the period 1998-2000, are presented: surface elevation changes, displacement and total mass tr ansport. The total gain in ice volume in the receiving area, due to the surge, is considerably smaller than the loss in the reservoir area. The difference is mainly due to enhanced melting rates on the larger surface area of the crevassed glacier surface, and increased turbulent fluxes above the surface, but also due to increased frictional melting at the bed during the surge. A two-dimensional vertically integrated numerical flow model, of standard shallow-ice approximation type, is used to show that a modeled glacier that is similar in size to Dyngjujökull and subject to the same mass balance has three times higher velocities than the measured velocity during the quiescent phase. Adding surges in the numerical model, by periodically increasing the sliding velocity, causes the glacier to retreat and oscillate around a smaller state when subject to the same mass-balance regime. Lowering the equilibrium line by 50 m lets the modeled surging glacier oscillate around a size similar to that of the present glacier, indicating that surging is an efficient long-term ablation mechanism.

Björnsson, H., Pálsson, F., and Guðmundsson, S. (2001) The response of Arctic Ice Masses to Climate change (ICEMASS). SIUI, Final report. European Commission, Framework IV, Environmental and Climate Research Programme (DG XII), contract ENV4-CT97-0490, RH-10-2001: Reykjavík, Raunvísindastofnun Háskólans, p. 19.

During the years 1998-2000, the Science Institute, University of Iceland carried out measurements of the ice cap Vatnajökull (8200 km2) to quantify the mass balance components and their spatial and temporal variability. Meteorological observations were collected for the calibration of models of the energy and mass balance of Vatnajökull, and to calculate the energy balance components responsible for melting during the summer months. Further, we evaluated the impact of the volcanic eruptions in October 1996 and December 1998 mass balance of the ice cap; both direct melting and the effect of reduced albedo on the radiation balance. We also evaluated the effect of the recent surges in Vatnajökull on the downglacier mass transport. The winter balance is to a large extent determined by orographic effects, decreasing with increasing distance from the southern coast of Iceland. The summer balance decreases also along this transect due to decreasing albedo in the ablation areas. In *the year 1997-98, the average winter balance for the entire ice cap was about 1.14 m of water equivalent, the summer balance –2.08 m and the net balance –0.93 m. The accumulation area comprised 44 % of the total area of the ice cap. In the year 1998-99, the average winter balance was only about 1.36 m, the summer balance – 1.83 m and the net balance –0.47 m. The accumulation area comprised about 54 % of the total area of the ice cap. In the year 1999-2000, the average winter balance was only about 1.46 m, the summer balance –2.31 m and the net balance –0.85 m. The accumulation area comprised about 48 % of the total area of the ice cap. A rise in the equilibrium line by 100 m due to a climate change would reduce the net balance of Vatnajökull by about 0.75 m of water equivalent per year. In the ablation area radiation provides typically two-thirds of the melt energy and turbulent exchange one-third during the summer period May-August, and turbulent fluxes about one-third. In the accumulation area turbulent exchange becomes less significant. Spatial and temporal variations of the radiation balance are due to increasing solar radiation with elevation (due to low-lying clouds) and decreasing albedo towards the western part of the ice cap. Surface albedo varies enormously in space and time and values as low as 0.1 are found in places where volcanic ash layers melt out. Katabatic flow shapes the microclimate of the glacier except during the passage of intense storms. Two main factors determine the distribution of turbulent heat flux components: higher temperatures on the western and southern slopes of the ice cap than the northern parts, and the increasing strength of catabatic winds downglacier. The total loss of the ice cap's volume in 1997-2000 was 18.5 km3, which is about 0.5 % of its volume. During the period 1991-2000 the mass balance has been negative by 16 km3. In addition to this, the volume of ice melted by the volcanic eruption in October 1996 was 4 km3. The loss of the surface net balance during the year 1996-1997 was 8 km3, the total loss of the ice cap was 12 km3. The volcanic eruption in December 1998 melted only about 0.1 km3. The volcanic ash of the eruption in 1996 lowered the albedo by 20% in large areas and increased the annual ablation of Vatnajökull for one year by 10-15%. During the surge of Dyngjujökull (1100 km2) in 1999-2000 a mass of 13 km3 was transported downglacier from the accumulation area to the ablation area of that glacier outlet. During surges in Vatnajökull 1995-2000 altogether 23 km3 of ice were transported downglacier from the accumulation area. The summer ablation of the surging glacier outlets increases by 30 % during the first summer after a surge anddeclines gradually with time until the next surge takes place.*

Fischer, A., Rott, H., and Björnsson, H. (2003) "Observation of recent surges of Vatnajokull, Iceland, by means of ERS SAR interferometry": Annals of Glaciology, v. **37**: p. 69-76.

Recent surges of two outlet glaciers of the Vatnajökull ice cap, Iceland, were observed using European Remote-sensing Satellite (ERS) synthetic aperture radar (SAR) tandem interferograms from 12 different dates between December 1995 and January 2000. ERS SAR interferometry provided new information on the temporal and spatial variations in surface velocity during surges, after fieldwork became impossible. The area affected by the surge and therefore by increased basal sliding was delineated. The migration of flow divides on the ice cap during a surge was described. At Sylgjujökull, a western outlet glacier covering an area of 175 km(2), the fully developed surge and its abating phase were studied. Over a period of > 2 years after December 1995, the ice motion decreased steadily, with initially the highest velocities and subsequently the most pronounced decrease in velocity at the glacier terminus. The surge of Dyngjujökull, a northern outlet glacier covering an area of 1040 km(2), reached its maximum in 1999/2000. Slow acceleration over an area of about 200 km(2) was first observed between March 1996 and January 1997. The interferogram

from January 1999 shows a well-developed surge area, covering 210 km(2). This area more than doubled by January 2000, with maximum velocities reaching > 7 m d(-1). Between January 1997 and January 2000, the flow divide between Dyngju- and Skeiðarárjökull shifted 16 km to the south. The investigations indicate that a surge cycle on these glaciers spans several years, with slowly increasing motion over an extended area in the beginning, and more pronounced velocity changes during the active surge phase lasting 1-2 years.

Pálsson, F., Magnússon, E., and Björnsson, H. (2002) The surge of Dyngjujökull 1997-2000. Mass transport, ice flow velocities, and effects on mass balance and runoff, RH-01-2002: Reykjavík, Raunvísindastofnun Háskólans, p. 23.

5.4.6 Sylgjujökull

Fischer, A., Rott, H., and Björnsson, H. (2003) "Observation of recent surges of Vatnajokull, Iceland, by means of ERS SAR interferometry": Annals of Glaciology, v. **37**: p. 69-76.

Recent surges of two outlet glaciers of the Vatnajökull ice cap, Iceland, were observed using European Remote-sensing Satellite (ERS) synthetic aperture radar (SAR) tandem interferograms from 12 different dates between December 1995 and January 2000. ERS SAR interferometry provided new information on the temporal and spatial variations in surface velocity during surges, after fieldwork became impossible. The area affected by the surge and therefore by increased basal sliding was delineated. The migration of flow divides on the ice cap during a surge was described. At Sylgjujökull, a western outlet glacier covering an area of 175 km(2), the fully developed surge and its abating phase were studied. Over a period of > 2 years after December 1995, the ice motion decreased steadily, with initially the highest velocities and subsequently the most pronounced decrease in velocity at the glacier terminus. The surge of Dyngjujökull, a northern outlet glacier covering an area of 1040 km(2), reached its maximum in 1999/2000. Slow acceleration over an area of about 200 km(2) was first observed between March 1996 and January 1997. The interferogram from January 1999 shows a well-developed surge area, covering 210 km(2). This area more than doubled by January 2000, with maximum velocities reaching > 7 m d(-1). Between January 1997 and January 2000, the flow divide between Dyngju- and Skeiðarárjökull shifted 16 km to the south. The investigations indicate that a surge cycle on these glaciers spans several years, with slowly increasing motion over an extended area in the beginning, and more pronounced velocity changes during the active surge phase lasting 1-2 years.

5.4.7 Tungnaárjökull, Tungnárjökull

Andrzejewski, L. (2002) "The impact of surges on the ice-marginal landsystem of Tungnaárjökull, Iceland": Sedimentary Geology, v. **149**(1-3): p. 59-72.

Geomorphological mapping of the Tungnaárjökull marginal zone based on the analysis of aerial and satellite photographs and field research were used as the basis for determining its morphogenesis. The differentiation of glacial and glaciofluvial forms, their association, and their mode of formation allowed five different domains of the Tungnaárjökull marginal zone to be distinguished. They record the distinct mechanism

of glaciation and deglaciation of the glacier forefield, which is the result of the morphostructure of the volcanic substrate and the dynamics of the glacier snout. Structural and textural investigation of end moraine deposits and some proximal parts of the sandar allowed numerous glaciotectonic structures to be identified. Subglacial activity is conditioned by the local morphostructure of the substrate and transforms flat or undulated moraine surfaces and results in their drumlinisation. Reconstruction of the character of individual advances of Tungnaárjökull, from the end of the 19th century using geomorphological and sedimentological evidence within the ice marginal zone, suggest that they are consistent with surge-type advances. The configuration, dynamics and location of glacial streams in the marginal zone of Tungnaárjökull are conditioned by the Late Pleistocene volcanic relief. Where the arrangement of volcanic ridges is parallel to the glacier margin, its dynamics were restricted, creating groups of linear ice-contact forms. Where volcanic ridges were arranged perpendicularly to the glacier snout, conditions were suitable for the development of thrust end moraines and the formation of vast outwash plains.

Björnsson, H. (1970) "Hugleiðingar um jöklarannsóknir á Íslandi": Jökull, v. **20**: p. 15-26.

This paper gives a short outline of some aspects of glaciology with the main emphasis on topics related to meteorology and hydrology. A descriptive summary of the basic theory and modern measurement techniques is given along with suggestions for new research projects in Iceland. Following topics are discussed: The main links in the relation between glacier variations and climate, the mass balance, the energy budget, glacier response, kinematic waves, diffusion of kinematic waves, response time and lag time of a glacier. The value of measurements of glacier variations in Iceland is discussed in light of these topics. Furher, a description is given of glacier flow and glacier surges. Crystallographic problems are briefly mentioned. The paper concludes with a proposal for investigations on Tungnaárjökull.

Freysteinsson, S. (1968) "Tungnárjökull": Jökull, v. **18**: p. 371-388.

— (1984) "Tungnárjökull - langskurðarmæling 1959-1979 (Tungnárjökull Profile Surveys 1959-1979)": Jökull, v. **34**: p. 131-139.

Gudmundsson, G.H., Adalgeirsdottir, G., and Bjornsson, H. (2003) "Observational verification of predicted increase in bedrock-to-surface amplitude transfer during a glacier surge": Annals of Glaciology, v. **36**: p. 91-96.

The amplitude ratio between surface and bedrock topography has been predicted to depend strongly on the ratio of deformational velocity to mean basal sliding velocity. Observations made prior to and during a surge of Tungnaarjokull, Vatnajokull ice cap, Iceland, allow this prediction to be tested. During the surge, the ratio of internal deformational velocity and basal sliding (slip ratio) changed from about unity to a few hundred. The amplitude ratio changed from about 0.1 to about 0.7. This increase in amplitude ratio is in good overall agreement with predictions based on an analytical perturbation analysis for a linearly viscous medium which includes the effects of horizontal deviatoric stresses on glacier flow. An increase in amplitude ratio of this magnitude is not predicted by a similarly linearized analysis that employs the commonly used shallow-ice approximation. The strong increase in transfer amplitude *observed in the surge of Tungnaarjokull is a clear illustration of the effects of horizontal stress transmission on glacier flow reported here for the first time.*

Guðmundsson, A.T. (1986) "Mat á búskap og afrennsli Tungnaárjökuls og Brúarjökuls í Vatnajökli": Jökull, v. **36**: p. 75-82.

Guðmundsson, M.T., and Björnsson, H. (1992) Tungnaárjökull. I. Framhlaupið 1945-1946, RH-92-17: Reykjavík, Raunvísindastofnun Háskólans, p. 27.

— (1992) Tungnaárjökull. II. Breytingar á stærð, ísskriði og afrennsli eftir 1946, RH-92-19: Reykjavík, Raunvísindastofnun Háskólans, p. 39.

Kaldal, I., and Víkingsson, S. (2001) Umhverfi og orkuöflun - jöklalandslag. Síðujökull, Skaftárjökull, Tungnaárjökull og Sylgjujökull. Stöðuyfirlit í apríl 2001, IK-0001, Orkustofnun, Rannsóknasvið. Greinargerð.

Larsen, G., Guðmundsson, M.T., and Björnsson, H. (2000) Tephrostratigraphy of ablation areas of the Vatnajökull ice cap, Tungnaárjökull and Brúarjökull glaciers. Iceland 2000, Modern Processes and Past Environments: Keele, England, Keele University.

Larsen, G., Guðmundsson, M.T., and Björnsson, H. (1996) Gjóskulög í Tungnaárjökli: gossaga, aldur íss og dvalartími gjósku í jökli, Vorráðstefna 1996: "Eldgos í Vatnajökli 1996", ágrip erinda og veggspjalda: Reykjavík, Jarðfræðafélag Íslands, p. 33-35.

Molewski, P. (2005) REKONSTRUKCJA PROCESÓW GLACJALNYCH W WYBRANYCH STREFACH MARGINALNYCH LODOWCÓW ISLANDII - FORMY I OSADY. Reconstruction of glacial processes in the chosen marginal zones of the Icelandic glaciers - forms and deposits: Torun, Instytut Geografii UMK; Stowarzyszenie Geomorfologów Polskich, p. 148.

Rist, S. (1965) "Tungnárjökull": Jökull, v. **15**: p. 135-138.

Sigurðsson, O. (1994) "Tungnaárjökull veltur fram": Jökull, v. **44**: p. 1-2.

Vilmundardóttir, E.G., Snorrason, S.P., Larsen, G., and Aðalsteinsson, B. (1999) Bergrunnskort Tungnaárjökull 1913 I, 1:50.000. Unnið í Landfræðilegu upplýsingakerfi (ArcInfo), Landmælingar Íslands, Orkustofnun og Landsvirkjun.

5.4.8 Skaftárjökull

Guðmundsson, A.T. (1992) "Framhlaup Síðujökuls 1934 og Skaftárjökuls 1945": Náttúrufræðingurinn, v. **61**(2): p. 143-144.

5.4.9 Síðujökull

Björnsson, H., Pálsson, F., and Guðmundsson, M.T. (1994) Mat á áhrifum framhlaups Síðujökuls 1993-1994 á afrennsli jökulhlaups frá Skaftárkötlum til Hverfisfljóts, RH-95-19: Reykjavík, Raunvísindastofnun Háskólans, p. 10.

Friðgeirsson, Á., and Stefánsson, P. (1994) "Dances with glaciers": Iceland Review, v. **32**(2): p. 34-39, ill., diag., map.

Account of surge of Síðujökull, glacial tongue of Vatnajökull,which advanced 1200\g m in a few weeks at start of 1994

Guðmundsson, A.T. (1992) "Framhlaup Síðujökuls 1934 og Skaftárjökuls 1945": Náttúrufræðingurinn, v. **61**(2): p. 143-144.

— (1994) "Sjónarspilið á Síðujökli": Náttúrufræðingurinn, v. **64**(2): p. 161-163.

Sigurðsson, O. (1993) "Síðujökull á flugferð": Jökull, v. **43**: p. 72.

5.4.10 Framhlaup, ekki skilgreint nánar

Björnsson, H. (1973) "Rannsókn á framhlaupi jökla": Jökull, v. **23**: p. 18.

Björnsson, H., Jónsson, T., and Jóhannesson, T. (2005) "Comment on "Iceland as a heat island" by D.H. Douglass et al": Geophysical Research Letters, v. **32**(24).

Surges are common in all the major ice caps in Iceland, and historical reports of surge occurrence go back several centuries. Data collection and regular observation over the last several decades have permitted a detailed description of several surges, from which it is possible to generalize on the nature of surging in Icelandic glaciers. Combining the historical records of glacier-front variations and recent field research, we summarize the geographic distribution of surging glaciers, their subglacial. topography and geology, the frequency and duration of surges, changes in glacier surface geometry during the surge cycle, and measured velocity changes compared to calculated balance velocities. We note the indicators of surge onset and describe changes in ice, water and sediment fluxes during a surge. Surges accomplish a significant fraction of the total mass transport through the main outlet glaciers of ice caps in Iceland and have important implications for their hydrology. Our analysis of the data suggests that surge-type glaciers in Iceland are characterized by gently sloping surfaces and that they move too slowly to remain in balance given their accumulation rate. Surge frequency is neither regular nor clearly related to glacier size or mass balance. Steeply sloping glaciers, whether hard- or soft-bedded, seem to move sufficiently rapidly to keep in balance with the annual accumulation.

Björnsson, H., Pálsson, F., Sigurðsson, O., and Flowers, G.E. (2003) "Surges of glaciers in Iceland": Annals of Glaciology, v. **36**: p. 82-90.

Guðmundsson, M.T., Högnadóttir, and Björnsson, H. (1996) Effects of surges on runoff in glacial-fed rivers, *in* Sigurðsson, O., Einarsson, K., and Aðalsteinsson, H., eds., Nordic Hydrological Conference, Volume **1**: Reykjavík.

Gunnarsson, S. (1950-1953) Miðlandsöræfi Íslands, Hrakningar og heiðarvegir: Akureyri, Norðri, p. 214-244 í 1.b. .

van Dijk, T.A.G.P. (2002) Glacier surges as a control on the development of proglacial, fluvial landforms and deposits [**Unpublished PhD thesis**], University of Keele.

Þórarinsson, S. (1964) "Sudden advance of Vatnajökull outlet glaciers 1930-1964": Jökull, v. **14**: p. 76-89.

5.5 Jöklabúskapur, veðurfræði (mass balance, meteorology)

Aðalgeirsdóttir, G., Björnsson, H., and Jóhannesson, T. (2004) Vatnajökull ice cap results of computations with a dynamical coupled with a degree-day mass-balance model, RH-11-2004, Raunvísindastofnun Háskólans, p. 35 pp.

Aðalgeirsdóttir, G., Björnsson, H., Pálsson, F., and Magnússon, E. (2005) "Analyses of a surging outlet glacier of Vatnajökull ice cap, Iceland." Annals of Glaciology, v. **Vol. 42**(1): p. 23-28.

Many of the large outlet glaciers of Vatnajökull ice cap, Iceland, have a history of regular surges. The mass transport during surges can be up to 25% of the total ice flux. This is a considerable amount that affects the whole ice cap, the location of the ice divides, the flow field and the size and shape of the ice cap. Data from the surging outlet Dyngjujökull, on the northern side of Vatnajökull, which surged during the period 1998-2000, are presented: surface elevation changes, displacement and total mass tr ansport. The total gain in ice volume in the receiving area, due to the surge, is considerably smaller than the loss in the reservoir area. The difference is mainly due to enhanced melting rates on the larger surface area of the crevassed glacier surface, and increased turbulent fluxes above the surface, but also due to increased frictional melting at the bed during the surge. A two-dimensional vertically integrated numerical flow model, of standard shallow-ice approximation type, is used to show that a modeled glacier that is similar in size to Dyngjujökull and subject to the same mass balance has three times higher velocities than the measured velocity during the quiescent phase. Adding surges in the numerical model, by periodically increasing the sliding velocity, causes the glacier to retreat and oscillate around a smaller state when subject to the same mass-balance regime. Lowering the equilibrium line by 50 m lets the modeled surging glacier oscillate around a size similar to that of the present glacier, indicating that surging is an efficient long-term ablation mechanism.

Aðalgeirsdóttir, G., Guðmundsson, G.H., and Björnsson, H. (2000) "The response of a glacier to a surface disturbance: a case study on Vatnajökull ice cap, Iceland": Annals of Glaciology, v. **31**: p. 104-110.

In the course of a tremendous outburst flood (jökulhlaup) following the subglacial eruption in Vatnajökull, Iceland, in October 1996, a depression in the surface of the ice cap was created as a result of ice melting from the walls of a subglacial tunnel. The surface depression was initially approximately 6 km long, 800 m wide and 100 m deep. This "canyon" represents a significant perturbation in the geometry of the ice cap in this area where the total ice thickness is about 200-400 m. We present results of repeated measurements of flow velocities and elevation changes in the vicinity of the canyon made over a period of about 2 years. The measurements show a reduction in the depth of the canyon and a concomitant decrease in surface flow towards it over time. By calculating the transient evolution of idealized surface depressions using both analytical zeroth- and first-order theories, as well as the shallow-ice approximation (SIA) and a finite-element model incorporating all;all the terms of the momentum equations, we demonstrate the importance of horizontal stress gradients at the spatial scale of this canyon. The transient evolution of the cant on is calculated with a two-dimensional time-dependent finite-element model with flow parameters (the parameters A and n of Glen's flow law) that are tuned towards an optimal agreement with measured flow velocities. Although differences between measured and calculated velocities are comparable to measurement errors, the differences are not randomly distributed. The model is therefore not verified in detail. Nevertheless the model reproduces observed changes in the geometry over a 15 month time period reasonably well. The model also reproduces changes in both velocities and geometry considerably better than an alternative model based on the SIA.

— (2003) "A regression model for the mass-balance distribution of the Vatnajökull ice cap, Iceland": Annals of Glaciology, v. **37**: p. 189-193.

A non-linear regression model describing the mass-balance distribution of the whole Vatnajökull ice cap, Iceland, for the years 1992-2000 is presented. All available data from some 40 locations over this 9 year period were used to determine the parameters of the model. The regression model uses six adjustable parameters which all have a clear physical interpretation. They are the slope, direction and the height of the equilibrium-line altitude (ELA) plane, two altitude mass-balance gradients, and a maximum value of the surface mass balance. It is found that the temporal variation of the observed mass-balance distribution can be accurately described through annual shifts of the ELA. Annual shifts in ELA are on the order of 100 m, which is of the same magnitude as the change expected to be caused by the climate variation predicted during the next decades. A slight trend towards a more negative mass balance is detected during this 9 year period.

— (2005) "The volume sensitivity of Vatnajökull Ice Cap, Iceland, to perturbations in equilibrium line altitude." Journal of Geophysical Research, v. **110**(F04001).

The sensitivity of Vatnajökull ice cap, Iceland, to perturbations in equilibrium line altitude (ELA) is analyzed by performing a series of model experiments using a shallow ice approximation (SIA) flow model. For this purpose a simple but realistic parameterization for the mass balance is used that accurately simulates the observed variability in surface mass balance over a period of nine years. We find that because

of feedback between mass balance and altitude the ice cap either grows without bounds or settles to steady states depending on whether ELA is larger or smaller than a critical value ELAcrit. The largest modeled steady state is 60% of the current volume of the ice cap. The ice cap, as modeled, is therefore currently not close to a possible stable steady state. Past climate history and spatial and temporal variations in basal condition, such as surges, can be expected to have an influence on the ice cap and have to be taken into account when modeling the response of the ice cap to future climate change scenarios. For the neighboring ice cap, Hofsjökull, the relationship between ELA and volume is, in contrast, found to be simple, and Hofsjökull is close to a stable steady state with respect to the current climatic conditions. Introducing surges, which is not done here, will likely change the details of the ELA-volume relationship of Vatnajökull, presumably by making the relationship between volume and ELA more complex, and possibly less sensitive, as a further nonlinear feature is added to the model.

Aðalgeirsdóttir, G., Jóhannesson, T., Björnsson, H., Pálsson, F., and Sigurðsson, O. (2006) "Response of Hofsjökull and southern Vatnajökull, Iceland, to climate change": Journal of Geophysical Research v. **111**(F03001).

Possible changes in glacier mass balance are among the most important consequences of future climate change with both local and global implications, such as changes in the discharge of glacial rivers, changes in the vertical stratification in the upper layers of the Arctic Ocean, and a rise in global sea level. The response of the Hofsjökull and southern Vatnajökull ice caps in Iceland to climate change is analyzed with a vertically integrated, finite difference ice flow model coupled with a degree day mass balance model. Transient climate change simulations are forced with a climate change scenario for the Nordic countries, which for Iceland, specifies a warming rate of 0.15°C per decade in midsummer and 0.3°C per decade in midwinter, with a sinusoidal variation through the year starting from the baseline period 1981–2000. Precipitation is either held steady or is increased at 5% per °C of warming. Modeled ice volume is reduced by half within 100–150 years. About 2030, annual average runoff from the area that is presently covered by ice is projected to have increased by approximately 0.7 m yr−1 for Hofsjökull and by 1.4 m yr−1 for southern Vatnajökull. The sensitivity of the mass balance of the ice caps to climate change was found to be in the range 0.4–0.8 mw.e. yr−1 °C−1 for Hofsjökull and 0.8–1.3 mw.e. yr−1 °C−1 for southern Vatnajökull. The sensitivity remained within these ranges more than 150 years into the future.

Ahlmann, H.W. (1937) "Den svensk-islandska Vatnajokull-expeditionen": Ymer, v. **57**(1): p. 1-28, ill., diags., map.

Swedish-Icelandic Expedition to Vatnajökull, 1936, under author and Jón Eythórsson

— (1937) Den svensk-isländska Vatnajökull-expeditionen: Stockholm, 28 s., [3] mbl. br. : myndir, kort, línurit p.

— (1937) "Vatnajökull; Scientific results of the Swedish-Icelandic investigations 1936-37. Chapter 4. Vatnajökull in relation to other present-day Iceland glaciers": Geografiske Annaler, v. **19**(3-4): p. 212-229.

— (1938) The Vatnajökull Glacier : preliminary report on the work of the Swedish-Icelandic investigations 1936-1937: New York, American Geographical Society, 412.-438. s. : töflur, línurit, kort p.

— (1939) "Vatnajökull; Scientific results of the Swedish-Icelandic investigations 1936-37-38. Chapter 7.The regime of Hoffellsjökull": Geografiska Annaler, v. **21**(3-4): p. 171-188.

Summarizes chapters 5 and 6 (Vol.20, Hft.3-4, 1938, p.171-233 and Vol.21, Hft.1, 1939, p.39-66) on ablation and accumulation and discusses meteorological causes

— (1940) "Vatnajökull; Scientific results of the Swedish-Icelandic investigations 1936-37-38. Chapter 10. The relative influence of precipitation and temperature on glacier regime": Geografiske Annaler, v. **22**(3-4): p. 188-205.

Discusses observations from Hoffellsjökull. Also considers classification of glaciers in relation to altitude

— (1953) "Glacier studies in Iceland": Jökull, v. **3**(1).

Ahlmann, H.W., and Þórarinsson, S. (1937) "Vatnajökull; Scientific results of the Swedish-Icelandic investigations 1936-37. Chapter 1.Object, resources and general progress of the Swedish-Icelandic investigations": Geografiske Annaler, v. **19**(3-4): p. 146-160.

— (1937) "Vatnajökull; Scientific results of the Swedish-Icelandic investigations 1936-37. Chapter 3. Previous investigations of Vatnajökull, marginal oscillations of its outlet glaciers and general description of its morphology": Geografiske Annaler, v. **19**(3-4): p. 176-211.

— (1937) "Vatnajökull; Scientific results of the Swedish-Icelandic investigations 1936-37. Chapter 5. The ablation": Geografiske Annaler, v. **20**(3-4): p. 171-233.

— (1938) "The Vatnajökull Glacier; preliminary report on the work of the Swedish-Icelandic investigations 1936-37": Geographical Review, v. **28**(3): p. 412-438, ill., maps, tables.

— (1939) "Vatnajökull; Scientific results of the Swedish-Icelandic investigations 1936-37-38. Chapter 6. The accumulation": Geografiske Annaler, v. **21**(1): p. 39-66.

Ahlstrom, A.P., Mohr, J.J., Reeh, N., Christensen, E.L., and Hooke, R.L. (2005) "Controls on the basal water pressure in subglacial channels near the margin of the Greenland ice sheet": Journal of Glaciology, v. **51**(174): p. 443-450.

Assuming a channelized drainage system in steady state, we investigate the influence of enhanced surface melting on the water pressure in subglacial channels, compared to that of changes in conduit geometry, ice rheology and catchment variations. The analysis is carried out for a specific part of the western Greenland ice-sheet margin *between 66 degrees N and 66 degrees 30' N using new high-resolution digital elevation models of the subglacial topography and the ice-sheet surface, based on an airborne ice-penetrating radar survey in 2003 and satellite repeat-track interferometric synthetic aperture radar analysis of European Remote-sensing Satellite 1 and 2 (ERS-1/-2) imagery, respectively. The water pressure is calculated up-glacier along a likely subglacial channel at distances of 1, 5 and 9 km from the outlet at the ice margin, using a modified version of Rothlisberger's equation. Our results show that for the margin of the western Greenland ice sheet, the water pressure in subglacial channels is not sensitive to realistic variations in catchment size and mean surface water input compared to small changes in conduit geometry and ice rheology.*

Bassford, R.P., Siegert, M.J., Dowdeswell, J.A., Oerlemans, J., Glazovsky, A.F., and Macheret, Y.Y. (2006) "Quantifying the mass balance of ice caps on Severnaya Zemlya, Russian high arctic. I: Climate and mass balance of tle Vavilov Ice Cap": Arctic Antarctic and Alpine Research, v. **38**(1): p. 1-12.

Due to their remote location within file Russian High Arctic, little is known about the mass balance of ice caps on Severnaya Zemlya now and in the past. Such information is critical, however, to building a global picture of the cryospheric response to climate change. This paper provides a numerical analysis of the climate and mass balance of the Vavilov Ice Cap oil October Revolution Island. Mass balance model results are compared with available glaciological and climatological data. A reference climate was Constructed at file location of Vavilov Station, representing average conditions for file periods 1974-1981 and 1985-1988. The site of the station has a mean annual temperature of -16.5 degrees C, and an annual precipitation of 423 nm water equivalent. The mass balance model was calibrated to the measured mass balance, and tested against the time-dependent evolution of the englacial temperatures (to it depth of 15 m). The mass balance model was then converted toa distributed model for the entire Vavilov Ice Cap. Model results predict the spatial distribution of mass balance components over the ice cap. Processes involving refreezing of water are found to be critical to the ice cap's state of health. Superimposed ice makes Lip 40% of the total net accumulation, With the remaining 60% coming from firn that has been heavily densified by refreezing.

Bauer, A. (1955) "Contribution a la connaissance du Vatnajökull - Islande. Premier partie": Jökull, v. **5**: p. 11-22.

Calculation of volume, depths, altitudes, of Vatnajökull, Iceland; comparison with Hofsjökull, Langjökull, Myrdalsjökull

— (1956) "Contribution a la connaissance du Vatnajökull - Islande. Seconde partie": Jökull, v. **6**: p. 16-20.

Results of calculations (based on published data) of the mean elevation of the snow line and mass budget of the glacier used to determine its regime and type

Bergþórsson, P. (1969) "An estimate of drift ice and temperature in Iceland in 1000 years": Jökull, v. **19**: p. 94-101.

— (2004) Tilraunasalur veðranna, *in* Björnsson, H., ed., Jöklaveröld, náttúra og mannlíf: Reykjavík, Skrudda, p. 87-94.

Bjarnason, G.G., Jónsson, S., and Björnsson, H. (1998) Veður og jökulleysing. Líkangerð, IRIS-981201: Reykjavík, Raunvísindastofnun Háskólans.

— (2000) Túlkun geislunarmælinga á Vatnajökli, IRIS-001201: Reykjavík, Raunvísindastofnun Háskólans.

Björnsson, F. (1959) "Göngin í Hrútárjökli": Jökull, v. **9**: p. 30-32.

— (1977) "Veðurfar og snjóálag á Breiðamerkursandi": Veðrið, v. **1. hefti**: p. 27-30.

Björnsson, H. (1970) "Hugleiðingar um jöklarannsóknir á Íslandi": Jökull, v. **20**: p. 15-26.

This paper gives a short outline of some aspects of glaciology with the main emphasis on topics related to meteorology and hydrology. A descriptive summary of the basic theory and modern measurement techniques is given along with suggestions for new research projects in Iceland. Following topics are discussed: The main links in the relation between glacier variations and climate, the mass balance, the energy budget, glacier response, kinematic waves, diffusion of kinematic waves, response time and lag time of a glacier. The value of measurements of glacier variations in Iceland is discussed in light of these topics. Furher, a description is given of glacier flow and glacier surges. Crystallographic problems are briefly mentioned. The paper concludes with a proposal for investigations on Tungnaárjökull.

— (1982) "Jöklarannsóknir í þágu virkjanaaðila": Tímarit VFÍ: p. 44-52.

— (1984) Um líkön til reikninga á jökulleysingu: bráðnun og afrennsli, RH-01-84: Reykjavík, Raunvísindastofnun Háskólans og Landsvirkjun, p. 14.

— (1985) "The winter balance in Grímsvötn, Vatnajökull 1950-1985 (Summarizes available data for snow depths down to summer surface and winter balance calculated from snow density measurements)": Jökull, v. **35**: p. 107-109.

— (1988) "Hydrology of ice caps in volcanic regions": Societas Scientiarum Islandica, v. **Rit 45**: p. 139 p., 21 maps.

— (1996) Mass balance of Arctic Glaciers: Iceland. IASC REPORT No. 5., International Arctic Science Committee. Working Group on Arctic Glaciology: Sosnowiec-Oslo, p. 25-29.

— (2004) Jöklaveröld. Náttúra og mannlíf, Skrudda.

Björnsson, H., and Aðalgeirsdóttir, G. (1995) Veður á Brúarjökli og samanburður þess við leysingu á jökli og veður utan hans, RH-24-95: Reykjavík, Raunvísindastofnun Háskólans, p. 35.

Björnsson, H., Gjessing, Y., Hamran, S.E., Hagen, J.O., Liestol, O., Palsson, F., and Erlingsson, B. (1996) "The thermal regime of sub-polar glaciers mapped by multi-frequency radio-echo sounding": Journal of Glaciology, v. **42**(140): p. 23-32.

Björnsson, H., Guðmundsson, G.H., and Aðalgeirsdóttir, G. Flow modelling of a temperate ice cap, Vatnajökull Iceland.

The project aims at defining and testing two and three dimensional stationary and time dependent flow models to describe the ice cap Vatnajökull: general dynamics, flowlines, location of ice divides, velocity distribution, shape, thickness and extent, how close the ice cap is to an equilibrium state for the present mass balance distribution, its sensitivity to changes in mass balance and its response to climatic variations. The models will be tested on available boundary values from detailed maps of the ice surface and the bedrock, internal volcanic ash layers, observed mass balance and surface velocidy, and existing data of glacier variations for the last centuries. Mass balance models derived from the ongoing international Vatnajökull project TEMBA will be used as an input to studies of the glacier response to various scenarios of climatic change. Detailed observations and model studies will be carried out of the effect of bedrock irregularities. Field work started in August 1998, when GPS instruments from ETH, Zürich were used to measure velocity of the ice around a canyon that was created in the jökulhlaup that followed the 1996 eruption in Gjálp, Vatnajökull.

Björnsson, H., and Guðmundsson, S. (1996) Orkuþættir við yfirborð Vatnajökuls sumarið 1996, RH-30-97: Reykjavík, Raunvísindastofnun Háskólans, p. 73.

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Björnsson, H., Guðmundsson, S., and Haraldsson, H. (2000) Veðurathuganir og jökulleysing á Vatnajökli sumarið 1999, RH-16-2000: Reykjavík, Raunvísindastofnun Háskólans.

Björnsson, H., Guðmundsson, S., Haraldsson, H., and Pálsson, F. (1996) Veðurathuganir og jökulleysing á Vatnajökli sumarið 1995 og samanburður við veðurstöðvar utan jökuls, RH-18-96: Reykjavík, Raunvísindastofnun Háskólans, p. 71.

— (1998) Veðurathuganir og jökulleysing á Vatnajökli sumarið 1997, RH-05-98: Reykjavík, Raunvísindastofnun Háskólans, p. 66.

Björnsson, H., Guðmundsson, S., Pálsson, and Haraldsson, H. (1997) Veðurathuganir og jökulleysing á Vatnajökli sumarið 1996, RH-10-97: Reykjavík, Raunvísindastofnun Háskólans, p. 72.

Björnsson, H., Guðmundsson, S., and Pálsson, F. (2000) Afkoma og veðurþættir á Vatnajökli 1994-2000, Landsvirkjun.

— (2000) Mass and energy exchange of Vatnajökull ice cap, Iceland, 1994-2000, European Geophysical Society, XXVI General Assembly: Nice, France, p. 158.

— (2000) Meteorological observations on Vatnajökull: energy components, ablation and mass balance, The Icelandic Meteorological Office.

— (2004) Glacier winds on Vatnajökull ice cap, Iceland and their relation to temperatures of its environs, Third international symposium on artic glaciology: Geilo, Norway.

Björnsson, H., Guðmundsson, S., Pálsson, F., and Haraldsson, H. (1997) Veðurathuganir og jökulleysing á Vatnajökli sumarið 1997, RH-5-98: Reykjavík Raunvísindastofnun Háskólans, p. 66.

Björnsson, H., Guðmundsson, S., Pálsson, F., and Haraldsson, H.H. (2001) Mass and energy exchange of Vatnajökull ice cap, Iceland, 1992-2000, 2nd Circular International Symposium on Artic Feedbacks to Global Change: Arctic Centre, Rovaniemi, Finland.

— (2003) Energy balance and degree-day models of summer ablation on ice caps in Iceland, EGS-AGU-EUG Joint Assembly Nice, France.

— (2003) Energy balance and degree-day models of summer ablation on ice caps in Iceland, Vorráðstefna Jarðfræðifélags Íslands: Reykjavík.

— (2005) "Glacier winds on Vatnajökull ice cap, Iceland and their relation to temperatures of its environs": Annals of Glaciology, v. **42**(1): p. 291-296.

During the ablation season, the ice cap Vatnajökull (8100 km2) develops its own microclimate that we describe by meteorological data collected during the summers of 1994-2003. Persistent glacier winds are generated down the melting ice cap, whose variations in speed can be related empirically to the temperature fluctuations of the lowland environs of the ice cap. This suggests that climate warming would be accompanied by stronger glacier winds down the outlets of Vatnajökull, producing stronger turbulent fluxes that might amplify the melting rates in the lower ablation areas.

Björnsson, H., Jónsson, T., and Jóhannesson, T. (2005) "Comment on "Iceland as a heat island" by D.H. Douglass et al": Geophysical Research Letters, v. **32**(24).

Surges are common in all the major ice caps in Iceland, and historical reports of surge occurrence go back several centuries. Data collection and regular observation over the last several decades have permitted a detailed description of several surges, from which it is possible to generalize on the nature of surging in Icelandic glaciers. Combining the historical records of glacier-front variations and recent field research, we summarize the geographic distribution of surging glaciers, their subglacial. topography and geology, the frequency and duration of surges, changes in glacier surface geometry during the surge cycle, and measured velocity changes compared to calculated balance velocities. We note the indicators of surge onset and describe changes in ice, water and sediment fluxes during a surge. Surges accomplish a significant fraction of the total mass transport through the main outlet glaciers of ice caps in Iceland and have important implications for their hydrology. Our analysis of the data suggests that surge-type glaciers in Iceland are characterized by gently sloping surfaces and that they move too slowly to remain in balance given their accumulation rate. Surge frequency is neither regular nor clearly related to glacier size or mass balance. Steeply sloping glaciers, whether hard- or soft-bedded, seem to move sufficiently rapidly to keep in balance with the annual accumulation.

Björnsson, H., and Oerlemans, J. (1998) Report on the EISMINT workshop on Vatnajökull, EISMINT workshop on Vatnajökull: Skaftafell, Iceland.

Björnsson, H., and Pálsson, F. (1991) Vatnajökull, norðausturhluti, 1:100 000 Gagnasafnakort. Data source map, Raunvísindastofnun Háskólans og Landsvirkjun.

— (1991) Vatnajökull, norðausturhluti, 1:100 000. Jökulyfirborð. Glacier surface, Raunvísindastofnun Háskólans og Landsvirkjun.

— (1991) Vatnajökull, norðausturhluti, 1: 100 000. Ísa- og vatnaskil. Ice and water divides, Raunvísindastofnun Háskólans og Landsvirkjun.

— (1991) Vatnajökull, norðausturhluti, 1: 100 000. Ísaskil. Ice divides, Raunvísindastofnun Háskólans og Landsvirkjun.

— (1991) Vatnajökull, norðausturhluti, 1: 100 000. Ísþykkt. Ice thickness, Raunvísindastofnun Háskólans og Landsvirkjun.

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— (1991) Vatnajökull, norðausturhluti, 1: 100 000. Mættislínur. Water head potential, Raunvísindastofnun Háskólans.

— (1991) Vatnajökull, norðausturhluti, 1: 100 000. Vatnaskil. Water divides, Raunvísindastofnun Háskólans og Landsvirkjun.

— (1992) Vatnajökull, norðausturhluti, 1: 100 000. Gagnasafnakort. Data source map, Raunvísindastofnun Háskólans og Landsvirkjun.

— (1992) Vatnajökull, norðvesturhluti, 1:100 000. Ísþykkt. Ice thickness, Raunvísindastofnun Háskólans og Landsvirkjun.

— (1992) Vatnajökull, norðvesturhluti, 1:100 000. Jökulyfirborð. Glacier surface, Raunvísindastofnun Háskólans og Landsvirkjun.

— (1992) Vatnajökull, norðvesturhluti, 1:100.000. Gagnasafnakort. Data source map, Raunvísindastofnun Háskólans og Landsvirkjun.

— (1992) Vatnajökull, norðvesturhluti, 1: 100 000. Ísa- og vatnaskil. Ice and water divides, Raunvísindastofnun Háskólans og Landsvirkjun.

— (1992) Vatnajökull, norðvesturhluti, 1: 100 000. Ísaskil. Ice divides, Raunvísindastofnun Háskólans og Landsvirkjun.

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Björnsson, H., Pálsson, F., Aðalgeirsdóttir, G., and Guðmundsson, S. (2005) Mass balance of Vatnajökull (1991-2004) and Langjökull (1996-2004) ice caps, Iceland European Geosciences Union, General Assembly 2005: Vienna, Austria.

Björnsson, H., Pálsson, F., and Guðmundsson, M.T. (1993) Afkoma og hreyfing á vestanverðum Vatnajökli jökulárið 1991-1992, RH-93-14: Reykjavík, Jarðvísindastofnun Háskólans, p. 45.

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Björnsson, H., Pálsson, F., Guðmundsson, M.T., and Haraldsson, H. (1997) Afkoma, hreyfing og afrennsli á vestan- og norðanverðum Vatnajökli jökulárið 1995-1996, RH-24-97: Reykjavík, Raunvísindastofnun Háskólans, p. 57.

Björnsson, H., Pálsson, F., Guðmundsson, M.T., and Haraldsson, H.H. (1998) "Mass balance of western and northern Vatnajökull, Iceland, 1991-1995. " Jökull, v. **45**: p. 35-58.

During the period from 1991 to 1995, glacier mass balance has been monitored on the western and northern outlets of Vatnajökull (8100 km2; Fig. 1) which altogether comprise about half of the total area of the ice cap (4000 km2) and extend from an elevation of 2000 m down to 600 m. In the central areas of the ice cap, the winter balance has typically been about 2.5 m of water equivalent but the summer balance has varied from +0.5 to -0.5 m, and hence the net mass balance has varied from 2 to 3 m. At the glacier termini of 700-800 m elevation, the summer balance was typically about -5 m, and the winter balance 1.5 m on the western outlets and 0.5 m on the northern ones. The mean specific winter balance of the glaciers was fairly constant over this period but the summer balance, and hence the annual net balance, decreased year by year. The specific annual net balance was positive for all the northern outlets in the first three years due to cold spells and snowfall during the summers but slightly negative for the western ones in the third year. In the last year (1994-95) the mass balance was in general negative but close to zero for one outlet (Dyngjujökull, Fig. 2). For a year of zero net balance, the equilibrium line is estimated to be about 1100 m for the southwestern outlets but 1200-1300 m for the northwestern and northern outlets; the accumulation area is typically about 60% of the total glacier area and the specific runoff, corresponding to the summer balance, about 60 l s-1 km-2 averaged over the entire glacier and the whole year. During the years of the most positive mass balance this contribution from the summer balance dropped down to 30l s-1 km-2. Precipitation on the glaciers during summer may add 10-20 l s-1 km-2 to the specific discharge.

Björnsson, H., Pálsson, F., and Guðmundsson, S. (1998) Mass balance and meteorological observations on Vatnajökull 1997, RH-03-98, Raunvísindastofnun Háskóla Íslands (Science Institute, University of Iceland), p. 20 bls. .

— (2001) The response of Arctic Ice Masses to Climate change (ICEMASS). SIUI, Final report. European Commission, Framework IV, Environmental and Climate Research Programme (DG XII), contract ENV4-CT97-0490, RH-10-2001: Reykjavík, Raunvísindastofnun Háskólans, p. 19.

During the years 1998-2000, the Science Institute, University of Iceland carried out measurements of the ice cap Vatnajökull (8200 km2) to quantify the mass balance components and their spatial and temporal variability. Meteorological observations were collected for the calibration of models of the energy and mass balance of Vatnajökull, and to calculate the energy balance components responsible for melting during the summer months. Further, we evaluated the impact of the volcanic eruptions in October 1996 and December 1998 mass balance of the ice cap; both direct melting and the effect of reduced albedo on the radiation balance. We also evaluated the effect of the recent surges in Vatnajökull on the downglacier mass transport. The winter balance is to a large extent determined by orographic effects, decreasing with increasing distance from the southern coast of Iceland. The summer balance decreases also along this transect due to decreasing albedo in the ablation areas. In the year 1997-98, the average winter balance for the entire ice cap was about 1.14 m of water equivalent, the summer balance –2.08 m and the net balance –0.93 m. The accumulation area comprised 44 % of the total area of the ice cap. In the year 1998-99, the average winter balance was only about 1.36 m, the summer balance – 1.83 m and the net balance –0.47 m. The accumulation area comprised about 54 % of the total area of the ice cap. In the year 1999-2000, the average winter balance was only about 1.46 m, the summer balance –2.31 m and the net balance –0.85 m. The accumulation area comprised about 48 % of the total area of the ice cap. A rise in the equilibrium line by 100 m due to a climate change would reduce the net balance of Vatnajökull by about 0.75 m of water equivalent per year. In the ablation area radiation provides typically two-thirds of the melt energy and turbulent exchange one-third during the summer period May-August, and turbulent fluxes about one-third. In the accumulation area turbulent exchange becomes less significant. Spatial and temporal variations of the radiation balance are due to increasing solar radiation with elevation (due to low-lying clouds) and decreasing albedo towards the western part of the ice cap. Surface albedo varies enormously in space and time and values as low as 0.1 are found in places where volcanic ash layers melt out. Katabatic flow shapes the microclimate of the glacier except during the passage of intense storms. Two main factors determine the distribution of turbulent heat flux components: higher temperatures on the western and southern slopes of the ice cap than the northern parts, and the increasing strength of catabatic winds downglacier. The total loss of the ice cap's volume in 1997-2000 was 18.5 km3, which is about 0.5 % of its volume. During the period 1991-2000 the mass balance has been negative by 16 km3. In addition to this, the volume of ice melted by the volcanic eruption in October 1996 was 4 km3. The loss of the surface net balance during the year 1996-1997 was 8 km3, the total loss of the ice cap was 12 km3. The volcanic eruption in December 1998 melted only about 0.1 km3. The volcanic ash of the eruption in 1996 lowered the albedo by 20% in large areas and increased the annual ablation of Vatnajökull for one year by 10-15%. During the surge of Dyngjujökull (1100 km2) in 1999-2000 a mass of 13 km3 was transported downglacier from the accumulation area to the ablation area of that *glacier outlet. During surges in Vatnajökull 1995-2000 altogether 23 km3 of ice were transported downglacier from the accumulation area. The summer ablation of the surging glacier outlets increases by 30 % during the first summer after a surge anddeclines gradually with time until the next surge takes place.*

— (2002) Jöklarannsóknir, Vísindadagar Háskóla Íslands.

Björnsson, H., Pálsson, F., and Haraldsson, H.H. (2002) "Mass balance of Vatnajökull (1991-2001) and Langjökull (1996-2001), Iceland": Jökull, v. **51**: p. 75-78.

Björnsson, H., Rott, H., Guðmundsson, S., Fischer, A., Siegel, A., and Guðmundsson, M.T. (2001) "Glacier-volcano interactions deduced by SAR interferometry": Journal of Glaciology, v. **47**(156): p. 58-70.

Glacier-surface displacements produced by geothermal and volcanic activity beneath Vatnajökull ice cap in Iceland are described by field surveys of the surface topography combined with interferograms acquired from repeat-pass synthetic aperture radar images. A simple ice-flow model serves well to confirm the basic interpretation of the observations. The observations cover the period October 1996-January 1999 and comprise: (a) the ice-flow field during the infilling of the depressions created by the subglacial Gjálp eruption of October 1996, (b) the extent and displacement of the floating ice cover of the subglacier lakes of Grímsvötn and the Skaftá cauldrons, (c) surface displacements above the subglacier pathways of the jökulhlaups from the Gjálp eruption site and the Grimsvötn lake, (d) detection of areas of increased basal sliding due to lubrication by water, and (e) detection of spots of temporal displacement that may be related to altering subglacial volcanic activity. At the depression created by the Gjálp eruption, the maximum surface displacement rate away from the radar decreased from 27 cm d(-1) to 2 cm d(-1) over the period January 1997-January 1999. The observed vertical displacement of the ice cover of Grimsvötn changed from an uplift rate of 50 cm d(-1) to sinking of 48 cm d(-1), and for Skafta cauldrons from 2 cm d(-1) to 25 cm d(-1).

Black, J., Miller, G., Geirsdóttir, Á., Manley, W., and Björnsson, H. (2004) "Glaciological application of InSAR topography data of western Vatnajökull": Jökull, v. **54**: p. 37-56.

Boulton, G., and Zatsepin, S. (2006) "Hydraulic impacts of glacier advance over a sediment bed": Journal of Glaciology, v. **52**(179): p. 497 - 527.

A sedimentary sequence of till overlying a gravel aquifer was instrumented with waterpressure transducers prior to a small, anticipated surge of the margin of the glacier Breiðamerkurjökull in Iceland. The records of water pressure at each transducer site show a well-defined temporal sequence of hydraulic regimes that reflect the changing recharge of surface-derived meltwater, the pressure drop along the drainage pathway and the pattern of ice loading. The poroelastic and water-pressure response of glacially overridden sediments to the recharge rate is determined in the frequency domain through an analytic solution. This permits the in situ conductivity, compressibility and consolidation states of subglacial sediments to be derived, and reveals aquifer-scale compressibility that produces an important water-pressure wave associated with the advancing glacier. The model is then used to *explore how varying conductivity/compressibility, largely determined by granulometry, can determine drainage states and instabilities that may have a large impact on glacier/ice-sheet dynamics, and how the drainage time of surface water to the bed can determine the frequency response of subglacial groundwater regimes and their influence on subglacial sediment stability. Mismatches between model predictions and specific events in water-pressure records are used to infer processes that are not incorporated in the model: hydrofracturing that changes the hydraulic properties of subglacial sediments; the impact on groundwater pressure of subglacial channel formation; upwelling beyond the glacier margin; and rapid variations in the state of consolidation. The poroelastic model also suggests how seismic methods can be developed further to monitor hydraulic conditions at the base of an ice sheet or glacier.*

Boulton, G.S., Dobbie, K.E., and Zatsepin, S. (2001) "Sediment deformation beneath glaciers and its coupling to the subglacial hydraulic system": Quaternary International, v. **86**(1): p. 3-28.

The extent and style of shear deformation in sediments beneath modern glaciers and the geological evidence for such deformation in deposited sediments are reviewed. New evidence is presented from beneath a modern glacier of the spatial and temporal patterns of water pressure fluctuation and of time dependent patterns of deformation in sediments. It is concluded that in most experimental sites beneath soft-bedded modern glaciers, deformation is a significant or major contributor to glacier movement and the resultant discharge of till is large enough to make sediment deformation a major till forming process.Particular modes of deformation facilitate incorporation of underlying material into the till, whilst the capacity of a deforming till to absorb strain can protect the underlying strata from deformation, leading to the commonly found relationship where till overlies other strata with a sharp planar interface. It is argued that the almost ubiquitous occurrence of drumlins on the beds of former ice sheets is a reflection of the widespread occurrence of sediment deformation beneath them, with important implications for the coupling of ice sheet flow and bed properties.It is argued that the mechanical behaviour of the subglacial system is not simply determined by till properties but largely controlled by the subglacial water pressure regime determined by the nature of subglacial drainage. Results of field experiments show how the nature of the basal hydraulic system can play a vital role in controlling the coupling between the glacier and till deformation processes. They show that rapid glacier advances can produce undrained loading of sediments, that effective pressure may increase either upwards or downwards in a till according to the direction of drainage and that interstitial water pressures in subglacial sediments can show large and rapid variations, producing strong variations in the rate and distribution of strain and in the partitioning of basal movement between sliding and deformation.

Brandt, O., Björnsson, H., and Gjessing, Y. (2005) "Mass balance rates derived by mapping internal tephra layers in Myrdalsjökull and Vatnajökull ice caps, Iceland": Annals of Glaciology, v. **Vol. 42**(1): p. 284-290.

Internal tephra layers of known age have been detected by radio-echo soundings within the Mýrdalsjökull and Vatnajökull ice caps in Iceland. Assuming steady state, the estimated strain rates since these isochrones were deposited on the glacier surface have been used to calculate past average specific net balance rates in the accumulation zones along three flowlines on Mýrdalsjökull and one on Vatnajökull. For the period 1918-91 the specific mass-balance rate has been estimated to 4.5 and 3.5 m a−1 at 1350 m a.s.l. on the southern and northern slopes of Mýrdalsjökull, *respectively. At 1800 m elevation on the Bárdarbunga ice dome in Vatnajökull, the specific net balance averaged over the last three centuries is estimated to be about 2.1 m a−1. Given this specific net balance, a revised age-depth timescale is presented for a 400 m deep ice core recovered in 1972 from Bárdarbunga. The ice at the bottom is estimated to be from AD 1750.*

Bromwich, D.H., Bai, L.H., and Bjarnason, G.G. (2005) "High-resolution regional climate simulations over Iceland using Polar MM5": Monthly Weather Review, v. **133**(12): p. 3527-3547.

High-resolution regional climate simulations of Iceland for 1991-2000 have been performed using the fifth-generation Pennsylvania State University-National Center for Atmospheric Research (PSU-NCAR) Mesocale Model (MM5) modified for use in polar regions (Polar MM5) with three nested domains and short-duration integrations. The simulated results are compared with monthly mean surface observations from Iceland for 1991-2000 to demonstrate the high level of model performance; correlation coefficients exceed 0.9 for most variables considered. The simulation results are used to analyze the near-surface climate over Iceland. The simulated near-surface winds in winter are primarily katabatic. The land-sea-breeze circulation is clearly evident in summer. The land is colder than the ocean during winter. with a strong (weak) temperature gradient along the southern (northern) coast. This temperature pattern over the sloping terrain forces the katabatic wind. The diurnal cycle of near-surface air temperature is marked in summer over the land areas, which drives the land-sea breeze. The near-surface climate variations for extremes of the North Atlantic Oscillation (NAO) index during winter and summer result from the large-scale atmospheric advection conditions. The time-averaged mesoscale precipitation distribution over Iceland is reasonably well simulated by Polar MM5. Winter precipitation rates are double those during the summer, reflecting the much greater winter cyclonic activity. The simulated interannual precipitation variations during winter for 1991-2000 agree with those observed from snow accumulation measurements on the Vatnajokull ice cap. The winter precipitation decrease for 1991-2000 dominates the annual signal for all of Iceland except the northeastern and eastern parts where the precipitation increases. The large precipitation trends (decadal decrease of up to 50%) are caused by the eastward shift and weakening of the Icelandic low during the 1990s, as a result of changes in the NAO modulation of regional climate.

Böðvarsson, G. (1955) "On the flow of ice-sheets and glaciers": Jökull, v. **5**: p. 1-8.

Cailleau, A. (1958) "Remarques sur le Vatnajökull": Jökull, v. **8**: p. 12-14.

Calluy, G.H.K., Björnsson, H., Greuell, J., and Oerlemans, J. (2005) "Estimating the mass balance of Vatnajökull from NOAA-AVHRR imagery." Annals of Glaciology, v. **42A**(1): p. 118-124.

We investigate the possibility of obtaining the, Iceland, from US National Oceanic and Atmospheric Administration (NOAA) Advanced Very High Resolution Radiometer (AVHRR) albedo images for the years 1991-2002. De Ruyter de Wildt and others (2002) demonstrated that the mean potential absorbed radiation (〈Qpot,net〉) averaged over the melting season correlates well with the mean specific mass balance and that 〈Qpot,net〉 can be estimated from the evolution of the surface albedo.

Here, we improve the retrieval method of de Ruyter de Wildt and others (2002) by introducing the more realistic 6S atmospheric transfer model and by adding the latest narrow-to-broadband (NTB) albedo conversion equations. Bidirectional reflectance distribution functions for both ice and snow are used where appropriate. We show that the choice of the NTB conversion equations greatly influences the calculated 〈Qpot,net〉. Measured mass balance correlates well with 〈Qpot,net〉 if enough cloud-free images can be found through the year and if the spatial variation in measured mass balances is high enough. The correlation coefficient for all drainage basins combined is 0.92, with a residual standard deviation of 0.18 m w.e. We present an estimated mass-balance series for the whole of Vatnajökull based on our findings. Switching between different AVHRR instruments over time may cause serious errors in the calculated mass balance.

de Ruyter de Wildt, M., Oerlemans, J., and Björnsson, H. (2003) "A calibrated mass balance model for Vatnajökull, Iceland": Jökull, v. **52**: p. 1-20.

de Ruyter de Wildt, M.S.D., Klok, E.J., and Oerlemans, J. (2003) "Reconstruction of the mean specific mass balance of Vatnajokull (Iceland) with a seasonal sensitivity characteristic": Geografiska Annaler Series a-Physical Geography, v. **85A**(1): p. 57-72.

We present a Seasonal Sensitivity Characteristic (SSC) of Vatnajokull (Iceland), which consists of the sensitivity of the mean specific mass balance to monthly perturbations in temperature and precipitation. The climate in Iceland is predominantly maritime (high precipitation) although often the polar air mass influences the area. This results in temperature sensitivities that are high in summer and nearly zero during the winter months. In contrast, precipitation sensitivities are high in winter and low in summer. We use the SSC of Vatnajokull as a reduced mass balance model, with which we reconstruct the mass balance of Vatnajokull since 1825. The reduced model shows that changes in temperature and precipitation like the ones observed both have a significant impact upon the mass balance. The reconstructed mass balance records for two Icelandic glaciers correlate very well with mass balance records that are extracted from length records with a linear inverse model. This places confidence in both the reduced (forward) mass balance model and in the inverse model, although the forward method produces larger mass balance variations than the inverse method. For the south of Vatnajokull we find that after 1900, the length record is well explained by temperature variations alone, while another Icelandic glacier (Solheimajokull) was also influenced by precipitation variations.

de Ruyter de Wildt, M.S.D., and Oerlemans, J. (2003) "Satellite retrieval of mass balance: comparing SAR images with albedo images and in situ mass-balance observations": Journal of Glaciology, v. **49**(166): p. 437-448.

We present all analysis of many European Remote-sensing Satellite (ERS) synthetic aperture radar (SAR) images of Vatnajokull, Iceland, by comparing them with Advanced Very High Resolution Radiometer (AVHRR) images, massbalance observations and modelled firn stratigraphy Summer SAR and AVHRR images both detect the surface firn line (or the transient snow-line when it lies below the firn line) as a distinct boundary Winter SAR images of Vatnajokull generally display the late-summer surface firn line, and often also a transition at a higher elevation that possibly reflects a subsurface continuation of the firn line. Oil some winter images the firn line is not adequately detected, possibly due to a shallow firn pack. We found no differences

in backscatter between melting snow and firn, and for most years no differences in reflectance either. For Vatnajokull, equilibrium-line altitude is therefore not a particularly useful estimator of the mean specific mass balance (B-m). Unlike albedo images, SAR images do not display interannual variations of the signal within the accumulation area that are clearly related to B-m. Hence, SAR images of Vatnajokull contain less information about B-m than albedo images. However. for some drainage basins, mean transient snow-line/firn-line altitude during the melting season can be used to infer B-m.

de Ruyter de Wildt, M.S.D., Oerlemans, J., and Bjornsson, H. (2002) "A method for monitoring glacier mass balance using satellite albedo measurements: application to Vatnajokull, Iceland": Journal of Glaciology, v. **48**(161): p. 267-278.

We compare satellite albedo images of Vatnajokull, Iceland, with mass-balance measurements for the years 1991-99. We find that the equilibrium line is mostly not visible when it is located above its position of the previous year(s). Equilibrium-line detection is further hindered by clouds and a gradual transition between ice and firn or snow. Consequently, firn-line elevation at the end of the melting season is not particularly useful for estimating the annual mass balance. Instead, we propose to study the mean albedo of the entire ice cap throughout the melting season so that all available information about the surface albedo is taken into account. The mean net potential global radiation which can be estimated from the mean surface albedo alone, both depends on and influences summer melt. It also depends on winter precipitation and, integrated over the melting season, is found to relate linearly to the specific mass balance B (r = 0.87 and 0.94 for different outlets of Vatnajokull). B can be estimated quantitatively when this relation is known and qualitatively when it is not. The uncertainty in the satellite-derived value of B is 0.5-0.8 in w.e., which for Vatnajokull corresponds to about 27% of the interannual variability of B.

Denby, B., and Snellen, H. (2002) "A comparison of surface renewal theory with the observed roughness length for temperature on a melting glacier surface": Boundary-Layer Meteorology, v. **103**(3): p. 459-468.

The roughness lengths for momentum and temperature are calculated using the profile method on a melting glacier surface. Data from a 5-level 9-m meteorological mast positioned near the edge of Breidamerkurjokull, an outlet glacier of the Vatnajokull ice cap Iceland, are used for the calculations. The data are selected to avoid the presence of the katabatic wind speed maximum which would otherwise alter the scaling laws of the surface layer. The surface roughness length for momentum is determined to be 1.0 mm, similar to other estimates made on flat melting ice surfaces. The surface roughness length for temperature is found to be in good agreement with previously proposed surface renewal theories for the observed roughness Reynolds number range of 30 < Re- < 70.*

Dowdeswell, J.A. (1982) "Supraglacial Re-Sedimentation from Melt-Water Streams on to Snow Overlying Glacier Ice, Sylgjujokull, West Vatnajokull, Iceland": Journal of Glaciology, v. **28**(99): p. 365-375.

Dowdeswell, J.A., Hagen, J.O., Bjornsson, H., Glazovsky, A.F., Harrison, W.D., Holmlund, P., Jania, J., Koerner, R.M., Lefauconnier, B., Ommanney, C.S.L., and Thomas, R.H.

(1997) "The mass balance of circum-Arctic glaciers and recent climate change": Quaternary Research, v. **48**(1): p. 1-14.

The sum of winter accumulation and summer losses of mass from glaciers and ice sheets (net surface mass balance) varies with changing climate, In the Arctic, glaciers and ice caps, excluding the Greenland Ice Sheet, cover about 275,000 km(2) of both the widely glacierized archipelagos of the Canadian, Norwegian, and Russian High Arctic and the area north of about 60 degrees N in Alaska, Iceland, and Scandinavia, Since the 1940s, surface mass balance time-series of varying length have been acquired from more than 40 Arctic ice caps and glaciers, Most Arctic glaciers have experienced predominantly negative net surface mass balance over the past few decades. There is no uniform recent trend in mass balance for the entire Arctic, although some regional trends occur, Examples are the increasingly negative mass balances for northern Alaska, due to higher summer temperatures, and increasingly positive mass balances for maritime Scandinavia and Iceland, due to increased winter precipitation. The negative mass balance of most Arctic glaciers may be a response to a step-like warming in the early twentieth century at the termination of the cold Little Ice Age. Arctic ice masses outside Greenland are at present contributing about 0.13 mm yr(-1) to global sea-level rise.

Ebert, T. (2003) Identifying Glaciohydraulic Supercooling at Hoffelsjökull and Kvíárjökull, Iceland [**Unpublished MSc thesis**], Lehigh University.

Einarsson, M.Á. (1969) Hafísinn (Ritgerðasafn, fyrirlestrar haldnir á hafísráðstefnu í Reykjavík 27. jan.-7. feb. 1969; Bókin er helguð minningu Jóns Eyþórssonar)veðurfræðings: Reykjavík, Almenna bókafélagið, 552 s. : myndir, kort, línurit, töflur, uppdr. p.

Elliston, G.R. (1957) "A study of the ogive on some of the outlet glaciers of Öræfajökull": Jökull, v. **7**: p. 26-32.

Etzelmuller, B., and Björnsson, H. (2000) "Map analysis techniques for glaciological applications": International Geographical Information Science, v. **14**(6): p. 567-581.

This paper presents map analysis of digital elevation models for glaciological applications. The approach has been to combine spatial information describing the geometry of the glaciers with physical models of glaciological processes and to adjust empirical parameters to give a best fit with field observations. This applies to description of the basal shear stress and the resulting flow due to deformation of the ice. The outputs display spatial distributions, which can be adjusted to field observations through flexible routines of averaging the geographical information. Further, this approach is applied to description of the potential driving water along the bed, defined by the basal topography of the glacier and a model assuming that the basal water pressure is related to the thickness of the ice. The results produce predictions of the location of subglacial waterways and their drainage basins, which can be adjusted to field observations by choice of an empirical parameter, giving the basal water pressure as a fraction of the ice overburden pressure. A routine is presented that integrates the meltwater contribution downglacier to the various river outlets, given the glacier surface ablation.

Evans, D.J.A. (2001) "Glaciers": Progress in Physical Geography, 7, v. **25**: p. 428 - 439.

Evans, D.J.A., Lemmen, D.S., and Rea, B.R. (1999) "Glacial landsystems of the southwest Laurentide Ice Sheet: modern Icelandic analogues": Journal of Quaternary Science, v. **14**(7): p. 673-691.

Landform assemblages and associated stratigraphy, sedimentology and structure are used in the reconstruction of palaeo-ice-sheet dynamics in Alberta, western Canada. Interpretations are based upon the modern analogues from four outlet glaciers at the margins of Vatnajökull and Mýrdalsjökull, Iceland. In the area between Lloydminster and Lac la Biche, central Alberta, an extensive landform assemblage of megaflutings, crevasse-squeeze ridges and thrust-block-moraine arcs document the former surging of part of the margin of the Laurentide Ice Sheet during later stages of recession. This and form assemblage, including numerous exposures of glacitectonised bedrock and Quaternary sediments, is comparable to the landsystem of the surging glaciers Eyjabakkajökull and Brúarjokull in Iceland. Near High River southern Alberta, the former existence of an ice lobe characterised by active recession is recorded by closely spaced, low-amplitude recessional push moraines that drape tunnel valleys. These are comparable in form and pattern to annual push moraines and fluted till surfaces produced by Breidamerkurjokull and Sandfellsjokull, Iceland, and also include rimmed depressions produced by the escape of artesian water during ice-marginal pushing. This study provides interpretations of the regional glacial geomorphology of Alberta based upon comparisons of form and stratigraphy with modern glacial analogues, and provides an alternative to recent models which invoke large floods of subglacial meltwater to explain many of these same features. Implications for ice dynamics and regional till stratigraphies are discussed.

Eyles, N. (1979) "Facies of supraglacial sedimentation of Icelandic and Alpine temperate glaciers." Canadian Journal of Earth Sciences v. **16** (7): p. 1341-1361

Supraglacial debris transported by temperate valley glaciers is classified as supraglacial morainic till, distinct from lodgement till, and melt-out and flow till species on polar glaciers. In Iceland and the Alps, where annual discharges of supraglacial morainic till vary from 200-2000 m3 (compared with a maximum discharge of 26 000 m3 of lodgement till), till is deposited as three facies. Facies 1 occurs where supraglacial morainic till slows the rate of ice melt such that till is slowly superimposed on the subglacial surface in the form of stagnation or disintegration topography. Facies 2 occurs where the till cover is too thin or too coarse and ice melt is unretarded and supraglacial morainic till is deposited as a dispersed bouldery veneer by dumping during which gravity sorting occurs. Facies 3 refers to those stratigraphic sequences where irregular or lensate till horizons alternate repeatedly with ice-contact outwash.

Eyþórsson, J. (1951) "Þykkt Vatnajökuls (The thickness of Vatnajökull)": Jökull, v. **1**: p. 1-6.

— (1951) "Þykktarmælingar á Vatnajökli": Náttúrufræðingurinn, v. **21. árg.**(2. hefti): p. 90.

— (1957) "Safnmælir í Jökulheimum og vetrarsnjór á Vatnajökli (The totalisator at Jökulheimar and the winter snow on Vatnajökull)": Jökull, v. **7**: p. 59.

— (1958) "Safnmælir í Jökulheimum og vetrarsnjór á Vatnajökli (The totalisator at Jökulheimar and the winter snow on Vatnajökull)": Jökull, v. **8**: p. 33-34.

— (1960) "Safnmælir í Jökulheimum og vetrarsnjór á Vatnajökli. (The totalisator at Jökulheimar and the winter snow on Vatnajökull) ": Jökull, v. **10**: p. 29.

— (1960) Vatnajökull: Reykjavík, Almenna bókafélagið, 44 s., [62] mbls. : teikn., ritsýni, uppdr. p.

Fenn, C., and Ashwell, I. (1985) "Some observations on the characteristics of the drainage system of Kverkfjöll, central Iceland": Jökull, v. **35**: p. 79-82.

Flowers, G.E., Bjornsson, H., and Palsson, F. (2003) "New insights into the subglacial and periglacial hydrology of Vatnajokull, Iceland, from a distributed physical model": Journal of Glaciology, v. **49**(165): p. 257-270.

We apply a time-dependent distributed glaciohydraulic model to Vatnajokull ice cap, Iceland, aiming to determine the large-scale subglacial drainage structure, the importance of basally derived meltwater, the influence of a permeable glacier bed and Vatnajokull's discharge contribution to major rivers in Iceland. The model comprises two coupled layers that represent the subglacial horizon perched on a subsurface aquifer in the western sector and bedrock in the eastern sector. To initialize and drive the simulations, we use digital elevation models of the ice surface and bed, the 1999/2000 measured mass balance and an estimate of subglacial geothermal heat fluxes. The modelled subglacial flow field differs substantially from that derived by hydraulic-potential calculations, and the corresponding distribution of basal effective pressure shows a strong correlation between low effective pressure and surge-prone areas in northeastern and southern sectors of Vatnajokull. Simulations suggest that geothermally derived basal melt may account for up to similar to5% of the annual glacial discharge, and buried aquifers may evacuate up to similar to30% of subglacial water. Time-dependent tests yield estimates of the glacial discharge component in various outlet rivers and suggest a possible seasonal migration of subglacial hydraulic divides. This study of present-day Vatnajokull hydrology forms the starting point for investigations of its future evolution.

Flowers, G.E., Bjornsson, H., Palsson, F., and Clarke, G.K.C. (2004) "A coupled sheet-conduit mechanism for jökulhlaup propagation": Geophysical Research Letters, v. **31**(5).

The largest glacier outburst flood (jokulhlaup) ever recorded in Iceland occurred in 1996 and came from subglacial lake Grimsvotn in Vatnajokull ice cap. Among other noteworthy features, this flood was characterized by an unprecedentedly high lake level prior to flood initiation, extremely rapid linear rise in lake discharge, delay between the onset of lake drainage and floodwater arrival at the glacier terminus, formation of short-lived supraglacial fountains, and initially unchannelized outbursts of floodwater at the terminus. Observations suggest that the 1996 flood propagation mechanism was

fundamentally different than that of previously observed floods from Grimsvotn. We advance a new model whereby floodwater initially propagates in a turbulent subglacial sheet, which feeds a nascent system of conduits. This model is able to explain key observations made of the 1996 jokulhlaup and may shed light on other outburst floods that do not conform to the standard model.

Flowers, G.E., Marshall, S.J., Bjornsson, H., and Clarke, G.K.C. (2005) "Sensitivity of Vatnajokull ice cap hydrology and dynamics to climate warming over the next 2 centuries": Journal of Geophysical Research-Earth Surface, v. **110**(F2).

The sensitivity of Vatnajokull ice cap to future climate change is examined using spatially distributed coupled models of ice dynamics and hydrology. We simulate the evolving ice cap geometry, mass balance, velocity structure, subglacial water pressures and fluxes, and basin runoff in response to perturbations to a 1961-1990 reference climatology. For a prescribed warming rate of 2 degrees C per century, simulated ice cap area and volume are reduced by 12-15% and 18-25% within 100 years, respectively. Individual outlet glaciers experience 3-6 km of retreat in the first 100 years and a total retreat of 10-30 km over 200 years. For the same applied warming our results suggest a maximum increase in glacier-derived runoff of similar to 25% after 130 years. Ice cap thinning and retreat alters Vatnajokull's subglacial hydraulic catchment structure in the simulations, with up to several kilometers of local hydraulic divide migration. This serves to redistribute water among the major outlet rivers and, in extreme cases, to isolate river basins from glacially derived runoff. Glacier discharge from northern and northwestern Vatnajokull (distal from the coast) appears to be the most robust to climate warming, while discharge from Vatnajokull's southern margin (proximal to the coast) is particularly vulnerable. The latter reflects pronounced changes in the geometry of the southern outlet glaciers and has implications for glacier flood routing and frequency.

Freysteinsson, S. (1984) "Tungnárjökull - langskurðarmæling 1959-1979 (Tungnárjökull Profile Surveys 1959-1979)": Jökull, v. **34**: p. 131-139.

Galon, R. (1970) "Mechanism and Stages of Retreating of Skeiðarárjokull (Vatnajökull, Iceland)": Bulletin De L´Academie Polonaise Des Sciences-Serie Des Sciences Geologiques Et Geographiques, v. **18**(4): p. 245-?

Gao, J., and Liu, Y. (2001) "Applications of remote sensing, GIS and GPS in glaciology: a review ": Progress in Physical Geography, v. **25** (No. 4): p. 520-540.

Remote sensing has served as an efficient method of gathering data about glaciers since its emergence. The recent advent of Geographic Information Systems (GIS) and Global Positioning Systems (GPS) has created an effective means by which the acquired data are analysed for the effective monitoring and mapping of temporal dynamics of glaciers. A large number of researchers have taken advantage of remote sensing, GIS and GPS in their studies of glaciers. These applications are comprehensively reviewed in this paper. This review shows that glacial features identifiable from aerial photographs and satellite imagery include spatial extent, transient snowline, equilibrium line elevation, accumulation and ablation zones, and differentiation of ice/snow. Digital image processing (e.g., image enhancement, spectral ratioing and automatic classification) improves the ease and accuracy of mapping these *parameters. The traditional visible light/infrared remote sensing of two-dimensional glacier distribution has been extended to three-dimensional volume estimation and dynamic monitoring using radar imagery and GPS. Longitudinal variations in glacial extent have been detected from multi-temporal images in GIS. However, the detected variations have neither been explored nor modelled from environmental and topographic variables. GPS has been utilized independent of remote sensing and GIS to determine glacier ice velocity and to obtain information about glacier surfaces. Therefore, the potential afforded by the integration of nonconventional remote sensing (e.g., SAR interferometry) with GIS and GPS still remains to be realized in glaciology. The emergence of new satellite images will make remote sensing of glaciology more predictive, more global and towards longer terms.*

Gardarsson, S.M., and Eliasson, J. (2006) "Influence of climate warming on Hálslon reservoir sediment filling": Nordic Hydrology, v. **37**(3): p. 235-245.

Halslon reservoir is the main reservoir of the Kárahnjúkar hydropower project in the eastern highlands of Iceland. Studies for the environmental impact assessment for the hydropower project showed that sediment will fill the reservoir in about 500 years based on the present sediment transport rate. The main source of the sediment is the Brúarjökull outlet glacier which is a part of the Vatnajökull ice cap. Recent studies of the influence of climate warming on glaciers in Iceland show that they will decrease significantly and, in some cases, completely disappear during the next few hundred years. In this study, a glacier melt model for the Brúarjökull outlet glacier is constructed to predict how fast the glacier will retreat in response to accepted climate warming scenarios. The results from the glacier model are then used as input to a sediment transport mass balance model for the Hálslon reservoir, which predicts the influence of the retreat of the glacier on the sedimentation in the reservoir. The modeling shows that, instead of the reservoir being completely full of sediment in 500 years, the Halslon reservoir will at that time still have about 50-60% of its original volume as the sediment yield will decrease as a result of the decreasing glacier size.

Gíslason, S.R. (1990) "The chemistry of precipitation on the Vatnajökull glacier and chemical fractionation caused by the partial melting of snow": Jökull, v. **40**: p. 97-117.

Aim was to determine chemistry of 1987-88 precipitation on Vatnajökull, to look for spatial changes in snow chemistry, to study preferential release of salts and pollutants caused by partial melting of snow, and to develop model to analyze effect of degree of partial melting of snow on pH of meltwater. Snow at this location is uncontaminated by anthropogenic aerosol; thus,chemical constituents are primarily marine in origin

Greuell, W., and Oerlemans, J. (2005) "Validation of AVHRR- and MODIS-derived albedos of snow and ice surfaces by means of helicopter measurements ": Journal of Glaciology, v. **51**(172): p. 37-48.

We describe the validation of surface albedos of snow and glacier ice as derived from Advanced Very High Resolution Radiometer (AVHRR) and MOderate Resolution Imaging Spectrometer (MODIS) satellite data. For this purpose we measured surface albedos from a helicopter over Vatnajökull, Iceland, and the Kangerlussuaq transect (western part of the Greenland ice sheet) in Thematic Mapper (TM) bands 2 and 4 and AVHRR bands 1 and 2, and converted these values to 'measured albedos' in three MODIS bands. Relative to other validation methods, our helicopter measurements have the advantages of larger spatial coverage and of (almost) direct measurements

in satellite-sensor spectral bands. We found the smallest differences between the satellite-derived and helicopter albedos for the Kangerlussuaq transect: for AVHRR data a mean difference of 0.01 in both bands (with the satellite in near-nadir position) and for two MODIS images a mean difference of 0.00–0.02 for bands 2 and 4, and 0.03 for band 1. For two AVHRR images of Vatnajökull, we found mean differences of up to 0.06. Differences are primarily due to errors in the satellite-derived albedos, which, in turn, are mainly caused by errors in the calibration coefficients of the satellite sensors and insufficient knowledge of the angular distribution of the radiation reflected by snow and ice. Satellite data obtained from view zenith angles larger than ~50–55° appeared to be unsuitable.

Greuell, W., Reijmer, C.H., and Oerlemans, J. (2002) "Narrowband-to-broadband albedo conversion for glacier ice and snow based on aircraft and near-surface measurements": Remote Sensing of Environment, v. **82**(1): p. 48-63.

This article presents albedo measurements of snow and glacier ice at Vatnajökull (Iceland) and the Kangerlussuaq transect (Greenland). Radiative fluxes were measured in the broadband and in four narrowbands, namely, Thematic Mapper (TM) Bands 2 and 4, and Advanced Very High Resolution Radiometer (AVHRR) Bands 1 and 2. The incoming fluxes were measured near the ground and the outgoing fluxes from a helicopter. Extracts of the data collected over snow, ice, supraglacial moraines, supraglacial lakes, and tundra are discussed. Using the data sets from Iceland and Greenland, and data sets with entirely ground-based albedo measurements from the Morteratschgletscher (Switzerland) and Scharffenbergbotnen (Antarctica), new equations for narrowband-to-broadband (NTB) conversion were developed. They have a residual standard deviation of 0.011 for TM and 0.008 for AVHRR and can be applied without having to classify the surface. The helicopter data are also used to develop criteria for distinguishing different types of surfaces, which are needed for the application of Bidirectional Reflectance Distribution Functions (BRDFs). Snow can be distinguished from ice by defining a threshold for a single narrowband albedo. The ratio of the albedos in TM4 and TM2, and to a lesser extent, the ratio of the albedos in AVHRR2 and AVHRR1, may serve as a proxy for the surface characteristics of glacier ice in terms of concentrations of water, debris, and dust.

Gudmundsson, G.H., Adalgeirsdottir, G., and Bjornsson, H. (2003) "Observational verification of predicted increase in bedrock-to-surface amplitude transfer during a glacier surge": Annals of Glaciology, v. **36**: p. 91-96.

The amplitude ratio between surface and bedrock topography has been predicted to depend strongly on the ratio of deformational velocity to mean basal sliding velocity. Observations made prior to and during a surge of Tungnaarjokull, Vatnajokull ice cap, Iceland, allow this prediction to be tested. During the surge, the ratio of internal deformational velocity and basal sliding (slip ratio) changed from about unity to a few hundred. The amplitude ratio changed from about 0.1 to about 0.7. This increase in amplitude ratio is in good overall agreement with predictions based on an analytical perturbation analysis for a linearly viscous medium which includes the effects of horizontal deviatoric stresses on glacier flow. An increase in amplitude ratio of this magnitude is not predicted by a similarly linearized analysis that employs the commonly used shallow-ice approximation. The strong increase in transfer amplitude observed in the surge of Tungnaarjokull is a clear illustration of the effects of horizontal stress transmission on glacier flow reported here for the first time.

Guðmundsson, M.T., Björnsson, H., and Pálsson, F. (1995) "Changes in jökulhlaup sizes in Grímsvötn, Vatnajökull, Iceland, 1934-91, deduced from in-situ measurements of subglacial lake volume": Journal of Glaciology, v. **41** (138): p. 263-272.

A record of volumes of jökulhlaups from the subglacial Grimsvötn lake, Vatnajökull, Iceland, has been derived for the period 1934-91. The change in lake volume during jokulhlaups is estimated from the lake area, ice-cover thickness and the drop in lake level. The jökulhlaup volumes have decreased gradually during this period of low volcanic activity and declining geothermal power. The two Jokulhlaups in the 1930s each discharged about 4.5 km(3) (peak discharge 25-30 x 10(3) m(3) s(-1)). In the 1980s, jökulhlaup volumes were 0.6.-1.2 km(3) (peak discharge 2 x 10(3) m(3) s(-1)). The lake level required to trigger a jökulhlaup has risen as an ice dam east of the lake has thickened. Water flow in a jökulhlaup ceases when the base of a floating ice shelf covering Grimsvötn settles to about 1160 m a.s.l. Apparently, the jökulhlaups are cut off when the base of the ice shelf collapses on to a subglacial ridge bordering the lake on its eastern side. The decline in melting rates has resulted in a positive mass balance of the 160-170 km(2) Grimsvotn ice-drainage basin. Comparison of maps shows that the average positive mass-balance rate was 0.12 km(3) a(-1) (25% of the total accumulation) in the period 1946-87. A gradually increasing positive mass balance has prevailed since 1954, reaching 0.23 km(3) a(-1) in 1976-86 (48% of total accumulation).

Guðmundsson, A.T. (1986) "Mat á búskap og afrennsli Tungnaárjökuls og Brúarjökuls í Vatnajökli": Jökull, v. **36**: p. 75-82.

Guðmundsson, M.T. (2000) "Mass balance and precipitation on the summit plateau of Öræfajökull, SE-Iceland": Jökull, v. **48**: p. 49-54.

Guðmundsson, M.T., and Björnsson, H. (1992) Tungnaárjökull. II. Breytingar á stærð, ísskriði og afrennsli eftir 1946, RH-92-19: Reykjavík, Raunvísindastofnun Háskólans, p. 39.

Guðmundsson, M.T., and Högnadóttir (2003) Gjálp 1997-2002: Mælingar á ísskriði og varmaafli, RH-02-2003, Raunvísindastofnun Háskólans, p. 38.

Guðmundsson, M.T., Sigmundsson, F., Björnsson, H., and Högnadóttir (2004) "The 1996 eruption at Gjálp, Vatnajökull ice cap, Iceland: efficiency of heat transfer, ice deformation and subglacial water pressure": Bulletin of Volcanology, v. **66**(1): p. 46-65.

The 13-day-long Gjálp eruption within the Vatnajökull ice cap in October 1996 provided important data on ice-volcano interaction in a thick temperate glacier. The eruption produced 0.8 km(3) of mainly volcanic glass with a basaltic icelandite composition (equivalent to 0.45 km(3) of magma). Ice thickness above the 6-km-long volcanic fissure was initially 550-750 m. The eruption was mainly subglacial forming a 150-500 m high ridge; only 2-4% of the volcanic material was erupted subaerially. Monitoring of the formation of ice cauldrons above the vents provided data on ice melting, heat flux and indirectly on eruption rate. The heat flux was 5-6x10(5) W m(-2) in the first 4 days. This high heat flux can only be explained by fragmentation of magma into volcanic glass. The pattern of ice melting during and after the eruption indicates that the *efficiency of instantaneous heat exchange between magma and ice at the eruption site was 50-60%. If this is characteristic for magma fragmentation in subglacial eruptions, volcanic material and meltwater will in most cases take up more space than the ice melted in the eruption. Water accumulation would therefore cause buildup of basal water pressure and lead to rapid release of the meltwater. Continuous drainage of meltwater is therefore the most likely scenario in subglacial eruptions under temperate glaciers. Deformation and fracturing of ice played a significant role in the eruption and modified the subglacial water pressure. It is found that water pressure at a vent under a subsiding cauldron is substantially less than it would be during static loading by the overlying ice, since the load is partly compensated for by shear forces in the rapidly deforming ice. In addition to intensive crevassing due to subsidence at Gjálp, a long and straight crevasse formed over the southernmost part of the volcanic fissure on the first day of the eruption. It is suggested that the feeder dyke may have overshot the bedrock-ice interface, caused high deformation rates and fractured the ice up to the surface. The crevasse later modified the flow of meltwater, explaining surface flow of water past the highest part of the edifice. The dominance of magma fragmentation in the Gjálp eruption suggests that initial ice thickness greater than 600-700 m is required if effusive eruption of pillow lava is to be the main style of activity, at least in similar eruptions of high initial magma discharge.*

Guðmundsson, S. (1999) Energy balance and melting over glacier surface; Vatnajökull 1997 and 1998: Reykjavík, Raunvísindastofnun Háskólans, p. 73.

Automatic weather stations have been operated on Vatnajökull since 1994, to describe weather conditions and ablation and its connection to weather outside the glacier. In 1996 a two years glacial-meteorological experiment were started on the glacier in cooperation between the University of Iceland and the University of Utrecht, Netherlands. The main purpose was to improve the understanding of relation between glacier behavior and climate changing. This assignment was continued in 1998 as a two years multinational research project. Knowledge of energy balance is needed to understand the relationship between the glacier behaviour and climate changing. For this purpose, automatic weather stations capable of measuring the energy budget have been operated on Vatnajökull since 1996. The energy budget has been calculated for the summer of 1996 [1]. In this report, result of calculating the energy budget of the summers of 1997 and 1998 are presented. Two models were used to calculate the transfer of latent and sensible heat. The first approach uses one-level model for neutral air conditions given in [2]. The model has an advance of being relatively simple. The airflow at the glacier is typically not neutral. A model using one or two level measurements and an estimation of the eddy flux stability in [3] was tested on meteorological data from 1996 and 1997. A great advance of the later model is much less sensitivity to the surface roughness than the model for neutral air conditions.

— (2002) Myndir af þrívíðum yfirborðshreyfingum jarðar út frá samtúlkun á SAR bylgjuvíxl- og GPS mælingum. Ágrip., <u>Opinn Háskóli; fyrirlestur á vegum IEEE á Íslandi, nemendadeildar IEEE og Verkfræðideildar Háskólans</u>.

— (2004) Myndir af þrívíðum yfirborðshreyfingum jarðar út frá samtúlkun á SAR bylgjuvíxl- og GPS mælingum, <u>Raunvísindaþing</u>

Guðmundsson, S., and Björnsson, H. (2002) Glaciological researches in Iceland; remote sensing, mass- and meteorological observations and iceflow modelling, Institute for Meteorology and Geophysics. University of Innsbruck, Austria.

Guðmundsson, S., Björnsson, H., Haraldsson, H., and Pálsson (2000) Veðurathuganir og jökulleysing á Vatnajökli sumarið 1999, RH-16-00: Reykjavík, Raunvísindastofnun Háskólans.

Sumarið 1999 var haldið áfram rekstri sjálfvirkra veðurstöðva á Vatnajökli, sem hófst 1994 í þeim tilgangi að tengja sumarleysingu á jöklinum og veðurþætti. Alls voru settar upp sex stöðvar: í 1205 m hæð á Brúarjökli, 1100 m á Köldukvíslarjökli, 1725 m á Grímsfjalli , þrjár á Tungnaárjökli í 755 m, 1100 m og 1440 m. Að auki var veðurgögnum safnað í 725 m í Jökulheimum. Fimm af stöðvunum mynduðu línu sem náði frá 725 m í Jökulheimum, yfir Tungnaárjökul og upp í 1725 m á Grímsfjalli. Stöðvarnar sex á Vatnajökli mældu allar hita, raka, vind og alla geislunarþætti. Í Jökulheimum var ekki mæld stuttbylgjugeislun. Í þessari skýrslu er greint frá niðurstöðum gagnasöfnunar um veðurþætti í 2 m hæð en í annarri skýrslu mun greint frá útreikninga á orkuþáttum sem bárust að yfirborði jökulsins. Mælitæki voru sett upp af starfsmönnum Landsvirkjunar og Raunvísindastofnunar en úrvinnsla fór fram við Raunvísindastofnun. Verkefnið var að hluta styrkt af Evrópusambandinu, fjórða árið í röð.

Guðmundsson, S., Björnsson, H., Haraldsson, H., and Pálsson, F. (1999) Veðurathuganir og jökulleysing á Vatnajökli sumarið 1998, RH-13-99: Reykjavík, Raunvísindastofnun Háskólans.

Sumarið 1998 var haldið áfram rekstri sjálfvirkra veðurstöðva á Vatnajökli, sem hófst 1994 í þeim tilgangi að tengja sumarleysingu á jöklinum og veðurþætti. Alls voru settar upp fimm stöðvar: á Brúarjökli, Dyngjujökli, Köldukvíslarjökli og tvær á Tungnaárjökli. Allar stöðvarnar mæla nú sömu veðurþætti: hita, raka, vind og alla geislunarþætti. Önnur stöðin á Tungnaárjökli bilaði hins vegar svo að gögn fengust aðeins frá fjórum stöðvum. Í þessari skýrslu er greint frá niðurstöðum gagnasöfnunar um veðurþætti í 2 m hæð en í annarri skýrslu mun greint frá útreikninga á orkuþáttum sem bárust að yfirborði jökulsins. Mælitæki voru sett upp af starfsmönnum Landsvirkjunar og Raunvísindastofnunar en úrvinnsla fór fram við Raunvísindastofnun. Verkefnið var að hluta styrkt af Evrópusambandinu, þriðja árið í röð.

— (2001) Veðurathuganir og jökulleysing á Vatnajökli sumarið 2000, RH-17-2001: Reykjavík, Raunvísindastofnun Háskólans.

Sumarið 2000 var haldið áfram rekstri sjálfvirkra veðurstöðva á Vatnajökli, sem hófst 1994 í þeim tilgangi að tengja sumarleysingu á jöklinum og veðurþætti. Alls voru settar upp sex stöðvar: í 1205 m hæð á Brúarjökli, 1100 m á Köldukvíslarjökli, 1725 m á Grímsfjalli , þrjár á Tungnaárjökli í 755 m, 1235 m og 1440 m. Að auki var veðurgögnum safnað í 725 m í Jökulheimum. Eins og sumarið 1999 mynduðu fimm af stöðvunum línu sem náði frá 725 m í Jökulheimum, yfir Tungnaárjökul og upp í 1725 m á Grímsfjalli. Stöðvarnar sex á Vatnajökli mældu allar hita, raka, vind og alla geislunarþætti. Í Jökulheimum var ekki mæld langbylgjugeislun. Í þessari skýrslu er greint frá niðurstöðum gagnasöfnunar um veðurþætti í 2 m hæð en í annarri skýrslu mun greint frá útreikninga á orkuþáttum sem bárust að yfirborði jökulsins. Mælitæki voru sett upp af starfsmönnum Landsvirkjunar og Raunvísindastofnunar en úrvinnsla *fór fram við Raunvísindastofnun. Verkefnið var að hluta styrkt af Evrópusambandinu, fimmta árið í röð.*

— (2002) Veðurathuganir og jökulleysing á Vatnajökli og Langjökli sumarið 2001, RH-17-2002: Reykjavík, Raunvísindastofnun Háskólans.

Sumarið 2001 var haldið áfram rekstri sjálfvirkra veðurstöðva á Vatnajökli, sem hófst 1994 í þeim tilgangi að tengja sumarleysingu á jöklinum og veðurþætti. Stöðvarnar lágu á sniði upp vesturhluta jökulsins upp á Grímsfjall (1724 m) og niður norðausturhluta hans; tvær á Tungnaárjökli í 1100 m og 1445 m hæð og þrjár á Brúarjökli í 860 m, 1210 m og 1525 m hæð. Að auki var veðurgögnum safnað í 725 m hæð í Jökulheimum og 656 m við Kárahnjúka. Stöðvarnar á jöklinum mældu hita, raka, vind og alla geislunarþætti. Í Jökulheimum var ekki mæld langbylgjugeislun og engir geislunarþættir við Kárahnjúka. Á Langjökli voru reknar tvær veðurstöðvar. Stöðvarnar lágu á sniði eftir Hagafellsjökli vestari, í 490 m og 1060 m hæð. Að auki var hitagögnum safnað í 474 m hæð norðan við Skjaldbreið og í 299 m hæð á Söðulhólum. Í þessari skýrslu er greint frá niðurstöðum gagnasöfnunar um veðurþætti í 2 m hæð en í annarri skýrslu mun greint frá útreikningum á orkuþáttum sem bárust að yfirborði jöklanna. Mælitæki voru sett upp af starfsmönnum Landsvirkjunar og Raunvísindastofnunar en úrvinnsla fór fram við Raunvísindastofnun. Verkefnið var að hluta styrkt af Evrópusambandinu, sjötta árið í röð.

Guðmundsson, S., Björnsson, H., and Pálsson, F. (1999) Stafræn fjöltíðniratsjá til könnunar á innri gerð jökla, RH-14-99: Reykjavík, Raunvísindastofnun Háskólans.

— (2005) Jökulleysing: eðlisfræðileg og reynslubundin líkön, Verkefnafundur: Veður, vatn og orka: Orkustofnun, Reykjavík.

Guðmundsson, S., Björnsson, H., Pálsson, F., and Haraldsson, H. (2003) Comparison of physical and regression models of summer ablation on ice caps in Iceland, RH-15-2003: Reykjavík, Raunvísindastofnun Háskólans.

Automatic weather stations (AWSs) have been operated on ice caps in Iceland and in their surroundings during the summer months in the period 1994-2002 (Fig. 1) in order to calculate the energy balance and to derive empirical models of ablation. At the ice cap, the radiation components were all observed directly and the turbulent fluxes calculated from profile measurements of temperature, wind and humidity. Mean daily ablation was observed directly and the energy components calculated from meteorological parameters. This report presents results where AWSs data were used to optimise regression models of melting on Vatnajökull and provides a comparison with similar studies at Langjökull (Björnsson and others, submitted). The regression models were used to retrieve the total energy balance at sites of AWSs and the summer balance at locations of stakes from 1994-2002. The best overall degree-day predictions of daily melting rates were obtained by applying temperature observations outside the glacier, projected to the glacier with a constant lapse rate. This particularly applied during periods when the melting was primarily driven by the incoming solar radiation, suggesting that the solar radiation is more correlated to temperatures at the low-albedo surroundings of the glacier than thedamped temperatures above the melting glacier. Typically, realistic degree-day model predictions of the daily ablation were obtained during periods with high correlation between the total energy and the

eddy fluxes. Exceptions are seen in periods when the eddy fluxes fluctuated more due to wind speeds than temperatures. An empirical energy balance (EEB) model was derived and tested on the northeastern part of Vatnajökull. The model relates the turbulent heat fluxes to temperature outside the glacier and the net radiation to the surface albedo. Our meteorological data displays a correlation up to 0.8 or even more between temperature and wind speed. The precision of predicting of the annual turbulent heat fluxes could be enhanced by including an estimated wind speed that varies linearly with the temperature outside the glacier. Daily variation of net radiation could be reasonably simulated at the sites of the AWSs with the observed albedo. The variations of the annual values could be simulated based on empirical albedo values that are independent of time but vary with elevation and differ for the surface conditions of snow/firn/ice. More accurate estimation of albedo was needed to simulate the summer balance during the period 1994-2002 obtained from stakes at numerous points along transects. The net radiation is typically the main contributor to the melting and is mainly determined by the surface albedo, and hence, the performance of the EEB model depends highly on the accuracy of the assumed albedo.

— (2005) Energy balance calculations of Brúarjökull during the August 2004 floods in Jökla, N-Vatnajökull, Iceland, RH-03-2005: Reykjavík, Raunvísindastofnun Háskólans.

Vatnajökull ice cap (Fig. 1) is located in the North Atlantic Ocean close to the maritime southeastern coast of Iceland; the summers are mild, the annual precipitation extensive and the mass turnover high. The north facing Brúarjökull (1550 km2), the largest outlet of Vatnajökull (Fig. 1), is flat and with an elevation range of 600 to 1550 m a.s.l. over 45 km. In years of zero mass balance the equilibrium line is close to 1200 m and the accumulation zone is about 60% of the total glacier area. The main river draining Brúarjökull is Jökla with a glaciated water drainage basin of 1250 km2 (Fig. 1). One to three automatic weather stations, providing both the short- and long wave radiation balance, the transfer of turbulent heat fluxes, and the total energy supplied for melting, have been operated during the ablation season at Brúarjökull since 1996 (Figs. 1 and 2). Since 1992 annual summer and winter balance observations have been conducted at 15 sparse locations spread over the outlet glacier (Fig. 1). Records of temperature and precipitation near Vatnajökull, and discharge of the river Jökla (at Brú á Jökuldal, 40 km from the glacier margin, 20 km north of Kárahnjúkar), are available for the periods of the glaciological observations (Fig. 1). Large floods were observed in the river Jökla right after intensive precipitation 1 to 3 August 2004, and during an exceptionally warm and sunny period 9 to 14 August 2004. The three main objects of this work were to i) obtain energy budget maps (EBMs) of Brúarjökull over the summer 2004, ii) compare the glacier runoff as estimated with the EBMs to the August 2004 floods in Jökla and iii) use the EBMs to evaluate the results of calculating the runoff with three distinct regression models that use only temperature observation outside the glacier as an input. The EBMs allow us to relate the computed runoff to observed weather parameters, winter balance and surface characteristics and to see how the runoff compares to the measured riverdischarge.

Guðmundsson, S., Björnsson, H., Pálsson, F., and Haraldsson, H.H. (2005) "Energy balance of Brúarjökull and circumstances leading to the August 2004 floods in the river Jökla, N-Vatnajökull": Jökull, v. **55**: p. 121-138.

— (2005) Energy balance of Brúarjökull during the period of August 2004 floods in Jökla, CWE meeting: Reykjavík.

— (2006) Energy balance of Brúarjökull and circumstances leading to the August 2004 floods in the river Jökla, N-Vatnajökull, Raunvísindaþing.

— (2006) Energy balance of N-Vatnajökull, Iceland, during extreme glacial river floods, Vorráðstefna Jarðfræðifélags Íslands: Reykjavík.

— (2006) Energy balance of N-Vatnajökull, Iceland, during extreme glacial river floods, European Geosciences Union, General Assembly 2006: Vienna, Austria.

Guðmundsson, S., Björnsson, H., and Rott, H. (2002) Remote sensing on glaciers in Iceland, The International Arctic Science Committee (IASC), Working Group on Artic Glaciology, Annual Meeting: Obergurgl, Austria.

Guðmundsson, S., Guðmundsson, M.T., Björnsson, H., Sigmundsson, F., Rott, H., and Carstensen, J.M. (2002) "Three-dimensional glacier surface motion maps at the Gjálp eruption site, Iceland, inferred from combining InSAR and other ice-displacement data": Annals of Glaciology, v. **34**: p. 315-322.

We use topographically corrected interferograms, repeated global positioning system observations of locations of stakes and time series of elevation data to produce time series of high-resolution three-dimensional (3-D) ice surface motion maps for the infilling of the ice depression created by the 1996 subglacial eruption at the Gjalp volcano in Vatnajokull, Iceland. The ice inflow generated uplift in the central parts of the depression. During the first months, the uplift was much reduced by basal melting as the subglacial volcano cooled. For those motions surface-parallel ice flow cannot be assumed. The 3-D motion maps are created by an optimization process that combines the complementary datasets. The optimization is based on a Markov random-field regularization and a simulated annealing algorithm. The 3-D motion maps show the pattern of gradually diminishing ice flow into the depression. They provide a consistent picture of the 3-D motion field, both spatially and with time, which cannot be seen by separate interpretation of the complementary observations. The 3-D motion maps were used to calculate the cooling rate of the subglacial volcano for the first year after the eruption. First an uplift rate resulting solely from the inflow of ice was calculated from inferred horizontal motions. Basal melting was then estimated as the difference between the calculated uplift generated by the inflow of ice, and the observed uplift that was the combined result of ice inflow and basal melting. The basal melting was found to decline from 55 m(3) s(-1) (due to power of 18 GW) in January 1997 to 5 m(3) s(-1) (2 GW) in October 1997.

— (2002) Three-dimensional glacier surface motion maps deduced by combining InSAR data with other observations of ice displacement, The 25th Nordic Geological Winter Meeting Reykjavík, Iceland.

Guðmundsson, S., Guðmundsson, M.T., Sigmundsson, F., Björnsson, H., Helmut, R., and Carstensen, J.M. (2001) Three-dimensional glacier surface motion maps deduced by combining InSAR data with other observations of ice displacement, 4th international symposium on remote sensing in glaciology University of Maryland, Washington D.C.

Guðmundsson, S., Sigmundsson, F., and Carstensen, J.M. (2000) Three-dimensional surface motion maps estimated from combined InSAR and GPS data, EOS Transactions American Geophysical Union, 81, AGU Fall Meeting abstracts: SanFransisco, USA, p. F338.

— (2002) Three-dimensional surface motion maps estimated from combined InSAR and GPS data, Realistic Evaluation of Temporal Interaction of Natural hAzards (RETINA), second meeting 6-9 June 2002: Reykjavík, Iceland.

— (2002) "Three-dimensional surface motion maps estimated from combined InSAR and GPS data": Journal of Geophysical Research, v. **107**.

Guðmundsson, S., Sigmundsson, F., Guðmundsson, M.T., Björnsson, H., Rott, H., and Carstensen, J.M. (2001) Three-dimensional surface motion maps estimated from combined InSAR and GPS data, Vorráðstefna Jarðfræðifélags Íslands: Reykjavík.

Hall, D.K., Williams, R.S., and Sigurðsson, O. (1995) "Glaciological observations of Brúarjökull, Iceland, using synthetic aperture radar and thematic mapper satellite data": Annals of Glaciology, v. **21**: p. 271-276.

Hallgrímsson, M., and Þorbergsson, Þ. (1966) "Mælingar á Vatnajökli sumarið 1965": Jökull, v. **16**: p. 226-228.

Harris, T.D., Russell, A.J., Tweed, F.S., and Roberts, M.J. (submitted) Morphological and sedimentary signatures of glaciohydraulic supercooling, Iceland, Quaternary Science Reviews.

Helland, H. (1883) Om Islands Jökler og om Jökelelvenes Vandmængde og Slamgehalt, Archiv for Mathematik og Naturvidenskab, Volume **7**: Kristiania, p. 200-232.

Hubbard, A. (2006) "The validation and sensitivity of a model of the Icelandic ice sheet": Quaternary Science Reviews, v. **25**(17-18): p. 2297-2313.

The derivation and implementation of a three-dimensional model used to investigate the Last Glacial Maximum ice sheet across Iceland by Hubbard et al. [2006. A modelling insight into the Icelandic Last Glacial Maximum ice sheet. Quaternary Science Reviews] is described. It is applied at 2 km resolution and requires boundary distributions of topography, geothermal heat flux, surface air temperature and mass balance

calculated using a temperature-index approach based on reference distributions of annual temperature and precipitation. The model enables the variables of ice thickness, stress, strain and temperature to evolve freely through time and caters for the coupling of thermally triggered basal sliding with non-local dynamics through the computation of longitudinal stresses. It is driven through perturbations in sea-level and annual precipitation and temperature. A series of contemporary experiments are initiated to validate the model against the present ice cover across Iceland. Forcing the model from ice-free conditions with the 1961-1990 (reference) climatology yields a good simulation of all the ice masses except for Vatnajokull, where the model falls well short of its present margins. However, an experiment forced from ice-free conditions for 1000 years with a 2 [deg]C cooling perturbation, followed by 100 years of reference climatology yields a good simulation of Vatnajokull (in addition to other ice masses), implying that it is a remnant icecap, inherited from the Little Ice Age and perpetuated through strong ice elevation/mass balance coupling. An ensemble of experiments are initiated to investigate the sensitivity of the optimum LGM model isolated in Hubbard et al. (2006). Ice sheet volume and aspect ratio (but not area) are found to be sensitive to basal boundary conditions, in particular to the choice of sliding parameter and the applied geothermal conditions. Due to strong topographic control, in particular the configuration of offshore bathymetry and shelf break, ice sheet volume and area is sensitive to the calving parameter and sea-level change. However, an asymmetrical response indicates that the ice sheet is effectively decoupled from further climatic deterioration once it advances to the continental shelf break. These experiments imply that there is little latitude in the selection of model parameters which yields an ice sheet compatible with the available evidence and that the optimum LGM experiment represents a sound result. By inference, at least 63% of the optimum LGM ice sheet was grounded below sea-level implying potential instability with the onset of deglaciation.

Hubbard, A., Sugden, D., Dugmore, A., Norddahl, H., and Petursson, H.G. (2006) "A modelling insight into the Icelandic Last Glacial Maximum ice sheet": Quaternary Science Reviews, v. **25**(17-18): p. 2283-2296.

A three-dimensional thermomechanical model is used to investigate the Last Glacial Maximum (LGM) Icelandic ice sheet and the climate responsible for it at about 21 ka BP. A series of sensitivity experiments reveal that Iceland is susceptible to the onset large-scale glaciation with only a 3 1C cooling perturbation relative to recent (1961–1990) climate. A 5 1C cooling perturbation is enough to force an ice sheet to beyond the present day coastline in virtually all sectors. A suite of 15 experiments driven by a GRIP d18O time-series for 15,000 years from a climatic optimum at 36 ka to 21 ka BP scaled with 5.0–15.0 1C maximum cooling perturbation are initiated in order to identify a best-fit LGM ice sheet configuration compatible with the available empirical evidence. The optimum LGM model isolated requires an annual cooling of 10.0–12.5 1C relative to the recent climatology with over 50% precipitation suppression across the north and yields an extensive offshore ice sheet with an area of 3:29 x 105 km2 and a volume of 3:09 x 105 km3. Over-extension of ice extent across the northern shelf is addressed by the introduction of strong aridity across this region but otherwise the ice-sheet is well pinned to the continental shelf-break in remaining sectors which tends to decouple it from further climatic forcing. The optimum LGM ice-sheet has a substantial proportion of its base grounded below sea-level and is dominated by basal sliding which activates extensive zones of fast flow. This results in a highly dynamic, low aspect ice sheet with a mean ice thickness of 940m and a plateau elevation of

_2000m breached by numerous nunataks and ice-free zones providing potential, but spatially limited and frigid, ecological refugia through the vicissitudes of the LGM.

Höskuldsson, Á., Sparks, R.S.J., and Carroll, M.R. (2006) "Constraints on the dynamics of subglacial basalt eruptions from geological and geochemical observations at Kverkfjöll, NE-Iceland": Bulletin of Volcanology, v. **68**(7-8): p. 689-701.

The Kverkfjöll area, NE Iceland is characterised by subglacial basalt pillow lavas erupted under thick ice during the last major glaciation in Iceland. The water contents of slightly vesiculated glassy rims of pillows in six localities range from 0.85 +/- 0.03 to 1.04 +/- 0.03 wt%. The water content measurements allow the ice thickness to be estimated at between 1.2 and 1.6 km, with the range reflecting the uncertainty in the CO2 and water contents of the melt. The upper estimates agree with other observations and models that the ice thickness in the centre of Iceland was 1.5-2.0 km at the time of the last glacial maximum. Many of the pillows in the Kverkfjöll area are characterised by vesiculated cores (40-60% vesicles) surrounded by a thick outer zone of moderately vesicular basalt (15-20% vesicles). The core contains similar to 1 mm diameter spherical vesicles distributed uniformly. This observation suggests a sudden decompression and vesiculation of the still molten core followed by rapid cooling. The cores are attributed to a jökulhlaup in which melt water created by the eruption is suddenly released reducing the environmental pressure. Mass balance and solubility relationships for water allow a pressure decrease to be calculated from the observed change of vesicularity of between 4.4 and 4.7 MPa depressurization equivalent to a drop in the water level in the range 440-470 m. Consideration of the thickness of solid crust around the molten cores at the time of the jökulhlaup indicates an interval of 1-3 days between pillow emplacement and the jökulhlaup. Upper limits for ice melting rates of order 10(-3) m/s are indicated. This interpretation suggests that jökulhlaups can reactivate eruptions.

Ives, J.D., and King, C.A.M. (1954) "Glaciological observations on Morsárjökull, S.W. Vatnajökull. Part I: The ogive banding": Journal of Glaciology, v. **Vol. 2** (No. 16): p. 423-428/416.

— (1955) "Glaciological observations on Morsárjökull, S.W. Vatnajökull. Part II: Regime of the glacier, present and past": Journal of Glaciology, v. **Vol. 2** (No. 17): p. 477-482.

Jónsson, T., and Garðarsson, H. (2001) "Early instrumental meteorological observations in Iceland": Climatic Change v. **48**: p. p. 169-187.

Kaltenbock, R., and Obleitner, F. (1999) "On a low cloud phenomenon at the Breiðamerkurjökull Glacier, Iceland": Boundary-Layer Meteorology, v. **92**(1): p. 145-162.

An impressive cloud wall has frequently been observed on the southern slopes of the Vatnajökull ice sheet, which is located in south-eastern Iceland. Its optical and dynamic features suggest a delicate balance of the atmospheric agents involved. This has been confirmed by a thorough analysis of a well documented event and by statistics covering a whole summer season. As an exemplary event, the regional development of the associated cloud has basically been documented with *synchronous surface data along a suitable transect of the glacier. Data from tethered balloons, radiosoundings and routine synoptic data have also been exploited extensively. Cloud development was generally aided by a high moisture potential because of proximity to the open seas and the remnants of a frontal system. Furthermore the occurrence of the cloud phenomenon was associated with onshore (southerly) surface winds, assisting advection and lifting of the associated air masses above the slopes of the ice sheet. Northward protrusion of the associated cloud was apparently opposed by continuous katabatic winds and topographically induced lee effects.*

King, C.A.M., and Ives, J.D. (1955) "Glaciological observations on some of the outlet glaciers of south-west Vatnajökull, Iceland, 1954. Part I: Glacier regime": Journal of Glaciology, v. **Vol. 2** (No. 18): p. 563-569.

Accumulation and ablation measurements on Morsárjökull are described and tentative glacier budget for three seasons 1951-52,1952-53 and 1953-54 is presented. Observations of glacier flow on Morsárjökull, Svínafellsjökull and Skaftafellsjökull are considered. Recent fluctuations of snouts of Svínafellsjökull and Skaftafellsjökull are discussed and related to variations in height of accumulation zones of glaciers

— (1955) "Glaciological observations on some of the outlet glaciers of south-west Vatnajökull, Iceland, 1954. Part II: Ogives": Journal of Glaciology, v. **Vol. 2** (No. 19): p. 646-651.

Observations and measurements of ogives on Morsárjökull, Svínafellsjökull and Skaftafellsjökull are discussed. Problems associated with smaller ogives of Svínafellsjökull and ridges below ice falls are considered

Kjaer, K.H., Larsen, E., van der Meer, J., Ingólfsson, Ó., Kruger, J., Benediktsson, I.Ö., Knudsen, C.G., and Schomacker, A. (2006) "Subglacial decoupling at the sediment/bedrock interface: a new mechanism for rapid flowing ice": Quaternary Science Reviews, v. **25**(21-22): p. 2704-2712.

On millennial or even centennial time scales, the activity of rapid flowing ice can affect climate variability and global sea level through release of meltwater into the ocean and positive feedback loops to the climate system. At the surge-type glacier Brúarjökull, an outlet of the Vatnajökull ice cap, eastern Iceland, extremely rapid ice flow was sustained by overpressurized water causing decoupling beneath a thick sediment sequence that was coupled to the glacier. This newly discovered mechanism has far reaching consequences for our understanding of fast-flowing ice and its integration with sediment discharge and meltwater release.

Klok, E.J., and Oerlemans, J. (2003) "Deriving historical equilibrium-line altitudes from a glacier length record by linear inverse modelling": The Holocene, v. **13**(4): p. 343 - 351.

Glaciers have fluctuated in historic times and the length fluctuations of many glaciers are known. From these glacier length records, a climate reconstruction described in terms of a reconstruction of the equilibrium-line altitude (ELA) or the mass-balance can be extracted. In order to derive a climate signal from numerous glacier length records, a model is needed that takes into account the main characteristics of a glacier, but uses little information about the glacier itself. Therefore, a simple analytical model was *developed based on the assumption that the change in glacier length can be described by a linear response equation. Historical length observations, the climate sensitivity and the response time of a glacier were needed to calculate historical equilibrium-line altitudes. Both climate sensitivity and length response time were calculated from a perturbation analysis on the continuity equation. The model was tested on 17 European glacier length records. The results revealed that the ELA of most glaciers increased on average 54 m between AD 1920 and 1950. The results of the analytical model were compared to mass-balance reconstructions calculated with a numerical flowline model and derived from historical temperature and precipitation records. The findings lead us to believe that the analytical model could be very useful to gain information about the historical mass-balance rates and ELAs.*

Knudsen, Ó. (2001) Undirkælt vatn og ísmyndun undir sporðum skriðjökla í sunnanverðum Vatnajökli, Vorráðstefna 2001: ágrið erinda og veggspjalda: Hótel Loftleiðum, Reykjavík, Jarðfræðifélag Íslands.

Landl, B., Björnsson, H., and Kuhn, M. (2003) "The energy balance of calved ice in Lake Jökulsarlón, Iceland": Arctic Antarctic and Alpine Research, v. **35**(4): p. 475-481.

We describe energy fluxes involved in melting ice in the proglacial lake Jokulsarlon and the transport of thermal energy into the lake from the atmosphere and the sea. Data from earlier fieldwork and campaigns have been used to estimate the net radiation balance, the turbulent fluxes, the heat provided by inflowing seawater, and the glacial meltwater flux, From aerial photographs, DGPS measurements, and mass balance measurements, we calculated a calving flux of 260 x 10(6) m(3) yr(-1) for the present. The total energy required to melt all the ice in the lake is approximately 160 W m(-2) assuming that all the calved ice is melted during 1 yr. The most important contribution is heat from seawater. Radiation provides approximately 70 W m(-2). The albedo depends on the ice-covered fraction of the lake and ranges from 22% in summer to 41% in winter. The turbulent fluxes are around 10 W m(-2). Difficulties occurred in finding an appropriate range for the roughness parameter z(o), but the most likely values are in the range of a few centimeters. We considered different future scenarios with respect to inflow of seawater and air temperature, albedo, and even inhibition of seawater intrusion, which would have a significant impact on ice cover in the lake.

Lindroth, C. (1965) "Skaftafell, a living glacial refugium": OIKOS v. **suppl. 6**.

Lister, H. (1953) "Report on glaciology at Breiðamerkurjökull 1951": Jökull v. **3**: p. p. 23-31.

— (1959) "Micro meterology over dirt coned ice": Jökull, v. **9**: p. 1-6.

Magnússon, E., Björnsson, H., Dall, J., and Pálsson, F. (2005) "Volume changes of Vatnajökull ice cap, Iceland, due to surface mass balance, ice flow, and subglacial melting at geothermal areas": Geophysical Research Letters, v. **32**(5).

We present observed changes in the geometry of western Vatnajökull over a period of about ten years which are caused by the Comparison of two digital elevation models shows *that from 1985 to 1998 the outlet glaciers have lost 14 +/- 5 km(3), on the average 1 m yr(-1) evenly distributed over the area of 1360 km(2). However, the marginal areas of four outlets have gained up to 80 m in elevation and the uppermost parts have subsided similarly during surges. Altogether 26 +/- 3 km(3) were transported from the accumulation areas to the ablation areas of which 19 +/- 3 km(3) are attributed to surges. Comparison of DEM's from August 1997 and August 1998 revealed 10 ice cauldrons produced by subglacial geothermal activity, of which some were previously unknown.*

Magnússon, E., Björnsson, H., Pálsson, F., and Dall, J. (2004) "Glaciological application of InSAR topography data on western Vatnajökull": Jökull, v. **54**: p. 17-36.

Magnússon, E., Pálsson, F., and Björnsson, H. (2004) Yfirborð Brúar- og Eyjabakkajökuls og vatnasvið Jökulsár á Brú, Kreppu, Kverkár og Jökulsár á Fljótsdal 1946-2000, RH-10-2004: Reykjavík, Jarðvísindastofnun Háskólans, p. 32.

Magnússon, E., Rott, H., Björnsson, H., Roberts, M.J., Berthier, E., Geirsson, H., Pálsson, F., Gudmundsson, S., Bennett, R., and Sturkell, E. (2006) Unsteady Glacier Flow Revealed by Multi-Source Satellite Data, EOS Transactions American Geophysical Union. AGU Fall Meeting: SanFransisco, USA.

Malthe-Sorenssen, A., Walmann, T., Jamtveit, B., Feder, J., and Jossang, T. (1998) "Modeling and characterization of fracture patterns in the Vatnajökull glacier": Geology, v. **26**(10): p. 931-934.

The circular fracture pattern in the Vatnajökull glacier generated by a recent subglacial volcanic eruption was analyzed using methods based on fractal analysis. A crossover analysis based on estimates of the sampling bias showed that the fracture length was proportional to a power of the fracture area, providing a quantitative characterization of patterns of interacting fractures. A simple simulation model reproduces the most important visual and statistical characteristics of the observed fracture pattern. The model can be used to understand and separate the roles of material properties, deformation history, and geometry in geological fracture processes.

Mannerfelt, C. (2004) Hundalíf á Vatnajökli, *in* Björnsson, H., ed., Jöklaveröld, náttúra og mannlíf: Reykjavík, Skrudda, p. 289-318.

Marshall, S.J. (2005) "Recent advances in understanding ice sheet dynamics": Earth and Planetary Science Letters, v. **240**(2): p. 191-204.

Glaciers and ice sheets play a dynamic role in Earth's climate system, influencing regional- and global-scale climate and responding to climate change on time scales from years to millennia. They are also an integral part of Earth's landscape in alpine and polar regions, where they are an active agent in isostatic, tectonic, and Earth surface processes. This review paper summarizes recent progress in understanding and modelling ice sheet dynamics, from the microphysical processes of ice deformation in glaciers to continental-scale processes that influence ice dynamics. Based on recent insights and research directions, it can be expected that a new generation of ice sheet *models will soon replace the current standard. Improvements that can be foreseen in the near future include: (i) the addition of internally-consistent evolutionary equations for ice crystal fabric (anisotropic flow laws), (ii) more generalized flow laws that include different deformation mechanisms under different stress regimes, (iii) explicit incorporation of the effects of chemical impurities and grain size (dynamic recrystallization) on ice deformation, (iv) higher-order stress solutions to the momentum balance (Stokes' equation) that governs ice sheet flow, and (v) the continued merger of ice sheet models with increasingly complex Earth systems models, which include fully-coupled subglacial hydrological and geological processes. Examples from the Greenland Ice Sheet and Vatnajökull Ice Cap, Iceland are used to illustrate several of these new directions and their importance to glacier dynamics.*

Marshall, S.J., Bjornsson, H., Flowers, G.E., and Clarke, G.K.C. (2005) "Simulation of Vatnajokull ice cap dynamics": Journal of Geophysical Research-Earth Surface, v. **110**(F3).

We apply a coupled model of ice sheet dynamics and subglacial hydrology to investigate the dynamics and future evolution of the Vatnajokull ice cap, Iceland. In this paper we describe a new theoretical approach to introducing longitudinal stress coupling in the ice dynamics solution, and we analyze our ability to simulate the main features of Vatnajokull, with and without longitudinal stress effects. Equilibrium ice cap configurations exist for Vatnajokull but under a narrow range of climatic boundary conditions. Equilibrium reconstructions have an average ice thickness greater than what is observed at Vatnajokull, consistent with our inability to capture surge dynamics in Vatnajokull's outlet glaciers. Hydrological regulation of basal flow, longitudinal stress coupling, and a simple parameterization of the subglacial heat flux from Vatnajokull's geothermal cauldrons all help to reduce average ice thickness in the equilibrium reconstructions, but cases that reproduce the present-day ice volume have an ice cap area that is 5-10% less than the actual ice cap. Present-day reconstructions that adopt a realistic climate spin-up for the period 1600-1990 provide improved fits to the modern-day ice cap geometry. This indicates that climatic disequilibrium also plays a significant role in dictating Vatnajokull's morphology. Simulations for the period 1600-2300 illustrate that air temperature is the dominant control on Vatnajokull's volume and area. Longitudinal stress coupling and hydrological coupling both increase Vatnajokull's sensitivity to future warming.).

Molewski, P. (2005) REKONSTRUKCJA PROCESÓW GLACJALNYCH W WYBRANYCH STREFACH MARGINALNYCH LODOWCÓW ISLANDII - FORMY I OSADY. Reconstruction of glacial processes in the chosen marginal zones of the Icelandic glaciers - forms and deposits: Torun, Instytut Geografii UMK; Stowarzyszenie Geomorfologów Polskich, p. 148.

N.N. (1996) Mass balance of Arctic Glaciers, *in* Glaciology, W.G.o.A., ed., 1996 International Arctic Science Committee: IASC REPORT No. 5: Oslo, p. 25-29.

Nelson, A.E., Willis, I.C., and Cofaigh, C.Ó. (2005) "Till genesis and glacier motion inferred from sedimentological evidence associated with the surge-type glacier, Brúarjökull, Iceland": Annals of Glaciology, v. **42**(1): p. 14-22.

A study employing macro- and micro-sedimentological techniques was conducted at three sites with recently deglaciated sediments in the proglacial area of Brúarjökull, a surge-type outlet glacier of the Vatnajökull ice cap, Iceland. Tills at these sites were likely deposited and deformed during the 1963/64 surge. At the height of the last surge, these sediments were beneath 90-120 m of ice, and associated basal shear stresses would have been 24-32 kPa. Tills associated with the surge at these sites formed by a combination of subglacial sediment deformation and lodgement and are thus regarded as 'hybrid tills'. The tills show evidence of both ductile and brittle deformation Discontinuous clay lenses within the tills, indicating local ice-bed decoupling and sliding, imply that subglacial water pressures were spatially and temporally variable during the surge. The thickness of the subglacial deforming-till layer was 50-90 cm.

Obleitner, F. (2000) "The energy budget of snow and ice at Breiðamerkurjökull, Vatnajökull, Iceland": Boundary-Layer Meteorology, v. **97**(3): p. 385-410.

Measurements of the energy and mass budgets have been made at the equilibrium line of Breidamerkurjokull, a southern outlet glacier of Vatnajokull, Iceland. The glacier`s surface was melting for most of the measurement period, which allowed for a reliable closure of the energy budget. Sensitivity studies focussed mainly on potential effects of measurement errors, site-specific micrometeorological conditions, surface development and different parameterization of the turbulent fluxes. Although the high stability and a roughness disturbance imposed certain restrictions, these studies confirmed the applicability of the Monin-Obukhov framework for the evaluation of turbulent fluxes The characteristics of the energy and mass budgets are discussed with respect to various time scales and significant weather conditions. Due to the masking glacial boundary layer, warm fronts appeared comparatively weak compared to the more vigorous cold fronts. The latter were often associated with lee effects and give striking signals in the turbulent fluxes. Transition from snow to ice induced a distinct change in the regime because of related albedo and roughness effects. A compilation of the major energy budget components at glaciers all over the world confirms the maritime regime at Vatnajokull.

Obleitner, F., and De Wolde, J. (1999) "On intercomparison of instruments used within the Vatnajökull glacio-meteorological experiment": Boundary-Layer Meteorology, v. **92**(1): p. 27-37.

As an important deliverable of a glaciometeorological experiment the participating research institutes produced a common data set that consists of temperature, humidity, wind and radiation data collected by different types of weather station at an elevation of 2 m above the glacier surface. Although all of the instruments had been calibrated in laboratories, intercomparison measurements were carried out under field conditions before and after the Vatnajokull experiment. This note deals with the intercomparison measurements and considers the observed differences in sensor characteristics. In spite of the fact that different types and brands of sensors were used under difficult field circumstances, the estimated accuracy of the common data set obtained is almost as good as suggested by the manufacturers' specifications. The long-term stability of the sensor calibrations also proved to be good. The reliability of the observed values included in the common Vatnajokull dataset is therefore considered to be high.

Oerlemans, J., Björnsson, H., Kuhn, M., Obleitner, F., Pálsson, F., Smeets, C., Vugts, H.F., and De Wolde, J. (1999) "Glacio-meteorological investigations on Vatnajökull, Iceland, Summer 1996: An overview": Boundary-Layer Meteorology, v. **92**(1): p. 3-26.

We give an overview of a glacio-meteorological experiment carried out in the summer (melt season) of 1996 on the largest European ice cap, Vatnajokull, Iceland (area 8000 km(2); altitude range: from sea level to about 2000 m). The main goal was to understand how the energy used in the melting of snow and ice is delivered to the surface. Many meteorological stations were operated simultaneously on the ice cap, at almost all of which profile measurements were made. Cable balloons and radiosondes were used to probe the vertical structure of the boundary layer. It appears that the flow near the surface is katabatic most of the time, with the height of the wind maximum varying between a few metres and a few tens of metres. It is only during the passage of intense storms that the katabatic wind in the melt zone disappears. Global radiation increases significantly with altitude. Surface albedo varies enormously in space and time, with very low values (approximate to 0.1) being found at many places because of the melt out of volcanic ash layers. If we consider the total melt in the period 22 May-31 August 1996, we conclude that radiation typically provides two-thirds of the melt energy, and turbulent exchange of heat one-third. At locations high on the glacier, turbulent exchange becomes less significant.

Oerlemans, J., and Grisogono, B. (2002) "Glacier winds and parameterisation of the related surface heat fluxes": Tellus Series a-Dynamic Meteorology and Oceanography, v. **54**(5): p. 440-452.

The katabatic flow over glaciers is studied with data from automatic weather stations (AWS). We analyse data from the Morteratschgletscher (Switzerland), Vatnajokull (Iceland) and West Greenland, and conclude that katabatic flow is very common over melting glacier surfaces and rarely disrupted by the large-scale flow. Over small and medium-size glaciers the height of the wind maximum is generally low (typically 10 m), and vertical temperature differences near the surface are very large (up to 15 K over 4 m). In glacier mass-balance models there is a great need for parameterisations of the surface heat flux. We develop a simple method to estimate the sensible heat flux F-h, associated with the glacier wind. It is based on the classical Prandtl model for slope flows. We set the turbulent exchange coefficient proportional to the maximum wind speed (velocity scale) and the height of the wind maximum (length scale). The resulting theory shows that F-h, increases quadratically with the temperature difference between the surface and the ambient atmosphere; F-h, decreases with the square root of the potential temperature gradient of the ambient atmosphere; and F-h, is independent of the surface slope.

Parmhed, O., Oerlemans, J., and Grisogono, B. (2004) "Describing surface fluxes in katabatic flow on Breiðamerkurjökull, Iceland": Quarterly Journal of the Royal Meteorological Society, v. **130**(598): p. 1137-1151.

For very stable boundary layers there is no well-accepted theory today. In this study, an improved Prandtl model with varying diffusivity is applied to less than ideal conditions for pure katabatic flow pertaining to very stable boundary layers. We find that the improved Prandtl model adequately describes the usual and persistent katabatic glacier wind on Breiðamerkurjökull. This is true even for flows with very different heights and strengths of the jet. A theoretical estimate of the katabatic jet height, based on temperature deficit mid lapse rate, is verified. The calculated surface fluxes *compare well with the measured turbulence parameters. A possible reason for the robustness of the katabatic jet (and other low-level jets) is given in terms of the Scorer parameter.*

Pálsson, F., and Björnsson, H. (1998) Icemass: Mass balance and meteorological observations on Vatnajökull 1998, RH-24-98, Raunvísindastofnun Háskóla Íslands.

— (1999) Icemass: Mass balance and meteorological observations on Vatnajökull 1999. Field Report, RH-24-99 Raunvísindastofnun Háskóla Íslands.

— (2000) Icemass: Mass balance and meterological observations on Vatnajökull 2000 (field report) RH-24-2000: Reykjavík, Raunvísindastofnun Háskólans.

— (2000) Vatnsrennsli undan eystri hluta Fláajökuls, RH-14-00: Reykjavík, Raunvísindastofnun Háskólans.

Pálsson, F., Björnsson, H., Eydal, G.P., and Haraldsson, H.H. (2001) Vatnajökull: Mass balance, meltwater drainage and surface velocity of the glacial year 1999-2000, initial results. RH-01-2001, Orkustofnun (National Power Company), p. 30 p.

Pálsson, F., Björnsson, H., and Guðmundsson, S. (2003) SPICE, Mass balance surface velocity and meterological observations on Vatnajökull 2003, Annual Report to EU.

— (2004) SPICE, Mass balance surface velocity and meterological observations on Vatnajökull 2004, Annual Report to EU.

— (2005) Mass balance, surface velocity and meterological observations on Vatnajökull 2005, SPICE, Contract: EVK2-CT-2002-00152.

Pálsson, F., Björnsson, H., and Haraldsson, H. (2002) VATNAJÖKULL: Mass balance, meltwater drainage and surface velocity of the glacial year 2000-2001, RH-02-2002: Reykjavík, Raunvísindastofnun Háskólans.

Pálsson, F., Björnsson, H., and Magnússon, E. (1998) Könnun rennslisleiða vatns úr Skrámulóni, undir sporð Svínafellsjökuls, RH-08-98: Reykjavík, Raunvísindastofnun Háskólans.

Pálsson, F., Björnsson, H., Magnússon, E., and Haraldsson, H. (2004) VATNAJÖKULL: Mass balance, meltwater drainage and surface velocity of the glacial year 2001-2002, RH-21-2004: Reykjavík, Raunvísindastofnun Háskólans, p. 36.

— (2004) VATNAJÖKULL: Mass balance, meltwater drainage and surface velocity of the glacial year 2003-2004, RH-23-2004: Reykjavík, Raunvísindastofnun Háskólans, p. 37.

Pálsson, F., Björnsson, H., Magnússon, E., and Haraldsson, H.H. (2004) VATNAJÖKULL: Mass balance, meltwater drainage and surface velocity of glacial year 2002-2003, RH-22-2004, Raunvísindastofnun Háskólans, p. 36 pp.

Pálsson, F., Guðmundsson, S., and Björnsson, H. (2006) The impact of volcanic and geothermal activity on the mass balance of Vatnajökull, Third international symposium on ice-volcano interaction: Reykjavík, Iceland.

Pálsson, F., Magnússon, E., and Björnsson, H. (2002) The surge of Dyngjujökull 1997-2000. Mass transport, ice flow velocities, and effects on mass balance and runoff, RH-01-2002: Reykjavík, Raunvísindastofnun Háskólans, p. 23.

Pálsson, S. (1959) "Skýrsla um mælingar á Tungnárjökli": Jökull, v. **9**: p. 19-21.

Rasmussen, L.A. (2005) "Mass balance of Vatnajökull outlet glaciers reconstructed back to 1958": Jökull, v. **55**: p. 139-146.

Reijmer, C.H., Knap, W.H., and Oerlemans, J. (1999) "The surface albedo of the Vatnajokull ice cap, Iceland: A comparison between satellite-derived and ground-based measurements": Boundary-Layer Meteorology, v. **92**(1): p. 125-144.

The temporal and spatial variations in the surface albedo of the Vatnajökull ice cap, Iceland, are investigated. A time series of the surface albedo is composed for the summer of 1996 using satellite radiance measurements from the Advanced Very High Resolution Radiometer (AVHRR). This time series is compared with ground measurements carried out during a glacio-meteorological experiment during the same summer on the ice cap. The AVHRR is able to reproduce the development in time of the surface albedo fairly well. The large systematic differences found for some of the stations on the ice are attributed to sub-pixel-scale variations in the albedo. An attempt is made to confirm this hypothesis using satellite radiance measurements carried out by the Thematic Mapper (TM) and measurements made with a portable albedometer. The TM has a pixel size of 30 x 30 m whereas the pixel size of the AVHRR is 1 x 1 km. Although the TM measurements show greater variability in the albedo than do the AVHRR measurements, the large systematic difference remains. Measurements with the portable albedometer show a large spread in the albedo at sites with large systematic differences. This implies that the scale of the albedo variations is smaller than the scale of the AVHRR and TM pixels.

Rist, S. (1952) "Snjómæling á Vatnajökli": Jökull, v. **2**: p. 6-7.

— (1957) "Snjómæling á jöklum 1954 og 1955 (Snow survey on Icelandic glaciers 1954 and 1955)": Jökull, v. **7**: p. 33-36.

— (1965) "Tungnárjökull": Jökull, v. **15**: p. 135-138.

Roberts, M., Magnússon, E., Geirsson, H., and Sturkell, E. (2006) Meltwater dynamics beneath Skeiðarárjökull from continuous GPS measurements, Haustfundur Jarðfræðafélags Íslands 2006: Reykjavík, p. 23.

Roberts, M.J. (2002) Controls on Supraglacial Outlet Development during Glacial Outburst Floods [**Unpublished Ph.D. thesis**], Staffordshire University, U.K.

— (2005) "Jökulhlaups: A reassessment of floodwater flow through glaciers": Reviews of Geophysics, v. **43**(1).

[1] In glaciated catchments, glacier-generated floods (jökulhlaups) put human activity at risk with large, sporadic jökulhlaups accounting for most flood-related fatalities and damage to infrastructure. In studies of jökulhlaup hydrodynamics the view predominates that floodwater travels within a distinct conduit eroded into the underside of a glacier. However, some jökulhlaups produce subglacial responses wholly inconsistent with the conventional theory of drainage. By focusing on Icelandic jökulhlaups this article reassesses how floodwater flows through glaciers. It is argued that two physically separable classes of jökulhlaup exist and that not all jökulhlaups are an upward extrapolation of processes inherent in events of lesser magnitude and smaller scale. The hydraulic coupling of multiple, nonlinear components to the flood circuit of a glacier can induce extreme responses, including pressure impulses in subglacial drainage. Representing such complexity in mathematical form should be the basis for upcoming research, as future modeling results may help to determine the glaciological processes behind Heinrich events. Moreover, such an approach would lead to more accurate, predictive models of jökulhlaup timing and intensity.

Roberts, M.J., Russell, A.J., Tweed, F.S., and Knudsen, Ó. (2000) "Ice fracturing during jökulhlaups: implications for englacial floodwater routing and outlet development": Earth Surface Processes and Landforms, v. **25**: p. 1429-1446.

Theoretical studies of glacial outburst floods (jökulhlaups) assume that: (i) intraglacial floodwater is transported efficiently in isolated conduits; (ii) intraglacial conduit enlargement operates proportionally to increasing discharge; (iii) floodwater exits glaciers through pre-existing ice-marginal outlets; and (iv) the morphology and positioning of outlets remains fixed during flooding. Direct field observations, together with historical jökulhlaup accounts, confirm that these theoretical assumptions are not always correct. This paper presents new evidence for spatial and temporal changes in intraglacial floodwater routing during jökulhlaups; secondly, it identifies and explains the mechanisms controlling the position and morphology of supraglacial jökulhlaup outlets; and finally, it presents a conceptual model of the controls on supraglacial outbursts. Field observations are presented from two Icelandic glaciers, Skeiðarárjökull and Sólheimajökull. Video footage and aerial photographs, taken before, during and after the Skeiðarárjökull jökulhlaup and immediately after the

Sólheimajökull jökulhlaup, reveal changes in floodwater routing and the positioning and morphology of outlets. Field observations confirm that glaciers cannot transmit floodwater as efficiently as previously assumed. Rapid increases in jökulhlaup discharge generate basal hydraulic pressures in excess of ice overburden. Under these circumstances, floodwater can be forced through the surface of glaciers, leading to the development of a range of supraglacial outlets. The rate of increase in hydraulic pressure strongly influences the type of supraglacial outlet that can develop. Steady increases in basal hydraulic pressure can retro-feed pre-existing englacial drainage, whereas transient increases in pressure can generate hydraulic fracturing. The position and morphology of supraglacial outlets provide important controls on the spatial and temporal impact of flooding. The development of supraglacial jökulhlaup outlets provides a new mechanism for rapid englacial debris entrainment.

— (2000) "Rapid sediment entrainment and englacial deposition during jökulhlaups": Journal of Glaciology v. **46**: p. 349-351.

Englacial water flow is a commonly invoked hypothesis to account for the presence of water-worked sediment at high elevations within glaciers (e.g. Kirkbride and Spedding, 1996; Naslund and Hassinen, 1996; Glasser and others, 1999). However, subscribers to this hypothesis lack evidence for sediment entrainment by englacial water flow. Here we present direct field evidence for supraglacial outbursts and rapid englacial fluvial sediment deposition during two recent Icelandic jökulhlaups. Both of these jökulhlaups generated basal water pressures in excess of ice overburden, which fractured overlying ice, allowing sediment to be fluvially emplaced at high elevations within each glacier. Although these jökulhlaups were hydrologically extreme, similar short-term rates of increase in basal hydraulic pressure may be generated during lower-magnitude hydrological events. The recent Icelandic jökulhlaups therefore provide us with a direct insight into rapid sediment entrainment and englacial deposition, a process that could be applied to other high-water-pressure events.

— (2001) "Controls on englacial sediment deposition during the november 1996 jökulhlaup, Skeiðarárjökull, Iceland": Earth Surface Processes and Landforms, v. **26**: p. 935-952.

This paper presents sedimentary evidence for rapid englacial debris entrainment during jökulhlaups. Previous studies of jökulhlaup sedimentology have focused predominantly on proglacial impact, rather than depositional processes within glaciers. However, observations of supraglacial floodwater outbursts suggest that englacial sediment emplacement is possible during jökulhlaups. The November 1996 jökulhlaup from Skeidarárjökull, Iceland presented one of the first opportunities to examine englacial flood deposits in relation to former supraglacial outlets. Using observations from Skeidarárjökull, this paper identifies and explains controls on the deposition of englacial flood sediments and presents a qualitative model for englacial jökulhlaup deposition. Englacial jökulhlaup deposits were contained within complex networks of upglacier-dipping fractures. Simultaneous englacial deposition of fines and boulder-sized sediment demonstrates that englacial fracture discharge had a high transport capacity. Fracture geometry was an important control on the architecture of englacial jökulhlaup deposits. The occurrence of pervasively frozen flood deposits within Skeidarárjökull is attributed to freeze-on by glaciohydraulic supercooling. Floodwater, flowing subglacially or through upglacier-dipping fractures, would have supercooled as it was raised to the surface faster than its pressure-melting point could increase as glaciostatic pressure decreased. Evidence for floodwater contact with the glacier bed is supported by the ubiquitous occurrence of sheared diamict rip-ups and intra-clasts *of basal ice within jökulhlaup fractures, deposited englacially some 200–350 m above the bed of Skeidarárjökull. Evidence for fluidal supercooled sediment accretion is apparent within stratified sands, deposited englacially at exceptionally high angles of rest in the absence of post-depositional disturbance. Such primary sediment structures cannot be explained unless sediment is progressively accreted to opposing fracture walls. Ice retreat from areas of former supraglacial outbursts revealed distinct ridges characterized by localized upwellings of sediment-rich floodwater. These deposits are an important addition to current models of englacial sedimentation and demonstrate the potential for post-jökulhlaup landform development.*

— (2002) Controls on the Development of Supraglacial Floodwater Outlets during Jökulhlaups *in* Snorrason, A., Finsdottir, H.P., and Moss, M., eds., The Extremes of the Extremes. Proceedings of a symposium held July 2000 at Reykjavik, Iceland: International Association of Hydrological Sciences Red Book Publication 271, p. 71-76.

Recent field observations have revealed that jökulhlaups with a near-instantaneous rise to peak discharge can generate temporary hydraulic pressures capable of forcing floodwater through the surface of glaciers. This paper identifies and explains the controls on the development of supraglacial jökulhlaup outlets. Field evidence is presented from two recent Icelandic jökulhlaups, which produced multiple supraglacial outbursts. Subglacial hydraulic pressure increase is identified as the principal control on supraglacial outlet development during jokulhlaups. A near-instantaneous rise to peak subglacial water pressure can produce supraglacial outbursts by hydrofracturing. Pressure increases below the hydrofracturing threshold, but above ice overburden pressure, can back-feed pre-existing drainage, resulting in outbursts from moulins and crevasses. Hydrofracture outbursts can route water to areas of the glacier not normally inundated by floods, and can control the spatial distribution of ice block release.

Roberts, M.J., Tweed, F.S., Russell, A.J., Knudsen, Ó., Lawson, D.E., Larson, G.J., Evenson, E.B., and Björnsson, H. (2002) "Glaciohydraulic supercooling in Iceland": Geology, v. **30**(no. 5): p. 439-442; 6 figures.

We present evidence of glaciohydraulic supercooling under jökulhlaup and ablation dominated conditions from two temperate Icelandic glaciers. Observations show that freezing of sediment-laden meltwater leads to intraglacial debris entrainment during normal and extreme hydrologic regimes. Intraglacial frazil ice propagation under normal ablation-dominated conditions can trap copious volumes of sediment, which forms anomalously thick sections of debris-rich ice. Glaciohydraulic supercooling plays an importantrole in intraglacial debris entrainment and should be given more attention in models of basal ice development. Extreme jökulhlaup conditions can result in significant intraglacial sediment accretion by supercooling, which may explain the concentration of englacial sediments deposited in Heinrich layers in the North Atlantic during the last glaciation.

Rolstad, C., and Oerlemans, J. (2005) "The residual method for determination of the turbulent exchange coefficient applied to automatic weather station data from Iceland, Switzerland and West Greenland": Annals of Glaciology, v. **42**: p. 367-372.

The surface energy balance of glaciers is studied to determine their sensitivity to climate variations. It is known that the turbulent heat fluxes are sensitive to increases in temperature. Automatic weather station data from ablation regions are used to *measure melt rates, radiative fluxes and the meteorological data required to determine turbulent heat fluxes using bulk formulas. The turbulent exchange coefficient must be determined for closure of the energy budget. The available methods are the eddy correlation method, the profile method and the residual method, which is applied and tested here. in the residual method the coefficient is determined by fitting a calculated melt curve to an observed melt curve. The coefficients are estimated for three sites: for Vatnajokull, Iceland, C-h = (1.3 +/- 0.55) X 10(-3) (1998) and C-h = (2.5 +/- 1.1) X 10(-3) (1999); for Morteratschgletscher, Switzerland, C-h = (2.1 +/- 0.55) X 10(-3) (1998); and for West Greenland, C-h = (2.0 +/- 0.52) X 10(-3) (1998-2000). It is found that the coefficient can be determined to within 26% uncertainty under the following conditions: all terms in the energy balance are measured, there is no differential melt on the glacier surface, the melt curves are fitted when the entire snow layer has melted, and the measurement period is several weeks.*

Scharrer, K., Mayer, C., Nagler, T., Rott, H., Münzer, U., and Gudmundsson, Á. (2007 (in press)) "Effects of ash-layers of the 2004 Grímsvötn eruption on SAR backscatter in the accumulation area of Vatnajökull": Annals of Glaciology, v. **45**.

Sigmundsson, F. (1991) "Postglacial Rebound and Asthenosphere Viscosity in Iceland": Geophysical Research Letters, v. **18**(6): p. 1131-1134.

During the Weichselian glaciation Iceland was covered with an ice cap which caused downward flexure of the Earth's surface. The post-glacial rebound in Iceland was very rapid, being completed in about 1000 years. The length of this time interval constrains the maximum value of asthenosphere viscosity in Iceland to be 1x10(19) Pa s or less. Further clarification of the ice retreat and uplift history may reveal lower viscosity. Current changes in the mass balance of Icelandic glaciers must lead to measureable elevation changes considering this low viscosity. Expected current elevation changes around the Vatnajökull ice cap are of the order of 1 cm per year, due to mass balance change in this century.

Sigurgeirsson (1952) "Kristalgerð íssins": Jökull, v. **2**: p. 26-28.

Soderberg, S., and Parmhed, O. (2006) "Numerical modelling of katabatic flow over a melting outflow glacier": Boundary-Layer Meteorology, v. **120**(3): p. 509-534.

A realistic simulation of katabatic flows is not a straightforward task for numerical models. One complicating factor is that katabatic flows develop within a stably stratified boundary layer, which is poorly resolved and described in many numerical models. To capture the jet-shaped shallow flow a model set-up with high vertical resolution is also required. In this study, 'a state of the art' mesoscale numerical model is applied in a simulation of katabatic flow over a melting glacier. A basic agreement between observations and model results is found. From scale analysis, it is concluded that the simulated flow can be classified as katabatic. Although the background flow varies in strength and direction, the simulated katabatic flow over Breiðamerkurjökull is persistent. Two factors vital for this persistence are identified. First, the melting snow maintains the surface temperature close to 0 degrees C while the air temperature warms adiabatically as it descends the slope. This provides a 'self enhanced' negative buoyancy that drives the flow to a balance with local friction. Second, the jet-like shape of the resulting flow gives rise to a large 'curvature term' in the Scorer parameter, *which becomes negative in the upper jet. This prevents vertical wave propagation and isolates the katabatic layer of the influence from the free troposphere aloft. Our results suggest that the formation of local microclimates dominated by katabatic flow is a general feature over melting glaciers. The modelled turbulence structure illustrates the importance of non-local processes. Neglecting the vertical transport of turbulence in katabatic flows is not a valid assumption. It is also found that the local friction velocity remains larger than zero through the katabatic jet, due to directional shear where the scalar wind speed approaches its maximum.*

Stefánsson, R. (1997) Freysnes í Öræfum : saga og náttúrulýsing: Skaftafell, Hótel Skaftafell, 30, [1] s. : myndir, kort p.

Swift, D.A., Evans, D.J.A., and Fallick, A.E. (2006) "Transverse englacial debris-rich ice bands at Kvíárjökull, southeast Iceland." Quaternary Sciences Reviews v. **25**(13-14): p. 1708-1718

Thick exposures of debris-rich ice at various Icelandic glaciers are central to the debate over the prevalence of glacial sediment transfer by glaciohydraulic supercooling. We present physical analyses of ice and debris at Kvíárjokull, a temperate glacier in southeast Iceland with a terminal glacier-bed overdeepening, where stratified debris-rich ice forms up to metre-thick transverse englacial bands. Our results are not consistent with debris-rich ice formation predominantly by supercooling because: (1) 137Cs was absent from sediment filtered from debris-rich ice; (2) isotopic analysis (δD and δ18O) demonstrated no clear pattern of isotopic enrichment of debris-rich ice with respect to englacial ice; and (3) melt-out debris from debris-rich ice included large striated clasts from both fluvial and basal sources. We support transverse englacial debris-rich ice band formation by the thickening and elevation of basal materials in a region of longitudinally compressive ice flow situated between the reverse slope of the overdeepening and the base of an ice fall. Debris band form and distribution are likely to be controlled by thrusting along transverse englacial foliae associated with the formation of band ogives on the glacier surface.prevalence of glacial sediment transfer by glaciohydraulic supercooling. We present physical analyses of ice and debris at Kvíárjokull, a temperate glacier in southeast Iceland with a terminal glacier-bed overdeepening, where stratified debris-rich ice forms up to metre-thick transverse englacial bands. Our results are not consistent with debris-rich ice formation predominantly by supercooling because: (1) 137Cs was absent from sediment filtered from debris-rich ice; (2) isotopic analysis (δD and δ18O) demonstrated no clear pattern of isotopic enrichment of debris-rich ice with respect to englacial ice; and (3) melt-out debris from debris-rich ice included large striated clasts from both fluvial and basal sources. We support transverse englacial debris-rich ice band formation by the thickening and elevation of basal materials in a region of longitudinally compressive ice flow situated between the reverse slope of the overdeepening and the base of an ice fall. Debris band form and distribution are likely to be controlled by thrusting along transverse englacial foliae associated with the formation of band ogives on the glacier surface.

Swithinbank, C.W.M. (1950) "The origin of dirt cones on glaciers": Journal of Glaciology, v. **1**(8): p. 461-465, diags.

Describes characteristics and probable development of dirt cones on Vatnajökull, Iceland

— (1950) "Oxford University Iceland Expedition of 1947. Meteorology": Meteorological Magazine, v. **79**(938): p. 222-224.

Summary of observations on and near Vatnajöukull

Tweed, F.S., Roberts, M.J., and Russell, A.J. (2005) "Hydrologic monitoring of supercooled discharge from Icelandic glaciers: hydrodynamic and sedimentary significance": Quaternary Science Reviews, v. **24**(22): p. 2308-2318.

Knowledge of how glaciers entrain sediment is central to understanding processes of glacier movement and products of glacial sediment deposition. Previous work has shown that if the total hydraulic potential of subglacial meltwater increases more rapidly than the resulting mechanical energy can be transformed into sensible heat, then supercooling and ice growth will result. This process causes frazil ice to grow onto adjacent glacier ice, which acts to trap sediment in flowing meltwater eventually producing sedimentary inclusions within glacier ice. Supercooling has been recognised as a sediment entrainment mechanism at glaciers in Alaska, and more recently at several temperate Icelandic glaciers. Here we present short-period temperature measurements and field evidence of glaciohydraulic supercooling from three Icelandic glaciers. Temperature measurements demonstrate that supercooling occurs over a range of hydrological conditions and that the process does not operate continuously at all instrumented sites. Measurements of supercooling during a small jökulhlaup are also presented. Progressive accretion of supercooled meltwater creates sediment-laden ice exposures adjacent to active artesian vents. Understanding controls on the efficacy and pervasiveness of hydraulic supercooling is important for decoding the sedimentary record of modern and ancient glaciers and ice sheets.

Van der Avoird, E., and Duynkerke, P.G. (1999) "Turbulence in a katabatic flow - Does it resemble turbulence in stable boundary layers over flat surfaces?" Boundary-Layer Meteorology, v. **92**(1): p. 39-66.

Turbulence measurements performed in a stable boundary layer over the sloping ice surface of the Vatnajökull in Iceland are described. The boundary layer, in which katabatic forces are stronger than the large-scale forces, has a structure that closely resembles that of a stable boundary layer overlying a flat land surface, although there are some important differences. In order to compare the two situations the set-up of the instruments on an ice cap in Iceland was reproduced on a flat grass surface at Cabauw, the Netherlands. Wind speed and temperature gradients were calculated and combined with flux measurements made with a sonic anemometer in order to obtain the local stability functions phi(m) and phi(h) as a function of the local stability parameter z/L. Unlike the situation at Cabauw, where phi(m) was linear as a function of z/L, in the katabatically forced boundary layer, the dependence of phi(m) on stability was found to be non-linear and related to the height of the wind maximum. Thermal stratification and the depth of the stable boundary layer however seem to be rather similar under these two different forcing conditions. Furthermore, measurements on the ice were used to construct the energy balance. These showed good agreement between observed melt and components contributing to the energy balance: net radiation (supplying 55% of the energy), sensible heat flux (30%) and latent heat flux (15%). Local sources and sinks in the turbulent kinetic energy budget are summed and indicate a reasonable balance in near-neutral conditions but not in more stable situations. The standard deviation of the velocity fluctuations sigma(u), sigma(v), and *sigma(w), can be scaled satisfactorily with the local friction velocity u(*) and the standard deviation of the temperature fluctuation sigma(theta) with the local temperature scale theta(*).*

van der Veen, C.J. (2002) "Calving glaciers": Progress in Physical Geography v. **26**(No. 1): p. 96-122.

Based on a review of observations on different types of calving glaciers, a simple calving model is proposed. Glaciers that exist in a sufficiently cold climate can form floating ice shelves and ice tongues that typically do not extend beyond confinements such as lateral fjord walls or mountains, and ice rises. If the local climate exceeds the thermal limit of ice shelf viability, as is the case for temperate glaciers, no floating tongue can be maintained and the position of the terminus is determined by the thickness in excess of flotation. If the snout is sufficiently thick, a stable terminus position at the mouth of the confining fjord - usually marked by a terminal shoal - can be maintained. Further advance is not possible because of increasing sea-floor depth and diverging flow resulting from lack of lateral constraints. If a mass balance deficiency causes the terminal region to thin, retreat is initiated with the calving front retreating to where the thickness is slightly in excess of flotation. In that case, the calving rate is determined by glacier speed and thickness change at the glacier snout. Advance or retreat of the calving front is not driven by changes in the calving rate, but by flow-induced changes in the geometry of the terminal region. This model is essentially different from prior suggestions in which some empirical relation - most commonly the water-depth model - is used to calculate calving rate and the rate of retreat or advance of the terminus.

Wadell, H. (1920) "Vatnajökull. Some studies and observations from the greatest glacial area in Iceland": Geografiske Annaler, v. **4**: p. 300-323.

Wildt, M., Oerlemans, J., and Björnsson, H. (2003) "A calibrated mass balance model for Vatnajökull, Iceland": Jökull, v. **52**: p. 1-20.

Wildt, M.S., Klok, E.J., and Oerlemans, J. (2003) "Reconstruction of the mean specific mass balance of Vatnajökull (Iceland) with a Seasonal Sensitivity Characteristic": Geografiska Annaler, v. **85A**(1): p. 57-72.

Abstract We present a Seasonal Sensitivity Characteristic (SSC) of Vatnajökull (Iceland), which consists of the sensitivity of the mean specific mass balance to monthly perturbations in temperature and precipitation. The climate in Iceland is predominantly maritime (high precipitation) although often the polar air mass influences the area. This results in temperature sensitivities that are high in summer and nearly zero during the winter months. In contrast, precipitation sensitivities are high in winter and low in summer. We use the SSC of Vatnajökull as a reduced mass balance model, with which we reconstruct the mass balance of Vatnajökull since 1825. The reduced model shows that changes in temperature and precipitation like the ones observed both have a significant impact upon the mass balance. The reconstructed mass balance records for two Icelandic glaciers correlate very well with mass balance records that are extracted from length records with a linear inverse model. This places confidence in both the reduced (forward) mass balance model and in the inverse model, although the forward method produces larger mass balance variations than the inverse method. For the south of Vatnajokull we find that after 1900, the length record is well explained *by temperature variations alone, while another Icelandic glacier (Sólheimajokull) was also influenced by precipitation variations.*

Williams, R.S., Jr. (1976) Vatnajökull icecap, Iceland, *in* Williams, R.S., Jr., and Carter, W.D., eds., ERTS-1: A new window on our planet: U.S. Geological Survey Professional Paper 929, p. 188-193.

Williams, R.S. (1983) "Satellite glaciology in Iceland (Jöklar Íslands kannaðir úr gervituglum)": Jökull, v. **33**: p. 3-12.

Williams, R.S., Hall, D.K., and Benson, C.S. (1991) "Analysis of Glacier Facies Using Satellite Techniques": Journal of Glaciology, v. **37**(125): p. 120-128.

The different snow and ice types on a glacier may be subdivided according to the glacier-facies concept. The surficial expression of some facies may be detected at the end of the balance year by the use of visible and near-infrared image data from the Landsat multispectral scanner (MSS) and thematic mapper (TM) sensors. Ice and snow can be distinguished by reflectivity differences in individual or ratioed TM bands on Bruarjokull, an outlet glacier on the northern margin of the Vatnajökull ice cap, Iceland. The Landsat scene shows the upper limit of wet snow on 24 August 1986. Landsat-derived reflectance is lowest for exposed ice and increases markedly at the transient snow line. Above the slush zone is a gradual increase in near-infrared reflectance as a result of decreasing grain-size of the snow, which characterizes drier snow. Landsat data are useful in measuring the areal extent of the ice facies, the slush zone within the wet-snow facies (combined wetsnow, percolation and dry-snow facies), and the respective positions of the transient snow line and the slush limit. In addition, fresh snowfall and/or airborne contaminants, such as soot and tephra, can limit the utility of Landsat data for delineation of the glacier facies in some cases.

Williams, R.S., and Þórarinsson, S. (1973) "ERTS-1 image of the Vatnajökull area: General comments": Jökull, v. **23**: p. 1-6.

Williams, R.S.J. (1987) Satellite remote sensing of Vatnajökull, Iceland, Proceedings of the Second Symposium on Remote Sensing in Glaciology held at the University of Cambridge, United Kingdom, 8-9 and 11-12 September 1986: Annals og Glaciology, Vol. 9: Cambridge, International Glaciological Society, p. 127-135.

Assesses various types of image data acquired by Landsat multispectral scanner (MSS) and Seasat synthetic aperture radar (SAR) for their value in glaciological studies of this ice cap. More information about surface morphology was available from former than from latter

Þórarinsson, S. (1939) "Vatnajökull; Scientific results of the Swedish-Icelandi investigations 1936-37-38. Chapter 8.Hoffellsjökull, its movement and drainage": Geografiska Annaler, v. **21**(3-4): p. 189- 215.

— (1952) "Svigður á Morsárjökli (Chevrons on Morsárjökull)": Jökull, v. **2**: p. 22-24.

— (1953) "Svigður á Svínafellsjökli í Öræfum": Jökull v. **3**: p. 39-40.

— (1960) "Glaciological knowledge in Iceland before 1800. A historical outline (Þekking Íslendinga á jöklum fram til 1800)": Jökull, v. **10**: p. 1-18.

— (1965) "Skárar á jökli": Jökull, v. **15**: p. 147.

Þórarinsson, S., and Sigurðsson, S. (1947) "Volcano-glaciological investigations in Iceland during the last decade": Polar Record, v. **33-34**: p. 60-64.

Þórarinsson, S., Sæmundsson, K., and Williams, J.R.S. (1973) "ERTS-1 image of Vatnajökull: Analysis of glaciological, structural and volcanic features. (Ágrip) ": Jökull, v. **23**: p. 7-17.

Þórðarson, T. (1943) "Vatnadagurinn mikli": Tímarit Máls og menningar v. **4**(2.h.): p. s. 69-84.

— (1972) Vatnadagurinn mikli, Frásagnir / Þórbergur Þórðarson: Reykjavík, Mál og menning.

5.6 Vatnafræði (hydrology)

Ahlstrom, A.P., Mohr, J.J., Reeh, N., Christensen, E.L., and Hooke, R.L. (2005) "Controls on the basal water pressure in subglacial channels near the margin of the Greenland ice sheet": Journal of Glaciology, v. **51**(174): p. 443-450.

Assuming a channelized drainage system in steady state, we investigate the influence of enhanced surface melting on the water pressure in subglacial channels, compared to that of changes in conduit geometry, ice rheology and catchment variations. The analysis is carried out for a specific part of the western Greenland ice-sheet margin between 66 degrees N and 66 degrees 30' N using new high-resolution digital elevation models of the subglacial topography and the ice-sheet surface, based on an airborne ice-penetrating radar survey in 2003 and satellite repeat-track interferometric synthetic aperture radar analysis of European Remote-sensing Satellite 1 and 2 (ERS-1/-2) imagery, respectively. The water pressure is calculated up-glacier along a likely subglacial channel at distances of 1, 5 and 9 km from the outlet at the ice margin, using a modified version of Rothlisberger's equation. Our results show that for the margin of the western Greenland ice sheet, the water pressure in subglacial channels is not sensitive to realistic variations in catchment size and mean surface water input compared to small changes in conduit geometry and ice rheology.

Ágústsdóttir, A.M. (1990) Efnafræði jökulárvatns í Öræfum [**4. árs ritgerð**]: Reykjavík, Háskóli Íslands.

Árnason, B. (1968) "Tvívetni í grunnvatni og jöklum á Íslandi (Deuterium in ground water and glaciers in Iceland)": Jökull, v. **18**: p. 337-349.

— (1976) "Groundwater systems in Iceland traced by deuterium": Societas Scientiarum Islandica, v. **Rit 42**: p. 236 p.

Árnason, S. (1998) Mæling á rennsli og hitastigi í Jökulsá á Breiðamerkursandi, *in* Orkustofnun, ed., Vatnamælingar, greinargerð 1998-12-10, Orkustofnun.

Berthier, E., Björnsson, H., Pálsson, F., Feigl, K.L., Llubes, M., and Remy, F. (2006) "The level of the Grimsvötn subglacial lake, Vatnajökull, Iceland, monitored with SPOT5 images": Earth and Planetary Science Letters, v. **243**(1-2): p. 293-302.

We describe the vertical displacement field of an ice shelf floating on a subglacial lake, Grimsvötn, located underneath the Vatnajokull ice cap (Iceland). The uplift is measured using the correlation of two satellite optical SPOT5 images acquired 5 days apart with similar, non-vertical incidence angles. This is the first time correlation of optical images has been used to measure vertical displacements. Our technique is suitable for mapping short-term elevation changes of glaciers. If the surface features are preserved, vertical displacements can be measured every 25 m with an accuracy of about 0.5 m.The uplift map of Grimsvotn shows that 10.9 (+/- 1) km2 of ice was floating between 11 and 16 August 2004. The ice shelf rose by 1.7 (+/- 0.6) m indicating that the volume of liquid water in the lake increased by 0.018 (+/- 0.007) km3. Our field observations show that surface melting due to meteorological processes contributed 70% of the accumulated water, hence, the rest originated from ice melted by the subglacial geothermal activity. The power required to melt 0.005 km3 (water equivalent) of basal ice in 5 days is 4000 MW. The applicability of the technique can be extended to volcanology and seismology, and even landslides or subsidence, when finer-resolution optical images become available. Applied to two pairs of images, it could solve for the 3-dimensional displacements of the Earth's surface.

Björnsson, H. (1970) "Hugleiðingar um jöklarannsóknir á Íslandi": Jökull, v. **20**: p. 15-26.

This paper gives a short outline of some aspects of glaciology with the main emphasis on topics related to meteorology and hydrology. A descriptive summary of the basic theory and modern measurement techniques is given along with suggestions for new research projects in Iceland. Following topics are discussed: The main links in the relation between glacier variations and climate, the mass balance, the energy budget, glacier response, kinematic waves, diffusion of kinematic waves, response time and lag time of a glacier. The value of measurements of glacier variations in Iceland is discussed in light of these topics. Furher, a description is given of glacier flow and glacier surges. Crystallographic problems are briefly mentioned. The paper concludes with a proposal for investigations on Tungnaárjökull.

— (1982) "Drainage Basins on Vatnajökull Mapped by Radio Echo Soundings": Nordic Hydrology, v. **13**(4): p. 213-232.

Describes technique and presents results from two areas on ice cap which were surveyed as part of hydrological study. Soundings provide detailed maps of ice surface and sub-ice bedrock, and information on ice thickness

— (1988) "Hydrology of ice caps in volcanic regions": Societas Scientiarum Islandica, v. **Rit 45**: p. 139 p., 21 maps.

— (1998) "Hydrological characteristics of the drainage system beneath a surging glacier": Nature, v. **395**: p. 771-774.

A unique combination of natural circumstances allows us to assess current theories about water flow beneath glaciers. Outburst floods from the subglacial lake, Grímsvötn, have taken place before, during and subsequent to surging of Skeiðarárjökull, the glacier beneath which they drain. The observable drainage patterns associated with these floods show the different nature of the basal water conduit system of the glacier during surge and non-surge phases. During surge, basal water is dispersed slowly across the bed in a distributed drainage system; but when the glacier is not surging, water is transported rapidly through a system of tunnels.

Björnsson, H., Jónsson, T., and Jóhannesson, T. (2005) "Comment on "Iceland as a heat island" by D.H. Douglass et al": Geophysical Research Letters, v. **32**(24).

Surges are common in all the major ice caps in Iceland, and historical reports of surge occurrence go back several centuries. Data collection and regular observation over the last several decades have permitted a detailed description of several surges, from which it is possible to generalize on the nature of surging in Icelandic glaciers. Combining the historical records of glacier-front variations and recent field research, we summarize the geographic distribution of surging glaciers, their subglacial. topography and geology, the frequency and duration of surges, changes in glacier surface geometry during the surge cycle, and measured velocity changes compared to calculated balance velocities. We note the indicators of surge onset and describe changes in ice, water and sediment fluxes during a surge. Surges accomplish a significant fraction of the total mass transport through the main outlet glaciers of ice caps in Iceland and have important implications for their hydrology. Our analysis of the data suggests that surge-type glaciers in Iceland are characterized by gently sloping surfaces and that they move too slowly to remain in balance given their accumulation rate. Surge frequency is neither regular nor clearly related to glacier size or mass balance. Steeply sloping glaciers, whether hard- or soft-bedded, seem to move sufficiently rapidly to keep in balance with the annual accumulation.

Björnsson, H., Pálsson, F., and Guðmundsson, M.T. (1996) Afkoma, hreyfing og afrennsli á vestan- og norðanverðum Vatnajökli jökulárið 1994-1995, RH-23-95: Reykjavík, Raunvísindastofnun Háskólans, p. 34.

Björnsson, H., Pálsson, F., Guðmundsson, M.T., and Haraldsson, H. (1997) Afkoma, hreyfing og afrennsli á vestan- og norðanverðum Vatnajökli jökulárið 1995-1996, RH-24-97: Reykjavík, Raunvísindastofnun Háskólans, p. 57.

Björnsson, H., Pálsson, F., and Magnússon, E. (1999) Skeiðarárjökull: landslag og rennslisleiðir vatns undir sporði, RH-11-99: Reykjavík, Raunvísindastofnun Háskólans, p. 20.

Björnsson, S. (1987) "Helgi Arason. Rafvæðing og fleira": Skaftfellingur, v. **5. árg.**: p. 95-103.

Boulton, G., and Zatsepin, S. (2006) "Hydraulic impacts of glacier advance over a sediment bed": Journal of Glaciology, v. **52**(179): p. 497 - 527.

A sedimentary sequence of till overlying a gravel aquifer was instrumented with waterpressure transducers prior to a small, anticipated surge of the margin of the glacier Breiðamerkurjökull in Iceland. The records of water pressure at each transducer site show a well-defined temporal sequence of hydraulic regimes that reflect the changing recharge of surface-derived meltwater, the pressure drop along the drainage pathway and the pattern of ice loading. The poroelastic and water-pressure response of glacially overridden sediments to the recharge rate is determined in the frequency domain through an analytic solution. This permits the in situ conductivity, compressibility and consolidation states of subglacial sediments to be derived, and reveals aquifer-scale compressibility that produces an important water-pressure wave associated with the advancing glacier. The model is then used to explore how varying conductivity/compressibility, largely determined by granulometry, can determine drainage states and instabilities that may have a large impact on glacier/ice-sheet dynamics, and how the drainage time of surface water to the bed can determine the frequency response of subglacial groundwater regimes and their influence on subglacial sediment stability. Mismatches between model predictions and specific events in water-pressure records are used to infer processes that are not incorporated in the model: hydrofracturing that changes the hydraulic properties of subglacial sediments; the impact on groundwater pressure of subglacial channel formation; upwelling beyond the glacier margin; and rapid variations in the state of consolidation. The poroelastic model also suggests how seismic methods can be developed further to monitor hydraulic conditions at the base of an ice sheet or glacier.

Boulton, G.S., Dobbie, K.E., and Zatsepin, S. (2001) "Sediment deformation beneath glaciers and its coupling to the subglacial hydraulic system": Quaternary International, v. **86**(1): p. 3-28.

The extent and style of shear deformation in sediments beneath modern glaciers and the geological evidence for such deformation in deposited sediments are reviewed. New evidence is presented from beneath a modern glacier of the spatial and temporal patterns of water pressure fluctuation and of time dependent patterns of deformation in sediments. It is concluded that in most experimental sites beneath soft-bedded modern glaciers, deformation is a significant or major contributor to glacier movement and the resultant discharge of till is large enough to make sediment deformation a major till forming process.Particular modes of deformation facilitate incorporation of underlying material into the till, whilst the capacity of a deforming till to absorb strain can protect the underlying strata from deformation, leading to the commonly found relationship where till overlies other strata with a sharp planar interface. It is argued that the almost ubiquitous occurrence of drumlins on the beds of former ice sheets is a *reflection of the widespread occurrence of sediment deformation beneath them, with important implications for the coupling of ice sheet flow and bed properties.It is argued that the mechanical behaviour of the subglacial system is not simply determined by till properties but largely controlled by the subglacial water pressure regime determined by the nature of subglacial drainage. Results of field experiments show how the nature of the basal hydraulic system can play a vital role in controlling the coupling between the glacier and till deformation processes. They show that rapid glacier advances can produce undrained loading of sediments, that effective pressure may increase either upwards or downwards in a till according to the direction of drainage and that interstitial water pressures in subglacial sediments can show large and rapid variations, producing strong variations in the rate and distribution of strain and in the partitioning of basal movement between sliding and deformation.*

Carrivick, J.L. (2006) "Application of 2D hydrodynamic modelling to high-magnitude outburst floods: An example from Kverkfjöll, Iceland": Journal of Hydrology, v. **321**(1-4): p. 187-199.

High-magnitude outburst floods cause rapid landscape change and are a hazard to life, property and infrastructure. However, high-magnitude fluvial processes and mechanisms of erosion, transport and deposition are very poorly understood, and remain largely unquantified. This poor understanding is partly because of the inherent difficulty of directly measuring high-magnitude outburst floods, but also because of the limitations and assumptions of 1D models and other palaeohydrological methods, which reconstructions of high-magnitude floods have to date relied upon. This study therefore applies a 2D hydrodynamic model; SOBEK, to reconstructing a high-magnitude outburst flood. This method offers the first calculations of high-magnitude fluvial flow characteristics within an anastomosing network of simultaneously inundated channels, including; sheet or unconfined flow, simultaneous channel and sheet flow, flow around islands, hydraulic jumps, multi-directional flow including backwater areas, hydraulic ponding and multiple points of flood initiation. 2D-modelling of outburst floods clearly has the potential to revolutionise understanding of high-magnitude spatial and temporal hydraulics and high-magnitude flow phenomena, geomorphological and sedimentological processes, and hence rapid fluvial landscape change. This potential for new understanding is because of the now wide availability of high-resolution DEM data for large and often inaccessible areas, and the availability of remotely-sensed data that can parameterise outburst flood sources, such as glacial lakes, for example. Additionally, hydraulic models and computing power are now sufficient to cope with large (5,000,000 grid cells) areas of inundation and large (100,000 m3 s-1) peak discharges.

Carrivick, J.L., Russell, A.J., Tweed, F.S., and Twigg, D. (2004) "Palaeohydrology and sedimentary impacts of jokulhlaups from Kverkfjoll, Iceland": Sedimentary Geology, v. **172**(1-2): p. 19-40.

Jökulhlaups (glacial outburst floods) occur frequently within Iceland and within most glaciated regions of the world. The largest jökulhlaups known to have occurred within Iceland drained from the northern margin of the Vatnajökull and along the Jökulsá a Fjöllum during the Holocene. However, little is known about the number, age and flow characteristics of the Jökulsá a Fjöllum jokulhlaups. One source of meltwater into the Jökulsá a Fjöllum is Kverkfjöll, a glaciated stratovolcano. This paper provides detailed sedimentological evidence demonstrating that jokulhlaups have routed through Kverkfjallarani and hence from Kverkfjöll. Sedimentological evidence of jökulhlaups *includes valley-fill deposits and slack water deposits. Lithofacies, which are indicative of high-magnitude fluvial sedimentation, show that these deposits cannot be the result of nonjökulhlaup processes. The situation and nature of the sediments permit palaeoflow reconstructions. Fine-grained deposits within slack water deposits mark a break in jökulhlaup deposition and suggest that at least three jökulhlaups have drained through Hraundalur, the predominant valley within Kverkfjallarani. Evidence of lava overrunning `wet' jökulhlaup deposits indicates that jökulhlaups occurred in close association with volcanic eruptions in the Biskupsfell fissure. The largest jökulhlaup was initially hyperconcentrated and subsequently became more fluid. Slope-area reconstructions indicate that the largest jökulhlaup had a probable average peak discharge of 45,000-50,000 m3 s-1; however, the peak discharge attenuated by 25-30% in just 25 km. These observations quantify the number, rheology, hydraulics and chronology of jokulhlaups from Kverkfjöll and hence within the Jökulsa a Fjöllum. This study presents a model of jökulhlaup impacts and characteristics from glaciated volcanoes and/or within volcanic rifting zones.*

Dingerdis, I. (2005) Water flow and distribution in catchments with basaltic rocks. Field experiments and groundwater modelling in Skaftafell National Park [**MSc Hydrology thesis**]: Wageningen, Wageningen University.

Dowdeswell, J.A. (1982) "Supraglacial Re-Sedimentation from Melt-Water Streams on to Snow Overlying Glacier Ice, Sylgjujokull, West Vatnajokull, Iceland": Journal of Glaciology, v. **28**(99): p. 365-375.

Etzelmuller, B., and Björnsson, H. (2000) "Map analysis techniques for glaciological applications": International Geographical Information Science, v. **14**(6): p. 567-581.

This paper presents map analysis of digital elevation models for glaciological applications. The approach has been to combine spatial information describing the geometry of the glaciers with physical models of glaciological processes and to adjust empirical parameters to give a best fit with field observations. This applies to description of the basal shear stress and the resulting flow due to deformation of the ice. The outputs display spatial distributions, which can be adjusted to field observations through flexible routines of averaging the geographical information. Further, this approach is applied to description of the potential driving water along the bed, defined by the basal topography of the glacier and a model assuming that the basal water pressure is related to the thickness of the ice. The results produce predictions of the location of subglacial waterways and their drainage basins, which can be adjusted to field observations by choice of an empirical parameter, giving the basal water pressure as a fraction of the ice overburden pressure. A routine is presented that integrates the meltwater contribution downglacier to the various river outlets, given the glacier surface ablation.

Eyþórsson, J. (1964) Breer og bremalinger. Islands Hydrology I, Den 4. Nordiske Hydrologikonferense 10.-15. ág. 1964. Islands Hydrologi I, Volume **4**: Reykjavík, Orkumálastjóri, Vatnamælingar, p. 1-9.

Fenn, C., and Ashwell, I. (1985) "Some observations on the characteristics of the drainage system of Kverkfjöll, central Iceland": Jökull, v. **35**: p. 79-82.

Flowers, G.E., Bjornsson, H., and Palsson, F. (2003) "New insights into the subglacial and periglacial hydrology of Vatnajokull, Iceland, from a distributed physical model": Journal of Glaciology, v. **49**(165): p. 257-270.

We apply a time-dependent distributed glaciohydraulic model to Vatnajökull ice cap, Iceland, aiming to determine the large-scale subglacial drainage structure, the importance of basally derived meltwater, the influence of a permeable glacier bed and Vatnajokull's discharge contribution to major rivers in Iceland. The model comprises two coupled layers that represent the subglacial horizon perched on a subsurface aquifer in the western sector and bedrock in the eastern sector. To initialize and drive the simulations, we use digital elevation models of the ice surface and bed, the 1999/2000 measured mass balance and an estimate of subglacial geothermal heat fluxes. The modelled subglacial flow field differs substantially from that derived by hydraulic-potential calculations, and the corresponding distribution of basal effective pressure shows a strong correlation between low effective pressure and surge-prone areas in northeastern and southern sectors of Vatnajökull. Simulations suggest that geothermally derived basal melt may account for up to similar to 5% of the annual glacial discharge, and buried aquifers may evacuate up to similar to30% of subglacial water. Time-dependent tests yield estimates of the glacial discharge component in various outlet rivers and suggest a possible seasonal migration of subglacial hydraulic divides. This study of present-day Vatnajökull hydrology forms the starting point for investigations of its future evolution.

Flowers, G.E., Bjornsson, H., Palsson, F., and Clarke, G.K.C. (2004) "A coupled sheet-conduit mechanism for jökulhlaup propagation": Geophysical Research Letters, v. **31**(5).

The largest glacier outburst flood (jökulhlaup) ever recorded in Iceland occurred in 1996 and came from subglacial lake Grimsvötn in Vatnajökull ice cap. Among other noteworthy features, this flood was characterized by an unprecedentedly high lake level prior to flood initiation, extremely rapid linear rise in lake discharge, delay between the onset of lake drainage and floodwater arrival at the glacier terminus, formation of short-lived supraglacial fountains, and initially unchannelized outbursts of floodwater at the terminus. Observations suggest that the 1996 flood propagation mechanism was fundamentally different than that of previously observed floods from Grimsvötn. We advance a new model whereby floodwater initially propagates in a turbulent subglacial sheet, which feeds a nascent system of conduits. This model is able to explain key observations made of the 1996 jokulhlaup and may shed light on other outburst floods that do not conform to the standard model.

Flowers, G.E., Marshall, S.J., Bjornsson, H., and Clarke, G.K.C. (2005) "Sensitivity of Vatnajokull ice cap hydrology and dynamics to climate warming over the next 2 centuries": Journal of Geophysical Research-Earth Surface, v. **110**(F2).

The sensitivity of Vatnajokull ice cap to future climate change is examined using spatially distributed coupled models of ice dynamics and hydrology. We simulate the evolving ice cap geometry, mass balance, velocity structure, subglacial water pressures and fluxes, and basin runoff in response to perturbations to a 1961-1990 reference climatology. For a prescribed warming rate of 2 degrees C per century, simulated ice cap area and volume are reduced by 12-15% and 18-25% within 100 years,

respectively. Individual outlet glaciers experience 3-6 km of retreat in the first 100 years and a total retreat of 10-30 km over 200 years. For the same applied warming our results suggest a maximum increase in glacier-derived runoff of similar to 25% after 130 years. Ice cap thinning and retreat alters Vatnajokull's subglacial hydraulic catchment structure in the simulations, with up to several kilometers of local hydraulic divide migration. This serves to redistribute water among the major outlet rivers and, in extreme cases, to isolate river basins from glacially derived runoff. Glacier discharge from northern and northwestern Vatnajokull (distal from the coast) appears to be the most robust to climate warming, while discharge from Vatnajokull's southern margin (proximal to the coast) is particularly vulnerable. The latter reflects pronounced changes in the geometry of the southern outlet glaciers and has implications for glacier flood routing and frequency.

Gardarsson, S.M., and Eliasson, J. (2006) "Influence of climate warming on Hálslon reservoir sediment filling": Nordic Hydrology, v. **37**(3): p. 235-245.

Halslon reservoir is the main reservoir of the Kárahnjúkar hydropower project in the eastern highlands of Iceland. Studies for the environmental impact assessment for the hydropower project showed that sediment will fill the reservoir in about 500 years based on the present sediment transport rate. The main source of the sediment is the Brúarjökull outlet glacier which is a part of the Vatnajökull ice cap. Recent studies of the influence of climate warming on glaciers in Iceland show that they will decrease significantly and, in some cases, completely disappear during the next few hundred years. In this study, a glacier melt model for the Brúarjökull outlet glacier is constructed to predict how fast the glacier will retreat in response to accepted climate warming scenarios. The results from the glacier model are then used as input to a sediment transport mass balance model for the Hálslon reservoir, which predicts the influence of the retreat of the glacier on the sedimentation in the reservoir. The modeling shows that, instead of the reservoir being completely full of sediment in 500 years, the Halslon reservoir will at that time still have about 50-60% of its original volume as the sediment yield will decrease as a result of the decreasing glacier size.

Ghatan, G.J., and Head, J.W. (2004) "Regional drainage of meltwater beneath a Hesperian-aged south circumpolar ice sheet on Mars": Journal of Geophysical Research-Planets, v. **109**(E7): p. -.

Five sinuous valleys that begin near the margins of the Hesperian-aged Dorsa Argentea Formation (DAF) are examined using Mars Global Surveyor Mars Orbiter Laser Altimeter data. These valleys are carved into the surrounding Noachian cratered terrain and extend away from the DAF for lengths up to 1600 km before terminating in the Argyre basin 1-3 km below their starting elevations. The association of these valleys with the DAF, thought to be the volatile-rich deposits of a previously widespread circumpolar ice sheet, supports the scenario whereby the valleys formed contemporaneously with the DAF and served as conduits for drainage of meltwater associated with the melting and retreat of the ice sheet. Examination of the head regions of three of the valleys reveals pits and basins carved into the local deposits of the DAF closely associated with the valley heads. On the basis of the distribution of these pits and basins, their morphologies, size, spacing, and basal elevations similar to the nearby valleys, we conclude that the pits and basins represent the expression of the valleys within the DAF. We suggest that the pits and basins resulted from surface collapse of the deposits due to basal drainage of meltwater beneath the thinning ice *sheet. Sinuous ridges within some of the basins appear similar to terrestrial eskers and further support this scenario.*

Ghatan, G.J., Head, J.W., and Pratt, S. (2003) "Cavi Angusti, Mars: Characterization and assessment of possible formation mechanisms": Journal of Geophysical Research-Planets, v. **108**(E5): p. -.

[1] Cavi Angusti represent a series of large irregular depressions localized in part of the south circumpolar area previously mapped as the Hesperian-aged Dorsa Argentea Formation. Their origin has primarily been interpreted to be due to eolian deflation or subglacial melting. We use MGS MOLA and MOC data to analyze the largest of these features (similar to100 x 50 km, and up to about 1500 m deep). These data reveal terraced interiors, centrally located equidimensional and elongated edifices, and lava-flow-like structures that strongly suggest that this basin formed as a result of magmatic intrusion and extrusion, causing heating and melting of a volatile-rich substrate and drainage and loss of the liquid water. Volume estimates and heat transfer calculations are consistent with a mechanism involving a combination of intrusion and extrusion very similar to that observed to be responsible for Icelandic subglacial eruptions and meltwater generation. Mounds and ridges in the floors of other depressions suggest that this mechanism may have operated in at least several other features of the Cavi. Eolian activity, sublimation, and solution are also likely to have played a role in further modification of these features. Meltwater from basin formation appears to have drained laterally and may also have reentered the regional subsurface groundwater system.

Gíslason, S.R. (1990) "The chemistry of precipitation on the Vatnajökull glacier and chemical fractionation caused by the partial melting of snow": Jökull, v. **40**: p. 97-117.

Aim was to determine chemistry of 1987-88 precipitation on Vatnajökull, to look for spatial changes in snow chemistry, to study preferential release of salts and pollutants caused by partial melting of snow, and to develop model to analyze effect of degree of partial melting of snow on pH of meltwater. Snow at this location is uncontaminated by anthropogenic aerosol; thus,chemical constituents are primarily marine in origin

— (1993) "Efnafræði úrkomu, jökla, árvatns, stöðuvatna og grunnvatns á Íslandi": Náttúrufræðingurinn, v. **63**(3-4): p. 219-236.

Gíslason, S.R., Eiríksdóttir, E.S., Sigfússon, B., Elefsen, S.Ó., and Harðardóttir, J. (2004) Efnasamsetning og rennsli Skaftár; í septemberhlaupi 2002, sumarrennsli 2003 og í septemberhlaupi 2003 RH-07-2004 Raunvísindastofnun Háskólans, p. 21 pp.

Gíslason, S.R., Ingvarsson, G.B., Eiríksdóttir, E.S., Sigfússon, B., Elefsen, S.Ó., Harðardóttir, J., Kristinsson, B., and Þorláksdóttir, S.B. (2005) Efnasamsetning og rennsli straumvatna á slóðum Skaftár 2002 til 2004, RH-12-2005, Raunvísindastofnun Háskólans, p. 54 pp.

Gíslason, S.R., Snorrason, A., Kristmannsdóttir, H.K., Sveinbjörnsdóttir, A.E., Torsander, P., Ólafsson, J., Castet, S., and Dupre, B. (2002) "Effects of volcanic eruptions on the

CO2 content of the atmosphere and the oceans: the 1996 eruption and flood within the Vatnajökull Glacier, Iceland": Chemical Geology, v. **190**(1-4): p. 181-205.

The October 1996 eruption within the Vatnajökull Glacier, Iceland, provides a unique opportunity to study the net effect of volcanic eruptions on atmospheric and oceanic CO2. Volatile elements dissolved in the meltwater that enclosed the eruption site were eventually discharged into the ocean in a dramatic flood 35 days after the beginning of the eruption, enabling measurement of 50 dissolved element fluxes. The minimum concentration of exsolved CO2 in the 1x1012 kg of erupted magma was 516 mg/kg, S was 98 mg/kg, Cl was 14 mg/kg, and F was 2 mg/kg. The pH of the meltwater at the eruption site ranged from about 3 to 8. Volatile and dissolved element release to the meltwater in less than 35 days amounted to more than one million tonnes, equal to 0.1% of the mass of erupted magma. The total dissolved solid concentration in the floodwater was close to 500 mg/kg, pH ranged from 6.88 to 7.95, and suspended solid concentration ranged from 1% to 10%. According to H, O, C and S isotopes, most of the water was meteoric whereas the C and S were of magmatic origin. Both C and S went through isotopic fractionation due to precipitation at the eruption site, creating "short cuts" in their global cycles. The dissolved fluxes of C, Ca, Na, Si, S and Mg were greatest ranging from 1.4x1010 to 1.4x109 mol. The dissolved C flux equaled 0.6 million tonnes of CO2. The heavy metals Ni, Mn, Cu, Pb and Zn were relatively mobile during condensation and water-rock interactions at the eruption site. About half of the measured total carbon flood flux from the 1996 Vatnajokull eruption will be added to the long-term CO2 budget of the oceans and the atmosphere. The other half will eventually precipitate with the Ca and Mg released. Thus, for eruptions on the ocean floor, one can expect a net long-term C release to the ocean of less than half that of the exsolved gas. This is a considerably higher net C release than suggested for the oceanic crust by Staudigel et al. [Geochim. Cosmochim. Acta, 53 (1989) 3091]. In fact, they suggested a net loss of C. Therefore, magma degassed at the ocean floor contributes more C to the oceans and the atmosphere than magma degassed deep in the oceanic crust. The results of this study show that subglacial eruptions affecting the surface layer of the ocean where either Mn, Fe, Si or Cu are rate-determining for the growth of oceanic biomass have a potential for a transient net CO2 removal from the ocean and the atmosphere. For eruptions at high latitudes, timing is crucial for the effect of oceanic biota. Eruptions occurring in the wintertime when light is rate-determining for the growth of biota have much less potential for bringing about a transient net negative CO2 flux from the ocean atmosphere reservoir.

Guðmundsson, A.T. (1986) "Mat á búskap og afrennsli Tungnaárjökuls og Brúarjökuls í Vatnajökli": Jökull, v. **36**: p. 75-82.

Guðmundsson, M.T., Högnadóttir, and Björnsson, H. (1996) Effects of surges on runoff in glacial-fed rivers, *in* Sigurðsson, O., Einarsson, K., and Aðalsteinsson, H., eds., Nordic Hydrological Conference, Volume **1**: Reykjavík.

Guðmundsson, S., Björnsson, H., Aðalgeirsdóttir, G., Jóhannesson, T., Pálsson, F., and Sigurðsson, O. (2006) Áhrif loftlagsbreytinga á stærð og afrennsli Langjökuls, Hofsjökuls og suður Vatnajökuls, Orkuþing 2006: Reykjavík.

Guðmundsson, S., Björnsson, H., Pálsson, F., and Haraldsson, H. (2005) Energy balance calculations of Brúarjökull during the August 2004 floods in Jökla, N-Vatnajökull, Iceland, RH-03-2005: Reykjavík, Raunvísindastofnun Háskólans.

Vatnajökull ice cap (Fig. 1) is located in the North Atlantic Ocean close to the maritime southeastern coast of Iceland; the summers are mild, the annual precipitation extensive and the mass turnover high. The north facing Brúarjökull (1550 km2), the largest outlet of Vatnajökull (Fig. 1), is flat and with an elevation range of 600 to 1550 m a.s.l. over 45 km. In years of zero mass balance the equilibrium line is close to 1200 m and the accumulation zone is about 60% of the total glacier area. The main river draining Brúarjökull is Jökla with a glaciated water drainage basin of 1250 km2 (Fig. 1). One to three automatic weather stations, providing both the short- and long wave radiation balance, the transfer of turbulent heat fluxes, and the total energy supplied for melting, have been operated during the ablation season at Brúarjökull since 1996 (Figs. 1 and 2). Since 1992 annual summer and winter balance observations have been conducted at 15 sparse locations spread over the outlet glacier (Fig. 1). Records of temperature and precipitation near Vatnajökull, and discharge of the river Jökla (at Brú á Jökuldal, 40 km from the glacier margin, 20 km north of Kárahnjúkar), are available for the periods of the glaciological observations (Fig. 1). Large floods were observed in the river Jökla right after intensive precipitation 1 to 3 August 2004, and during an exceptionally warm and sunny period 9 to 14 August 2004. The three main objects of this work were to i) obtain energy budget maps (EBMs) of Brúarjökull over the summer 2004, ii) compare the glacier runoff as estimated with the EBMs to the August 2004 floods in Jökla and iii) use the EBMs to evaluate the results of calculating the runoff with three distinct regression models that use only temperature observation outside the glacier as an input. The EBMs allow us to relate the computed runoff to observed weather parameters, winter balance and surface characteristics and to see how the runoff compares to the measured riverdischarge.

Guðmundsson, S., Björnsson, H., Pálsson, F., and Haraldsson, H.H. (2005) "Energy balance of Brúarjökull and circumstances leading to the August 2004 floods in the river Jökla, N-Vatnajökull": Jökull, v. **55**: p. 121-138.

— (2005) Energy balance of Brúarjökull during the period of August 2004 floods in Jökla, CWE meeting: Reykjavík.

— (2006) Energy balance of Brúarjökull and circumstances leading to the August 2004 floods in the river Jökla, N-Vatnajökull, Raunvísindaþing.

Gunnlaugsson, E., and others (1974) Hornafjörður. Athugun varðandi neysluvatn., O.S.J.K.D. 74-06 (eða 86), p. 1-6 + kort.

Hallgrímsson, H. (2002) "Gígjustrengur Jöklu": Glettingur, v. **12**(1): p. 20-29.

Helland, H. (1883) Om Islands Jökler og om Jökelelvenes Vandmængde og Slamgehalt, Archiv for Mathematik og Naturvidenskab, Volume **7**: Kristiania, p. 200-232.

Jónsson, J. (1955) "The Hoffellssandur. Part II. Tillite in the basalt formation in East Iceland. Meteorological Observations. Hydrology of the Glacial River Austurfljót. Ice-marginal Lakes at Hoffellsjökull. On the formation of Frontal Glacial Lakes. The Groundwater." Geografiske Annaler, v. **1955**(3-4 h.): p. 17-245 ?

Tillite in the basalt formation in East Iceland. Meteorological Observations. Hydrology of the Glacial River Austurfljót. Ice-marginal Lakes at Hoffellsjökull. On the formation of Frontal Glacial Lakes. The Groundwater.

Jónsson, J., Hjulström, F., and Sundborg, Å. (1957) The Hoffellssandur a glacial outwash plain : scientific results of the expeditions to south-eastern Iceland in 1951-52 from the Geographical department of Uppsala university. Särtryck ur Geografiska Annaler 1957 nr. 2-3 s. 144-212, Uppsala universitet.

Marren, P.M. (2002) Criteria for distinguishing high magnitude flood events in the proglacial fluvial sedimentary record, The Extremes of the Extremes: Extraordinary Floods: IAHS Publ. no. 271: Proceedings of a symposium held at Reykjavik, Iceland, July 2000, p. 237-241.

Recognizing high magnitude or extreme floods in the sedimentary record is important if estimates of their geomorphic and sedimentary significance over long time scales (i.e. 102–103 years) are to be made. Standard regime or palaeocompetence based palaeohydraulic approaches present one set of solutions to this problem. An alternative is to examine the sedimentary record to determine the dominant depositional processes in any particular environment. Specifically, it is important to assess the role of high magnitude floods within the sedimentary record. This paper presents a set of criteria, based on flow rheology, sediment structures, clast orientation and sediment architecture and geometry, which are designed to critically determine the magnitude–frequency regime of fluvial sediments. The criteria were derived from literature on the sedimentary impact of high magnitude floods and from fieldwork in southeast Iceland.

Marshall, S.J. (2005) "Recent advances in understanding ice sheet dynamics": Earth and Planetary Science Letters, v. **240**(2): p. 191-204.

Glaciers and ice sheets play a dynamic role in Earth's climate system, influencing regional- and global-scale climate and responding to climate change on time scales from years to millennia. They are also an integral part of Earth's landscape in alpine and polar regions, where they are an active agent in isostatic, tectonic, and Earth surface processes. This review paper summarizes recent progress in understanding and modelling ice sheet dynamics, from the microphysical processes of ice deformation in glaciers to continental-scale processes that influence ice dynamics. Based on recent insights and research directions, it can be expected that a new generation of ice sheet models will soon replace the current standard. Improvements that can be foreseen in the near future include: (i) the addition of internally-consistent evolutionary equations for ice crystal fabric (anisotropic flow laws), (ii) more generalized flow laws that include different deformation mechanisms under different stress regimes, (iii) explicit incorporation of the effects of chemical impurities and grain size (dynamic recrystallization) on ice deformation, (iv) higher-order stress solutions to the momentum balance (Stokes' equation) that governs ice sheet flow, and (v) the *continued merger of ice sheet models with increasingly complex Earth systems models, which include fully-coupled subglacial hydrological and geological processes. Examples from the Greenland Ice Sheet and Vatnajökull Ice Cap, Iceland are used to illustrate several of these new directions and their importance to glacier dynamics.*

Marshall, S.J., Bjornsson, H., Flowers, G.E., and Clarke, G.K.C. (2005) "Simulation of Vatnajokull ice cap dynamics": Journal of Geophysical Research-Earth Surface, v. **110**(F3).

We apply a coupled model of ice sheet dynamics and subglacial hydrology to investigate the dynamics and future evolution of the Vatnajokull ice cap, Iceland. In this paper we describe a new theoretical approach to introducing longitudinal stress coupling in the ice dynamics solution, and we analyze our ability to simulate the main features of Vatnajokull, with and without longitudinal stress effects. Equilibrium ice cap configurations exist for Vatnajokull but under a narrow range of climatic boundary conditions. Equilibrium reconstructions have an average ice thickness greater than what is observed at Vatnajokull, consistent with our inability to capture surge dynamics in Vatnajokull's outlet glaciers. Hydrological regulation of basal flow, longitudinal stress coupling, and a simple parameterization of the subglacial heat flux from Vatnajokull's geothermal cauldrons all help to reduce average ice thickness in the equilibrium reconstructions, but cases that reproduce the present-day ice volume have an ice cap area that is 5-10% less than the actual ice cap. Present-day reconstructions that adopt a realistic climate spin-up for the period 1600-1990 provide improved fits to the modern-day ice cap geometry. This indicates that climatic disequilibrium also plays a significant role in dictating Vatnajokull's morphology. Simulations for the period 1600-2300 illustrate that air temperature is the dominant control on Vatnajokull's volume and area. Longitudinal stress coupling and hydrological coupling both increase Vatnajokull's sensitivity to future warming.).

Ng, F., and Björnsson, H. (2003) "On the Clague-Mathews relation for jökulhlaups": Journal of Glaciology, v. **49**(165): p. 161-172.

In the empirical study of jokulhlaups, the peak discharge, Q(max),and water volume drained by the ice-dammed lake during the floods, V-t, appear to follow a power-law relation Q(max) = KVtb, where K are b are constants determined from field data. First identified by Clague and Mathews (1973), this relation is a useful reference for predicting flood magnitude, but its physical origin remains unclear. Here, we develop the theory that connects it to contemporary models for Simulating the flood hydrograph. We explain how the function Q(max) = f(V-t) arises from Nye's (1976) theory of time-dependent water flow in a subglacial channel coupled to a lake, and we describe how discharge volume data record the (monotonically increasing) form of this function so long as the lake is not emptied in the floods. The Grimsvötn jökulhlaups present an example where, because of partial draining of the lake, agreement between the model-derived f and data is excellent. It is documented that other lake systems drain completely, but we explain how the exponent b approximate to 2/3 observed for them collectively is due primarily to a scaling effect related to their size, modified by other factors such as the flood initiation process.

Nicholas, A.P., and Sambrook Smith, G.H. (1998) "Relationships Between Flow Hydraulics, Sediment Supply, Bedload Transport and Channel Stability in the Proglacial Virkisá River, Iceland": Geografiska Annaler, v. **80A**(2): p. 111-122.

We present data from a proglacial river in Iceland that exhibits very different sedimentological characteristics when compared to its alpine counterparts. The braidplain is characterised by coarse outburst gravels that inhibit sediment transport and channel change. Bedload transport is restricted to the movement of fine-grained gravels that pass through the channel system without promoting significant changes in channel geometry. Bar forms are erosional features, inherited from the last major peak flow, rather than depositional in nature. On the basis of our observations we conclude that braidplain morphology is controlled by low frequency, high magnitude flow events, possibly associated with glacial outburst floods. This is in marked contrast to process-form relationships in more dynamic alpine proglacial channels that are characterised by high rates of sediment transport and channel change.

Old, G.H., Lawler, D.M., and Snorrason, A. (2005) "Discharge and suspended sediment dynamics during two jökulhlaups in the Skaftá river, Iceland": Earth Surface Processes and Landforms, v. **30**(11): p. 1441-1460.

This paper investigates the dynamics and significance of discharge and suspended sediment transport (SST) during two jökulhlaups (glacier outburst floods) in the Skaftá River, south Iceland. Jökulhlaups occur frequently in many glacial environments and are highly significant in the gemorphological evolution of river basins and coastal environments. However, direct high-resolution monitoring of jökulhlaups has rarely been accomplished and hardly ever at more than one station in a downstream sequence. Here we present detailed data on jökulhlaup discharge and water quality from an intensive monitoring and sampling programme at two sites in summer 1997 when two jökulhlaups occurred. Evidence is discussed that supports the origin of both jökulhlaups being subglacial reservoirs, produced over several months by subglacial geothermal activity. At the downstream site, Asa-Eldvatn, the larger jökulhlaup (1) had a peak discharge of 572 m(3) s(-1) and a peak suspended sediment flux of 4650 kg s(-1)(channel-edge value) or 4530 kg s(-1) (cross-sectional). These values compare to the non-jökulhlaup flow of 120 m(3) s(-1) and suspended sediment flux of 190 kg s(-1)(channel-edge) or 301 kg s(-1) (cross-sectional). Significantly, the jökulhlaups transported 18(.)8 per cent of the annual runoff and 53 per cent of the annual suspended sediment transport in 6(.)6 per cent of the year. Furthermore, water chemistry, suspended sediment and seismic data suggest that volcanic activity and geothermal boiling (possibly including steam explosions) may have occurred during Jökulhlaup 1. The research illustrates the value of integrating high-resolution, multi-point field monitoring of meteorological, hydrological, hydrochemical, geomorphological and seismological data for understanding the dynamics, significance and downstream translation of jökulhlaups.

Pálsson, F., and Björnsson, H. (2000) Vatnsrennsli undan eystri hluta Fláajökuls, RH-14-00: Reykjavík, Raunvísindastofnun Háskólans.

Pálsson, F., Björnsson, H., and Magnússon, E. (1998) Könnun rennslisleiða vatns úr Skrámulóni, undir sporð Svínafellsjökuls, RH-08-98: Reykjavík, Raunvísindastofnun Háskólans.

Pálsson, S., Ingólfsson, P., and Tómasson, H. (1980) "Comparison of sediment load transport in the Skeiðarár jökulhlaups in 1972 and 1976 (Samanburður á aurburði í Skeiðarárhlaupum 1972 og 1976)": Jökull, v. **30**: p. 21-33.

Pálsson, S., and others (1999) Grímsvatnahlaupið fyrra 1996; greinargerð, unnið fyrir Vegagerðina, OS-99115: Reykjavík, Orkustofnun, Vatnamælingar, p. 26 s. : línurit, töflur.

Rist, S. (1990) Ár og vötn í einstökum landshlutum: Austurland, *in* Rist, S., ed., Vatns er þörf: Reykjavík, Menningarsjóður, p. 141-148.

— (1990) Vatns er þörf: Reykjavík, Menningarsjóður, 248 s. : myndir, kort, línurit, töflur, uppdr. p.

Roberts, M., Magnússon, E., Geirsson, H., and Sturkell, E. (2006) Meltwater dynamics beneath Skeiðarárjökull from continuous GPS measurements, Haustfundur Jarðfræðafélags Íslands 2006: Reykjavík, p. 23.

Roberts, M.J., Russell, A.J., Tweed, F.S., and Knudsen, Ó. (2000) "Ice fracturing during jökulhlaups: implications for englacial floodwater routing and outlet development": Earth Surface Processes and Landforms, v. **25**: p. 1429-1446.

Theoretical studies of glacial outburst floods (jökulhlaups) assume that: (i) intraglacial floodwater is transported efficiently in isolated conduits; (ii) intraglacial conduit enlargement operates proportionally to increasing discharge; (iii) floodwater exits glaciers through pre-existing ice-marginal outlets; and (iv) the morphology and positioning of outlets remains fixed during flooding. Direct field observations, together with historical jökulhlaup accounts, confirm that these theoretical assumptions are not always correct. This paper presents new evidence for spatial and temporal changes in intraglacial floodwater routing during jökulhlaups; secondly, it identifies and explains the mechanisms controlling the position and morphology of supraglacial jökulhlaup outlets; and finally, it presents a conceptual model of the controls on supraglacial outbursts. Field observations are presented from two Icelandic glaciers, Skeiðarárjökull and Sólheimajökull. Video footage and aerial photographs, taken before, during and after the Skeiðarárjökull jökulhlaup and immediately after the Sólheimajökull jökulhlaup, reveal changes in floodwater routing and the positioning and morphology of outlets. Field observations confirm that glaciers cannot transmit floodwater as efficiently as previously assumed. Rapid increases in jökulhlaup discharge generate basal hydraulic pressures in excess of ice overburden. Under these circumstances, floodwater can be forced through the surface of glaciers, leading to the development of a range of supraglacial outlets. The rate of increase in hydraulic pressure strongly influences the type of supraglacial outlet that can develop. Steady increases in basal hydraulic pressure can retro-feed pre-existing englacial drainage, whereas transient increases in pressure can generate hydraulic fracturing. The position and morphology of supraglacial outlets provide important controls on the spatial and temporal impact of flooding. The development of supraglacial jökulhlaup outlets provides a new mechanism for rapid englacial debris entrainment.

Robinson, Z.P. (2001) Groundwater geochemistry and behaviour in an Icelandic sandur [**Unpublished Ph.D. thesis**], Keele University, U.K.

Russell, A.J., Roberts, M.J., Fay, H., Marren, P.M., Cassidy, N.J., Tweed, F.S., and Harris, T. (2006) "Icelandic jokulhlaup impacts: Implications for ice-sheet hydrology, sediment transfer and geomorphology": Geomorphology, v. **75**(1-2): p. 33-64.

Glaciers and ice sheets erode, entrain, and deposit massive quantities of debris. Fluxes of subglacial meltwater exert a fundamental control on ice dynamics and sediment transport budgets. Within many glacial systems outburst floods jokulhlaups) constitute high magnitude, high frequency fluxes of meltwater relative to normal ablation controlled discharge. This paper presents a synthesis of research on recent Icelandic jokuthlaups and their geomorphological and sedimentary impact. We identify jokulhlaup impacts within subglacial, englacial and proglacial settings and discuss their wider significance for ice sheet hydrology, sediment transfer and geomorphology. Because jokulhlaups erode, deposit, and re-work sediment simultaneously, they usually cause significant glaciological and sedimentological impacts. Jokulhlaups that propagate as subglacial flood waves often produce widespread hydromechanical disruption at the glacier base. Recent Icelandic jokulhlaups have been recognised as highly efficient agents of reworking subglacial sediment and glacial sediment entrainment. Models of jokulhlaup impact, therefore, need to encompass the sub- and englacial environment in addition to the proglacial zone where research has traditionally been focussed. Most jokulhlaups transport sediment to proglacial sandar, and often directly to oceans where preservation potential of the impact is greater. Proglacial jokulhlaup deposits form distinctive sedimentary assemblages, coupled with suites of high-energy erosional landforms. This study of modem jokulhlaup processes and sedimentary products may be useful for the interpretation of meltwater processes associated with Quaternary ice sheets.

Sigbjarnarson, G. (1990) Vatnið og landið : ávörp , erindi og ágrip : vatnafræðiráðstefna haldin 22.-23. október 1987 í tilefni 40 ára afmælis Vatnamælinga og 20 ára afmælis Orkustofnunar : tileinkuð Sigurjóni Rist vatnamælingamanni sjötugum, Vatnafræðiráðstefna: Reykjavík : Orkustofnun, p. 307 s. : myndir, kort, línurit, töflur

Sigurðsson, F. (1990) "Groundwater from glacial areas in Iceland": Jökull, v. **40**: p. 119-146.

Sigvaldason, G.E. (1963) "Influence of the Geothermal Activity on the Chemistry of three Glacier Rivers": Jökull, v. **13. árg.**: p. 10-17.

Snorrason, Á., Björnsson, H., and Jóhannesson, H. (2000) Causes, characteristics and predictability of floods in regions with cold climate, *in* Parker, D.J., ed., Floods: Routledge Hazard and Disaster Series: London and New York, Routledge, p. 18.

Snorrason, S. (1978) Breytingar á jaðri Fláajökuls og rennsli frá honum: Reykjavík, Raunvísindastofnun Háskólans, p. 12.

Sumarliðason, P. (1965) "Vatnshæðarmælingar í Tungná við Félaga sumarið 1965 (Oscillations of river Tungnaá at Jökulheimar in summer 1965). " Jökull, v. **15**: p. 144-147.

Sævarsdóttir, R.H. (2002) Grunnvatn og vatnajarðfræði Skaftársvæðisins [**MSc thesis**]: Reykjavík, Háskóli Íslands

Theodórsson, P. (1968) "Þrívetni í grunnvatni og jöklum á Íslandi (Tritium in ground water and glaciers in Iceland)": Jökull, v. **18**: p. 350-358.

Theódórsson, P. (1977) Tilraun til að mæla rennsli í Skeiðará með geislavirku jóði, RH-77-4: Reykjavík, Raunvísindastofnun Háskólans, p. 8; línurit, teikn., töflur.

Tómasson, H., and others (1974) Efnisflutningar í Skeiðarárhlaupi 1972, OS-ROD-7407: Reykjavík, Orkustofnun. Raforkudeild, p. Óreglul. bls.tal : myndir, línurit, töflur.

Tómasson, H., Pálsson, S., and Vigfússon, G.H. (1996) Framburður svifaurs í Jökulsánum norðan Vatnajökuls, OS-96024/VOD-02: Reykjavík, Orkustofnun. Vatnsorkudeild ; 96-02, p. 93 s. : línurit, töflur ; 30 sm.

Tweed, F.S., and Russell, A.J. (1999) "Controls on the formation and sudden drainage of glacier-impounded lakes: implications for jökulhlaup characteristics ": Progress in Physical Geography, v. **23**(No. 1): p. 79-110.

Over the past few years there has been an increase in understanding of glacier-impounded or ‘ice-dammed’ lake behaviour. The spectacular jökulhlaup (catastrophic flood) from Grímsvötn, Iceland in November 1996 has both raised the profile of such events and emphasized the need for awareness of the processes involved. This review summarizes the extent of current knowledge of ice-dammed lakes, highlighting key developments and outlining areas of study still subject to difficulties. Controls on ice-dammed lake formation and persistence are identified, and cycles of jökulhlaup activity are related to glacier fluctuations. Ice-dammed lake drainage trigger mechanisms are reviewed and recent progress in the understanding of such mechanisms is emphasized. Controls on jökulhlaup routing and the development and character of jökulhlaup conduits are discussed and recent advances in jökulhlaup prediction, hydrograph modelling and peak discharge estimation are assessed. A process-based schematic model, drawing on published research, links ice-dammed lake occurrence and drainage to jökulhlaup characteristics. It is demonstrated that ice-dammed lake and ice-dam characteristics ultimately control seven key jökulhlaup attributes which determine the potential impact of jökulhlaups on both landscape and human activity in glaciated regions.

5.7 Djúpborun (deep core drilling, ice core drilling)

Árnason, B., Björnsson, H., and Theódórsson, P. (1973) Deep core drilling in temperate glacier in Iceland, RH-P-72-B1: Reykjavík, Raunvísindastofnun Háskólans, p. 14.

— (1974) "Mechanical drill for deep coring in temperate ice": Journal of glaciology, v. **13**(67): p. 133-139.

Describes construction and operation of rotary drill. Tests made during summer 1972 in accumulation area of Vatnajökull, Iceland

Björnsson, H. (1973) "Freezing on a rotary drill in temperate glacier ice": Jökull, v. **23**: p. 53-54.

Cause of freezing on drill used for deep core drilling on Vatnajökull, Iceland, in summer 1972

Brandt, O., Björnsson, H., and Gjessing, Y. (2005) "Mass balance rates derived by mapping internal tephra layers in Myrdalsjökull and Vatnajökull ice caps, Iceland": Annals of Glaciology, v. **Vol. 42**(1): p. 284-290.

Internal tephra layers of known age have been detected by radio-echo soundings within the Mýrdalsjökull and Vatnajökull ice caps in Iceland. Assuming steady state, the estimated strain rates since these isochrones were deposited on the glacier surface have been used to calculate past average specific net balance rates in the accumulation zones along three flowlines on Mýrdalsjökull and one on Vatnajökull. For the period 1918-91 the specific mass-balance rate has been estimated to 4.5 and 3.5 m a−1 at 1350 m a.s.l. on the southern and northern slopes of Mýrdalsjökull, respectively. At 1800 m elevation on the Bárdarbunga ice dome in Vatnajökull, the specific net balance averaged over the last three centuries is estimated to be about 2.1 m a−1. Given this specific net balance, a revised age-depth timescale is presented for a 400 m deep ice core recovered in 1972 from Bárdarbunga. The ice at the bottom is estimated to be from AD 1750.

Everest, J., and Bradwell, T. (2003) "Buried glacier ice in southern Iceland and its wider significance": Geomorphology, v. **52**(3-4): p. 347-358.

Geo-electrical resistivity surveys have been carried out at recently deglaciated sites in front of three glaciers in southern Iceland: Skeiðarárjökull, Hrútarjökull, and Virkisjökull. The results show the presence of old glacier ice beneath debris mantles of various thickness. We conclude that buried glacier ice has survived for at least 50 years at Virkisjökull and Hrútarjökull, and probably for over 200 years at Skeiðarárjökull. Additional data from a further site have identified a discontinuous ice core within 18th-century jokulhlaup deposits. Photographic and lichenometric evidence show that the overlying debris has been relatively stable, and hence melting of the ice at all four sites is proceeding slowly due to the heat-shielding properties of the overburden. The geomorphic implications are pertinent when considering the potential longevity of buried ice. The possible implications for dating techniques, such as lichenometry, radiocarbon dating and cosmogenic surface-exposure dating are also important, as long-term readjustments of surface forms may lead to dating inaccuracy. Finally, it is recognised that landscape development in areas of stagnant ice topography may post-

date initial deglaciation by a considerable degree. (C) 2002 Elsevier Science B.V. All rights reserved.

Larsen, G., Gudmundsson, M.T., and Bjornsson, H. (1998) "Eight centuries of periodic volcanism at the center of the Iceland hotspot revealed by glacier tephrostratigraphy": Geology, v. **26**(10): p. 943-946.

A record of volcanic activity within the Vatnajökull ice cap has been obtained by combining data from three sources: tephrostratigraphic studies of two outlet glaciers, a 415-m-long ice core from northwestern Vatnajökull, and written records. The record extends back to A.D. 1200 and shows that the volcanic activity has a 130-140 yr period, Intervals of frequent eruptions with recurrence times of three to seven years alternate with intervals of similar duration having much lower eruption frequency, In comparison with other parts of the plate boundary in Iceland, eruption frequency is greater, episodes of unrest are longer, and intervals of low activity are shorter. The high eruption frequency may be the result of a more sustained supply of magma, owing to the area's location above the center of the Iceland mantle plume. When combined with historical data on eruptions and earthquakes, our data indicate that rifting-related activity in Iceland as a whole is periodic and broadly in phase,vith the volcanic activity within Vatnajokull.

Norðdahl, H., and Pétursson, H.G. (1995) "Increased resolution of landbased glacial geological data in Iceland and comparison with deep-sea and ice-core data on climatic changes": Ice, v. **109**: p. 6-7.

Smith, K.T., and Dugmore, A.J. (2006) "Jökulhlaups circa Landnám: Mid- to late first millennium AD floods in South Iceland and their implications for landscapes of settlement": Geografiska Annaler Series a-Physical Geography, v. **88A**(2): p. 165-176.

This paper presents geomorphological and sedimentological evidence for three large-scale floods to the west of the ice-capped volcano Katla around the time of Norse settlement or Landnám (AD 870-930). These glacial outburst floods (jökulhlaups), the most recent prehistoric events in a series of Holocene floods in the Markarfljót valley, are securely dated by tephrochronology and radiocarbon dating to between c. AD 500 and c. AD 900. The environmental impact of these events would have been extensive, affecting both the highlands and about 40-50 km(2) of the coastal lowlands where about 15 of the 400 or so landnam farms in Iceland were sited. An awareness of environmental conditions and landscape stability around the time of the Norse colonisation of Iceland is important to understand the earliest settlement patterns because of the different constraints and opportunities that they represent.

Steinþórsson, S. (1977) "Tephra layers in a drill core from Vatnajökull ice cap. (Gjóskulögin í Bárðarbungukjarnanum) ": Jökull, v. **27**: p. 2-27.

— (1982) Gjóskulög í jökulkjarna frá Bárðarbungu, *in* Þórarinsdóttir, H., and aðrir, o., eds., Eldur er í norðri: afmælisrit helgað Sigurði Þórarinssyni sjötugum 8. janúar 1982 Reykjavík, Sögufélagið, p. [361]-368; Myndir, línurit, tafla.

Talwani, M., Hay, W., and Ryan, W.B.F. (1979) "Deep Drilling Results in the Atlantic Ocean: Continental Margins and Palaeoenvironments": American Geophysical Union , Maurice Ewing Series 3: p. 281-287.

Theodórsson, P. (1970) "Rannsóknir á Bárðarbungu 1969 og 1970 (Abstract. Deuterium and tritium in ice cores from Bárðarbunga on Vatnajökull)": Jökull, v. **20**: p. 1-14.

Deuterium and tritium in ice cores recovered from this part of Vatnajökull, Iceland; use in study of climate change

— (1973) "Djúpborun í Bárðarbungu": Jökull, v. **23**: p. 67-69.

Published 1974. Results of deep core drilling in this north-western part of Vatnajökull

— (2001) "Djúpborgun í Bárðarbungu. Minningabrot": Jökull, v. **50**: p. 109-118.

Zielinski, G.A., Germani, M.S., Larsen, G., Baillie, M.G.L., Whitlow, S., Twickler, M.S., and Taylor, K. (1995) "Evidence of the Eldgjá (Iceland) eruption in the GISP2 Greenland ice core: relationship to eruption processes and climatic conditions in the tenth century": Holocene, v. **5**(2): p. 129-140.

Þorsteinsson, Jóhannesson, T., Larsen, G., and Sigurðsson, O. (2003) Ice core drilling on the ice shelf covering the Grímsvötn subglacial lake, Research Report, National Geographic Society, p. 13.

— (2003) Ice core study on the Grímsvötn ice shelf, FRISP Workshop on Ice Shelf Processes: Ágrip og fyrirlestur: British Antarctic Survey, Cambridge.

Þorsteinsson, Jóhannesson, T., Larsen, G., Sigurðsson, O., Schmidt, K.G., and Forwick, M. (2003) Dust flux into the Grímsvötn subglacial lake, Vatnajökull ice cap, Iceland, estimated from ice core data, Third International Conference on Mars Polar Science and Exploration: Abstract #8134: Alberta, Canada, Lunar and Planetary Institute, Houston.

5.8 Eldgos undir jökli

5.8.1 Eldgos í Grímsvötnum eða Gjálp

Sjá 3.2.1 og 4.2.1

5.8.2 Eldgos í Bárðarbungu

Sjá 3.2.2 og 4.2.3

5.8.3 Eldgos í Kverkfjöllum

Sjá 3.2.3 og 4.2.5

5.8.4 Eldgos í Högöngum

Sjá 3.2.4

5.8.5 Eldgos í Þórðarhyrnu

Sjá 3.2.5 og 4.2.4

5.8.6 Eldgos í Hamrinum

Sjá 3.2.6

5.8.7 Eldgos í Skaftárkötlum

Sjá 4.2.2

5.8.8 Eldgos í Öræfajökli

Sjá 4.2.7

5.8.9 Eldgos í Esjufjöllum

Sjá 4.2.8

5.8.10 Eldgos undir jökli: almennar heimildir, ekki tengdar ákveðinni eldstöð

Allen, C.C. (1980) "Icelandic subglacial volcanism: thermal and physical studies": Journal of Geology, v. **88**: p. 108-117.

— (1980) "Subglacial volcanism in Iceland": Eos, Transactions of the American Geophysical Union, v. **61**: p. 69.

Allen, C.C., Jercinovic, M.J., and Allen, J.S.B. (1982) "Subglacial volcanism in north-central British Columbia and Iceland": Journal of Geology, v. **90**: p. 699-715.

Áskelsson, J. (1936) "On the last eruptions in Vatnajökull": Societas Scientiarum Islandica, v. **18**: p. 55 s., [10] mbl., [1] kortabl. br. : línurit, töflur.

Barker, G.S. (1982) A rock magnetic study of subglacial volcanoes in Iceland [**unpublished MSc thesis**], University of Georgia.

Björnsson, H. (2002) "Subglacial lakes and jökulhlaups in Iceland": Global and planetary change, v. **35**: p. 255-271.

Active volcanoes and hydrothermal systems underlie ice caps in Iceland. Glacier–volcano interactions produce meltwater that either drains toward the glacier margin or accumulates in subglacial lakes. Accumulated meltwater drains periodically in jökulhlaups from the subglacial lakes and occasionally during volcanic eruptions. The release of meltwater from glacial lakes can take place in two different mechanisms. Drainage can begin at pressures lower than the ice overburden in conduits that expand slowly due to melting of the ice walls by frictional and sensible heat in the water. Alternatively, the lake level rises until the ice dam is lifted and water pressure in excess of the ice overburden opens the waterways; the glacier is lifted along the flowpath to make space for the water. In this case, discharge rises faster than can be accommodated by melting of the conduits. Normally jökulhlaups do not lead to glacier surges but eruptions in ice-capped stratovolcanoes have caused rapid and extensive glacier sliding. Jökulhlaups from subglacial lakes may transport on the order of 107 tons of sediment per event but during violent volcanic eruptions, the sediment load has been 108 tons.

Björnsson, H., and Einarsson, P. (1990) "Volcanoes beneath Vatnajökull, Iceland: Evidence from radio echo-sounding earthquakes and jökulhlaups": Jökull, v. **40**: p. 147-168.

Integration of knowledge of subglacial topography, earthquake activity and jökulhlaups has contributed to more precise locations of the volcanic systems beneath Vatnajökull. Bárðarbunga is the centre of a volcanic system which includes the fissure swarms of Veiðivötn to the SW and Dyngjuháls to the NE. The Grímsvötn volcano is the centre of a system that comprises the Laki fissure swarm in the SW and extends for an unknown distance to the NE of the volcano. Þórðarhyrna is probably a separate central volcano within this system. The Kverkfjöll system can be traced 10 km to the SW of the Kverkfjöll volcano. It appears to be separated from the Grímsvötn volcano. The Askja fissure swarm extends beneath Dyngjujökull and can possibly be traced to the Grímsvötn volcano. Hamarinn and the ridge striking eastward from Hamarinn (Loki Ridge) are central volcanoes which together with the Fögrufjöll fissure swarm form a volcanic system. No support can be found in the topographic data for the existence of a central volcano near Breiðabunga. Volcanic activity in historical times has mainly been limited to the Grímsvötn and Bárðarbunga systems. Major rifting events have affected large sections of these volcanic systems but both have been remarkably quiet for the past decades. A few volcanic events are presumed to have occurred on the Hamarinn - Loki system and on the Askja fissure swarm beneath Dyngjujökull, but no event is known with certainty on the Kverkfjöll system. The rivers Skeiðará and Súla have the most frequent eruption-related jökulhlaups. They receive meltwater from the Grímsvötn caldera and the area to the SW of it, including Þórðarhyrna. Núpsvötn, Djúpá and Hverfisfljót drain the southwestern part of the Grímsvötn system, an area bounded by Þórðarhyrna, Geirvörtur, Hágöngur and Pálsfjall. Skaftá drains the Loki Ridge and the area west of Grímsvötn. Jökulhlaups in Kaldakvísl, and ultimately Þjórsá, must originate in the Bárðarbunga or the Hamarinn - Loki systems, and the only possible source for volcanic jökulhlaups in Skjálfandafljót is the northern part of the Bárðarbunga system. Jökulsá á Fjöllum may drain meltwater from activity in all the volcanic systems in northern Vatnajökull: Bárðarbunga, the Askja fissure swarm and Kverkfjöll. This includes the voluminous, ice-filled calderas of Bárðarbunga and

Kverkfjöll. Activity in the northern part of the Grímsvötn system may cause floods in Jökulsá á Fjöllum. Meltwater from volcanic activity on the SE flank of a ridge that strikes south from Kverkfjöll may drain to Jökulsá á Brú. Volcanic activity farther north on the E flanks of this ridge would cause floods in Kreppa.

Björnsson, H., Guðmundsson, S., Guðmundsson, M.T., and Rott, H. (2002) Glacier-volcano interactions deduced by SAR interferometry, The 25th Nordic Geological Winter Meeting: Reykjavík, Iceland.

Björnsson, H., Rott, H., Guðmundsson, S., Fischer, A., Siegel, A., and Guðmundsson, M.T. (2001) "Glacier-volcano interactions deduced by SAR interferometry": Journal of Glaciology, v. **47**(156): p. 58-70.

Glacier-surface displacements produced by geothermal and volcanic activity beneath Vatnajökull ice cap in Iceland are described by field surveys of the surface topography combined with interferograms acquired from repeat-pass synthetic aperture radar images. A simple ice-flow model serves well to confirm the basic interpretation of the observations. The observations cover the period October 1996-January 1999 and comprise: (a) the ice-flow field during the infilling of the depressions created by the subglacial Gjálp eruption of October 1996, (b) the extent and displacement of the floating ice cover of the subglacier lakes of Grímsvötn and the Skaftá cauldrons, (c) surface displacements above the subglacier pathways of the jökulhlaups from the Gjálp eruption site and the Grimsvötn lake, (d) detection of areas of increased basal sliding due to lubrication by water, and (e) detection of spots of temporal displacement that may be related to altering subglacial volcanic activity. At the depression created by the Gjálp eruption, the maximum surface displacement rate away from the radar decreased from 27 cm d(-1) to 2 cm d(-1) over the period January 1997-January 1999. The observed vertical displacement of the ice cover of Grimsvötn changed from an uplift rate of 50 cm d(-1) to sinking of 48 cm d(-1), and for Skafta cauldrons from 2 cm d(-1) to 25 cm d(-1).

Einarsson, P., and Björnsson, S. (1987) Jarðskjálftamælingar á Raunvísindastofnun Háskólans, *in* Sigfússon, I., ed., Í hlutarins eðli: Reykjavík, Menningarsjóður, p. 251-278.

Einarsson, T. (1966) "Physical aspects of sub-glacial eruptions (gos undir jökli frá eðlisfræðilegu sjónarmiði)": Jökull, v. **16**: p. 167-174.

Gudmundsson, G., and Saemundsson, K. (1980) "Statistical Analysis of Damaging Earthquakes and Volcanic Eruptions in Iceland from 1550-1978": Journal of Geophysics, v. **47**: p. 99-109.

Guðmundsson, A.T. (1986) Íslandseldar : eldvirkni á Íslandi í 10.000 ár Reykjavík, Vaka-Helgafell, 168 s. : myndir, teikn., kort, línurit, töflur p.

— (2001) Íslenskar eldstöðvar: Reykjavík, Vaka-Helgafell, 320 s. : myndir, kort, línurit, töflur p.

Guðmundsson, A.T., and (1996) Volcanoes in Iceland : 10.000 years of volcanic history: Reykjavík, Vaka-Helgafell, 136 s. : myndir, teikn., kort, töflur p.

Guðmundsson, A.T., and Sigurðsson, R.T. (1996) Vatnajökull : frost og funi: Reykjavík, Arctic Books, 46, [2] s. : myndir p.

— (1996) Vatnajökull: ice on fire: Reykjavík, Arctic Books.

Guðmundsson, A.T., Sigurðsson, R.T., and (1995) Light on ice : glaciers in Iceland: Seltjarnarnesi, Ormstunga, ISBN 9979904879 (ib.) p.

Guðmundsson, M.T. (2005) Subglacial volcanic activity in Iceland, *in* Caseldine, C., Russell, A.J., Harðardótir, J., and Knudsen, Ó., eds., Modern Processes, Past Environments, Elsevier, p. 127-151.

Guðmundsson, M.T., and Högnadottir, ó. (2007) "Volcanic systems and calderas in the Vatnajökull region, central Iceland: Constraints on crustal structure from gravity data": Journal of Geodynamics, v. **43**(1): p. 153-169.

A Bouguer anomaly map is presented of southern central Iceland, including the western part of Vatnajökull and adjacent areas. A complete Bouguer reduction for both ice surface and bedrock topography is carried out for the glaciated regions. Parts of the volcanic systems of Vonarskarð-Hágöngur, Barðarbunga-Veiðivötn, Grimsvötn-Laki, and to a lesser extent Kverkfjöll, show up as distinct features on the gravity map. The large central volcanoes with calderas: Vonarskarð, Barðarbunga, Kverkfjöll and Grimsvötn, are associated with 15-20 mGal gravity highs caused by high density bodies in the uppermost 5 km of the crust. Each of these bodies is thought to be composed of several hundred km3 of gabbros that have probably accumulated over the lifetime of the volcano. The Skaftarkatlar subglacial geothermal areas are not associated with major anomalous bodies in the upper crust. The central volcanoes of Vonarskarð and Hagöngur belong to the same volcanic system; this also applies to Barðarbunga and Hamarinn, and Grimsvötn and Þórðarhyrna. None of the smaller of the two volcanoes sharing a system (Hagöngur, Hamarinn and Þórðarhyrna) is associated with distinct gravity anomalies and clear caldera structures have not been identified. However, ridges in the gravity field extend between each pair of central volcanoes, indicating that they are connected by dense dyke swarms. This suggests that when two central volcanoes share the same system, one becomes the main pathway for magma, forming a long-lived crustal magma chamber, a caldera and large volume basic intrusive bodies in the upper crust. Short residence times of magma in the crust beneath these centres favour essentially basaltic volcanism. In the case of the second, auxillary central volcano, magma supply is limited and occurs only sporadically. This setting may lead to longer residence times of magma in the smaller central volcanoes, favouring evolution of the magma and occasional eruption of rhyolites. The eastern margin of the Eastern Volcanic Zone is marked by a NE-SW lineation in the gravity *field, probably caused by accumulation of low density, subglacially erupted volcanics within the volcanic zone. This lineation lies 5-10 km to the east of Grimsvötn.*

Guðmundsson, M.T., Larsen, G., Björnsson, H., and Sigmundsson, F. (2000) "Comment; subglacial eruptions and synthetic aperture radar images": EOS Transactions, American Geophysical Union, v. **81**: p. 134-135.

Guttormsson, H. (1993) Við rætur Vatnajökuls:byggðir, fjöll og skriðjöklar: Reykjavík.

Guttormsson, H., and Sigurðsson, O. (1997) Leyndardómar Vatnajökuls. Víðerni, fjöll og byggðir. Stórbrotin náttúra, eldgos og jökulhlaup.: Reykjavík Fjöll og firnindi.

Hafliðason, H., Eiríksson, J., and VanKreveld, S. (2000) "The tephrochronology of Iceland and the North Atlantic region during the Middle and Late Quaternary: a review": Journal of Quaternary Science v. **15**: p. 3-22.

The tephrochronology of Iceland and the North Atlantic region is reviewed in order to construct a unified framework for the last 400 kyr BP. Nearly all of the tephra layers described are also characterised geochemically. A number of new tephra layers are analysed for the first time for their geochemical signature and a number of pre-Holocene tephra layers have been given an informal denotation. The tephrostratigraphy of Ash Zone II is highlighted. Where possible the rhyolitic tephra layers found outside Iceland have been correlated to known Icelandic tephra layers or to the volcanic source area. The application of tephra fallout in various depositional environments is described and discussed

Harris, T.D. (2000) "Land of Ice and Fire": Earthwatch Journal, v. **19**(3): p. 30-33.

Helgason, E., Þórðarson, S., and Jónsson, S. (1937) Austur-Skaftafellssýsla.

Helland, H. (1883) "Om Vulkaner i og under Jökler på Island og om Jökulhlaup": Nordisk Tidskrift, v. **6**: p. 368-387.

Jonsson, S., Adam, N., and Bjornsson, H. (1998) "Effects of subglacial geothermal activity observed by satellite radar interferometry": Geophysical Research Letters, v. **25**(7): p. 1059-1062.

We use one day Synthetic Aperture Radar (SAR) interferograms from data of the Earth Remote Sensing Satellites ERS-1 and ERS-2 to study ice how and uplift of two surface depressions within the Vatnajokull ice cap, Iceland. The ice cauldrons are created by melting at subglacial geothermal areas. Meltwater accumulates in a reservoir under the cauldrons over 2 to 3 years until it drains in a jökulhlaup under the ice dam surrounding the reservoir. The ice surface in the depressions drops down by several tens of meters during these draining events but rises again, as ice flows into the depressions, until a jökulhlaup occurs again. Using SAR interferograms we quantify an uplift rate of about 2 to 18 cm/day within the jokulhlaup cycle varying with *the surface slope of the depressions. The uplift rate is high during the first months after a jökulhlaup when the cauldron is relatively deep with steep slopes, but the uplift rate decreases as the cauldron is gradually filled. A simple axisymmetric model simulating the ice-flow into one of the depressions describes quantitatively the filling rate of the cauldron and qualitatively the shape of the ice flow field. The best-fit model has an ice flow law parameter Ao that is about one order of magnitude lower than typically estimated for temperate glaciers.*

Jónsson, E. (2004) Í veröld jökla, sanda og vatna, *in* Björnsson, H., ed., Jöklaveröld, náttúra og mannlíf: Reykjavík, Skrudda, p. 11-86.

Jónsson, J. (1961) "Some observations on the occurrence of sideromelane and palagonite": Uppsala, Univ., Geol. Inst., B., v. **40**: p. 81-86.

Kjartansson, G. (1959) "The Moberg Formation: II In: Thorarinsson, S. (ed.) On the geology and geomorphology of Iceland": Geografiska Annaler, v. **41**: p. 139-143.

Lacasse, C., Sigurdsson, H., Carey, S., Paterne, M., and Guichard, F. (1996) "North Atlantic deep-sea sedimentation of Late Quaternary tephra from the Iceland hotspot": Marine Geology, v. **129**(3-4): p. 207-235.

Piston cores recovered from the North Atlantic were used to study the sedimentation of Holocene and Pleistocene volcanic ash in the Irminger and Iceland Basins. Ash Zones 1 (≈ 11,100 yr B.P.), 2 (≈ 55,000 yr B.P.) and 3 (≈ 305,000 yr B.P.) were identified from their major element glass composition. The silicic and alkalic Ash Zones 1 and 2 originate from the Southeastern Volcanic Zone of Iceland, where they correlate with the Sólheimar ignimbrite from Katla volcano and the Thórsmörk ignimbrite from Tindfjallajökull volcano, respectively. The low-alkali composition of silicic Ash Zone 3 indicates a source from one of the silicic centers in the active rift system. Ash Zones 2 and 3 occur in the Irminger Basin as dispersed glass shards over a depth interval of several tens of centimeters. Their compositional and granulometric characteristics reflect an initial fallout on pack-ice north of Iceland, followed by ice-rafting sedimentation in the Denmark Strait, prior to bioturbation. δ18O stratigraphy of foraminifera in the cores indicates that the ash zones were deposited during a cold interval, at the time when seas north of Iceland were ice-covered. Sedimentary features indicate that turbidity currents were also involved in the dispersal of Ash Zones 1 and 2 south of Iceland. The initiation of these gravity currents from the shelf can be attributed to either glacier bursts (jökulhlaups) carrying tephra, or the entrance of pyroclastic flows into the ocean.

Langley, K. (2000) A morphological investigation of volcanic activity beneath Vatnajökull, Iceland, interpreted from radio echo sounding data [**MSc thesis**]: Reykjavík, Háskóla Íslands.

Larsen, G. (2000) The icebreakers: Historical eruptions of subglacial volcanoes in Iceland, Volcano/ice interaction on Earth and Mars: Abstracts: Reykjavík, Iceland, p. 13-15.

— (2002) A brief overview of eruptions from ice-covered and ice-capped volcanic systems in Iceland during the past 11 centuries: frequency, periodicity and implications, *in* Smellie, J.L., and Chapman, M.G., eds., Volcano-Ice Interactions on Earth and Mars, Special Publications 202: London, Geological Society, p. 81-90.

Larsen, G., Gudmundsson, M.T., and Bjornsson, H. (1998) "Eight centuries of periodic volcanism at the center of the Iceland hotspot revealed by glacier tephrostratigraphy": Geology, v. **26**(10): p. 943-946.

A record of volcanic activity within the Vatnajökull ice cap has been obtained by combining data from three sources: tephrostratigraphic studies of two outlet glaciers, a 415-m-long ice core from northwestern Vatnajökull, and written records. The record extends back to A.D. 1200 and shows that the volcanic activity has a 130-140 yr period, Intervals of frequent eruptions with recurrence times of three to seven years alternate with intervals of similar duration having much lower eruption frequency, In comparison with other parts of the plate boundary in Iceland, eruption frequency is greater, episodes of unrest are longer, and intervals of low activity are shorter. The high eruption frequency may be the result of a more sustained supply of magma, owing to the area's location above the center of the Iceland mantle plume. When combined with historical data on eruptions and earthquakes, our data indicate that rifting-related activity in Iceland as a whole is periodic and broadly in phase,vith the volcanic activity within Vatnajokull.

Larsen, G., Gudmundsson, M.T., and Björnsson, H. (2004) Chronology of eruptions in ice-covered volcanic systems: Eruptions within the Vatnajökull glacier, Iceland, IAVCEI General Assembly: Abstracts: Pucon, Chile.

— (2005) "Increased eruption frequency in volcanoes below Vatnajökull ice cap, Iceland, predicted by tephrochronology": Geophysical Research Abstracts, v. **7**(10066).

Larsen, G., and Guðmundsson, M.T. (1997) Gos í eldstöðvum undir Vatnajökli eftir 1200 AD., *in* Haraldsson, H., ed., Vatnajökull. Gos og hlaup 1996: Reykjavík, Vegagerðin, p. 23-36.

Larsen, G., Guðmundsson, M.T., and Björnsson, H. (1996) Gjóskulög í Tungnaárjökli: gossaga, aldur íss og dvalartími gjósku í jökli, Vorráðstefna 1996: "Eldgos í Vatnajökli 1996", ágrip erinda og veggspjalda: Reykjavík, Jarðfræðafélag Íslands, p. 33-35.

— (1997) Gos í eldstöðvum undir Vatnajökli á sögulegum tíma: Vitnisburður gjóskulaga og ritaðra heimilda, Vorráðstefna 1997: "Eldgos í Vatnajökli 1996", ágrip erinda og veggspjalda: Reykjavík, Jarðfræðafélag Íslands, p. 7-9.

— (1997) Gos í eldstöðvum undir Vatnajökli á sögulegum tíma: vitnisburður gjóskulaga og ritaðra heimilda, Vorráðstefna 1997: ágrip erinda: Reykjavík, Jarðfræðifélag Íslands.

— (2004) "Elldr uppi i iij stodum fyrir sunnan". Gjóskulög og eldgos í Vatnajökli, Raunvísindaþing 2004: Reykjavík, p. 58.

Loftsson, M. (1999) Rit um jarðelda á Íslandi: Þorlákshöfn, Halla Kjartansdóttir.

Maclennan, J., Jull, M., McKenzie, D., Slater, L., and Grönvold, K. (2002) "The link between volcanism and deglaciation in Iceland": GEOCHEMISTRY GEOPHYSICS GEOSYSTEMS, v. **3**(11, 1062): p. 1-25.

Temporal variation in the eruption rate and lava composition in the rift zones of Iceland is associated with deglaciation. Average eruption rates after the end of the last glacial period, ~12 kyr BP, were up to 100 times higher than those from both the glacial period and recent times (<5 kyr BP). This peak in volcanic activity finished less than 2 kyr after the end of deglaciation. New geochemical data from ~80 basalt and picrite samples from the Theistareykir and Krafla volcanic systems show that there is a temporal variation in both the major and trace element composition of the eruptions. Early postglacial eruptions show a greater range in MgO contents than eruptions from other times, and at a fixed MgO content, the concentration of incompatible elements in subglacial eruptions is higher than that in early postglacial eruptions. Recent eruptions from the Krafla system have similar compositions to subglacial eruptions. The high eruption rates and low rare earth element (REE) concentrations in the lava from early postglacial times can be accounted for by increased melt generation rates in the shallow mantle caused by unloading of an ice sheet. Magma chamber processes such as crystallization and assimilation can produce the temporal variation in REE contents if garnet is present. However, garnet is not observed as a phenocryst or xenocryst phase and is not required to match the variation in major element contents observed at Krafla and Theistareykir. If the increase in eruption rates reflects increased melt production rates in the mantle, then the relative timing of deglaciation and the burst in eruption rates can be used to estimate the rate of melt transport in the mantle. The observed duration of enhanced eruption rates after deglaciation can be reproduced if the vertical melt extraction velocity is >50 m yr−1.

Moore, J.G., and Calk, L.C. (1991) "Degassing and differentiation in subglacial volcanoes, Iceland": Journal of Volcanological and Geothermal Research, v. **46**(1-2): p. 157-180.

Within the neovolcanic zones of Iceland many volcanoes grew upward through icecaps that have subsequently melted. These steep-walled and flat-topped basaltic subglacial volcanoes, called tuyas, are composed of a lower sequence of subaqueously erupted, pillowed lavas overlain by breccias and hyaloclastites produced by phreatomagmatic explosions in shallow water, capped by a subaerially erupted lava plateau. Glass and whole-rock analyses of samples collected from six tuyas indicate systematic variations in major elements showing that the individual volcanoes are monogenetic, and that commonly the tholeiitic magmas differentiated and became more evolved through the course of the eruption that built the tuya. At Herðubreið, the most extensively studies tuya, the upward change in composition indicates that more than 50 wt.% of the first erupted lavas need crystallize over a range of 60°C to produce the last erupted lavas. The S content of glass commonly decreases upward in the tuyas from an average of about 0.08 wt.% at the base to < 0.02 wt.% in the subaerially erupted lava at the top, and is a measure of the depth of water (or ice) above the eruptive vent. The extensive subsurface crystallization that generates the more evolved, lower-temperature melts *during the growth of the tuyas, apparently results from cooling and degassing of magma contained in shallow magma chambers and feeders beneath the volcanoes. Cooling may result from percolation of meltwater down cracks, vaporization, and cycling in a hydrothermal circulation. Degassing occurs when progressively lower pressure eruption (as the volcanic vent grows above the ice/water surface) lowers the volatile vapour pressure of subsurface melt, thus elevating the temperature of the liquidus and hastening liquid-crystal differentiation.*

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Pálsson, F., Guðmundsson, S., and Björnsson, H. (2006) The impact of volcanic and geothermal activity on the mass balance of Vatnajökull, Third international symposium on ice-volcano interaction: Reykjavík, Iceland.

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Thoroddsen, T. (1915) "Vulkaniske Udbrud i Vatnajökull paa Island": Geografisk Tidsskrift, v. **23**: p. 118-132.

Thoroddsen, o. (1908-1922) Eldgos í Vatnajökli, Lýsing Íslands: Kaupmannahöfn, Hið íslenska bókmenntafélag, p. 159-165.

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Thorseth, I.H., Furnes, H., and Tumyr, O. (1991) "A textural and chemical study of Icelandic palagonite of varied composition and its bearing on the mechanism of the glass-palagonite transformation": Geochim Cosmochim Acta, v. **55**: p. 731-749.

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5.9 Sprungugos

5.9.1 Vatnaöldur

Larsen, G. (1994) Gjóskulagatímatal og leiðarlög frá Eldgjárgosi og Vatnaöldugosi, RH-25-94: Reykjavik, Science Institute, p. 20.

5.9.2 Veiðivötn

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Detailed description of these lakes west of Vatnajökull, Iceland, including formation, discharge and biology

Björnsson, H., and Einarsson, P. (1990) "Volcanoes beneath Vatnajökull, Iceland: Evidence from radio echo-sounding earthquakes and jökulhlaups": Jökull, v. **40**: p. 147-168.

Integration of knowledge of subglacial topography, earthquake activity and jökulhlaups has contributed to more precise locations of the volcanic systems beneath Vatnajökull.

Bárðarbunga is the centre of a volcanic system which includes the fissure swarms of Veiðivötn to the SW and Dyngjuháls to the NE. The Grímsvötn volcano is the centre of a system that comprises the Laki fissure swarm in the SW and extends for an unknown distance to the NE of the volcano. Þórðarhyrna is probably a separate central volcano within this system. The Kverkfjöll system can be traced 10 km to the SW of the Kverkfjöll volcano. It appears to be separated from the Grímsvötn volcano. The Askja fissure swarm extends beneath Dyngjujökull and can possibly be traced to the Grímsvötn volcano. Hamarinn and the ridge striking eastward from Hamarinn (Loki Ridge) are central volcanoes which together with the Fögrufjöll fissure swarm form a volcanic system. No support can be found in the topographic data for the existence of a central volcano near Breiðabunga. Volcanic activity in historical times has mainly been limited to the Grímsvötn and Bárðarbunga systems. Major rifting events have affected large sections of these volcanic systems but both have been remarkably quiet for the past decades. A few volcanic events are presumed to have occurred on the Hamarinn - Loki system and on the Askja fissure swarm beneath Dyngjujökull, but no event is known with certainty on the Kverkfjöll system. The rivers Skeiðará and Súla have the most frequent eruption-related jökulhlaups. They receive meltwater from the Grímsvötn caldera and the area to the SW of it, including Þórðarhyrna. Núpsvötn, Djúpá and Hverfisfljót drain the southwestern part of the Grímsvötn system, an area bounded by Þórðarhyrna, Geirvörtur, Hágöngur and Pálsfjall. Skaftá drains the Loki Ridge and the area west of Grímsvötn. Jökulhlaups in Kaldakvísl, and ultimately Þjórsá, must originate in the Bárðarbunga or the Hamarinn - Loki systems, and the only possible source for volcanic jökulhlaups in Skjálfandafljót is the northern part of the Bárðarbunga system. Jökulsá á Fjöllum may drain meltwater from activity in all the volcanic systems in northern Vatnajökull: Bárðarbunga, the Askja fissure swarm and Kverkfjöll. This includes the voluminous, ice-filled calderas of Bárðarbunga and Kverkfjöll. Activity in the northern part of the Grímsvötn system may cause floods in Jökulsá á Fjöllum. Meltwater from volcanic activity on the SE flank of a ridge that strikes south from Kverkfjöll may drain to Jökulsá á Brú. Volcanic activity farther north on the E flanks of this ridge would cause floods in Kreppa.

Blake, S. (1984) "Magma mixing and hybridization processes at the alkalic, silicic, Torfajökull central volcano triggered by tholeiitic Veiðivötn fissuring, south Iceland": Journal of Volcanology and Geothermal Research, v. **22**(1-2): p. 1-31.

Around 19°W64°N19, in the Eastern Volcanic Zone of south Iceland, the southwestern extremity of the tholeiitic Veiðivötn fissure swarm abuts the northern periphery of the mildly alkaline silicic central volcano Torfajökull. Effusive mixed-magma eruptions in this area have been initiated by crustal rifting associated with lateral injection of tholeiitic magma into the rhyolitic Torfajökull chamber. Mixed rocks, in which cm- to dm-sized mafic inclusions constitute ~ 10% of the rhyolite lava are distinguished from hybrid rocks which are thorough mixtures having an homogeneous fabric.Mapping of the Domadalshraun lava (0.05-0.1 km3) reveals the early eruption of hybrid spatter and lava followed by less thoroughly blended mixed lava. Geochemical study discloses the participation of three end-members. Plagioclase-phyric tholeiite containing ~ 10-20% pl + cpx + o1 precipitated at ~ 1140-1160[deg]C is typical of the Veiðivötn component. The Torfajökull rhyolite contains ~ 10% crystals, dominantly anorthoclase and oligoclase, and is found to be compositionally zoned. Early-late trends include SiO2: 71.6-70.1%, A.I.: 1.07-0.86, Sr: 61-86 ppm and result from feldspar fractionation. The third end-member is a transitional alkali basaltic andesite ([identical to] hawaiite) belonging to the mafic magma suite associated with Torfajökull. This intermediate magma resided at depth within the stratified Torfajökull chamber and

contains xenocrystic feldspars which have settled out of the differentiating rhyolite. The calculated positions in tholeiite-rhyolite-basaltic andesite composition space of eight hybrid rocks show that hybridization was not a random process. No rhyolite/transitional alkali hybrids are present. The only two tholeiite/transitional alkali hybrids are both 0.45/0.55 blends of these two end-members. No rhyolite-bearing hybrid contains more than 20% transitional alkali magma. It is proposed that rhyolite/tholeiite hybrids are most likely to be generated where a shallow tholeiitic fissure has been laterally intruded into and above the roof of the rhyolitic chamber. Near the top of the fissure, tholeiite containing excess water may have been sufficiently vesicular for its bulk density to equal that of the rhyolitic magma. Calculations identify this critical depth as 0.75-1 km-coincident with calculated quenching pressures of small vesicular tholeiitic clots in the mixed lavas (assuming 1 wt.% water). Dense tholeiite at deeper levels in the dyke collapses into the chamber and is replaced by buoyantly rising rhyolite. Hybridization ensues where the rhyolite and vesicular tholeiite come together in the fissure. These and other relative-density controlled processes account for the selective nature of the hybridization process and the order in which hybrid and mixed magmas were erupted.The late 15th century Laugahraun and Sudurnamshraun flows at Landmannalaugar reveal participation of only tholeiitic and rhyolitic end-members. Hybrids are poorly represented and it is hypothesized that this is due to the deep ([greater-than or equivalent to] 1 km) intrusion of undersaturated tholeiite, which leads to the generation of mixed rather than hybrid magmas.These and other tholeiite/rhyolite mixed-magma eruptions in the area were triggered by lateral flow of tholeiite from the Veidivotn system, initiated by the overfilling of the Veiðivötn magma chamber, 40 km to the NE, in the style recognized at Krafla and elsewhere in Iceland. Future concern over any renewed activity in Veiðivötn should not, therefore, prohibit consideration of rhyolitic or mixed-magma eruptions being induced in the Torfajokull region.

Guðmundsson, A.T. (1986) Íslandseldar : eldvirkni á Íslandi í 10.000 ár Reykjavík, Vaka-Helgafell, 168 s. : myndir, teikn., kort, línurit, töflur p.

Guðmundsson, A.T., and (1996) Volcanoes in Iceland : 10.000 years of volcanic history: Reykjavík, Vaka-Helgafell, 136 s. : myndir, teikn., kort, töflur p.

Guðmundsson, M.T., and Högnadottir, Þ. (2007) "Volcanic systems and calderas in the Vatnajökull region, central Iceland: Constraints on crustal structure from gravity data": Journal of Geodynamics, v. **43**(1): p. 153-169.

A Bouguer anomaly map is presented of southern central Iceland, including the western part of Vatnajökull and adjacent areas. A complete Bouguer reduction for both ice surface and bedrock topography is carried out for the glaciated regions. Parts of the volcanic systems of Vonarskarð-Hágöngur, Barðarbunga-Veiðivötn, Grimsvötn-Laki, and to a lesser extent Kverkfjöll, show up as distinct features on the gravity map. The large central volcanoes with calderas: Vonarskarð, Barðarbunga, Kverkfjöll and Grimsvötn, are associated with 15-20 mGal gravity highs caused by high density bodies in the uppermost 5 km of the crust. Each of these bodies is thought to be composed of several hundred km3 of gabbros that have probably accumulated over the lifetime of the volcano. The Skaftarkatlar subglacial geothermal areas are not associated with major anomalous bodies in the upper crust. The central volcanoes of Vonarskarð and Hagöngur belong to the same volcanic system; this also applies to Barðarbunga and

Hamarinn, and Grimsvötn and Þórðarhyrna. None of the smaller of the two volcanoes sharing a system (Hagöngur, Hamarinn and Þórðarhyrna) is associated with distinct gravity anomalies and clear caldera structures have not been identified. However, ridges in the gravity field extend between each pair of central volcanoes, indicating that they are connected by dense dyke swarms. This suggests that when two central volcanoes share the same system, one becomes the main pathway for magma, forming a long-lived crustal magma chamber, a caldera and large volume basic intrusive bodies in the upper crust. Short residence times of magma in the crust beneath these centres favour essentially basaltic volcanism. In the case of the second, auxillary central volcano, magma supply is limited and occurs only sporadically. This setting may lead to longer residence times of magma in the smaller central volcanoes, favouring evolution of the magma and occasional eruption of rhyolites. The eastern margin of the Eastern Volcanic Zone is marked by a NE-SW lineation in the gravity field, probably caused by accumulation of low density, subglacially erupted volcanics within the volcanic zone. This lineation lies 5-10 km to the east of Grimsvötn.

Kaldal, I., Vilmundardóttir, E.G., and Larsen, G. (1988) Jarðgrunnskort Sigalda-Veiðivötn, 3340 J, 1:50.000: Reykjavík, Orkustofnun, Vatnsorkudeild, og Landsvirkjun.

Larsen, G. (1982) Volcanic history and prediction: The Veidivötn area, southern Iceland, IAVCEI-IAGC Scientific Assembly: Reykjavík, p. 118.

— (1984) "Recent volcanic history of the Veidivötn fissure swarm, southern Iceland-an approach to volcanic risk assessment": Journal of volcanology and geothermal research, v. **22**(1-2): p. 33-58.

The recent volcanic history of the southwestern part of the Veiðivötn fissure swarm, southern Iceland, provides a basis for assessment of volcanic risk in an area of large hydropower potential. Local tephrastratigraphy and regional tephrochronology provide relative and absolute dating of individual eruptions as well as information on the volume and distribution of the products formed in each eruption. Three large eruptions took place in this area in 1480 A.D., 900 A.D. and 150 A.D., respectively. Each eruption produced approx. 1 km3 (DRE) of basaltic, and minor amounts of silicic lava and tephra on fissures up to 42 km long. No evidence is found of smaller eruptions during this period. The estimated eruption frequency, one eruption every 600–800 years, implies that this part of the Veidivötn fissure swarm is inactive for long periods between relatively large volcanic events. A change in the mode of eruption from effusive to explosive took place during this period. The hazards posed by this area include far-reaching lava flows, widespread heavy tephra fall with thicknesses in excess of 2 m at distances of 10 km, and damming of a large glacial river with the consequent formation of unstable lakes. A volcano-tectonic model, which explains the observed eruption frequency and provides a basis for a long-term monitoring program, is proposed. Eruptions on the Veidivötn fissure swarm are interpreted as corollaries of rifting episodes initiated in the Bárdarbunga central volcano. Volcano-tectonic episodes affect the fissure swarm at an average interval of 100 years. Minor episodes are limited to the central volcano and adjacents parts of the fissure swarm. During the less frequent major episodes, rifting and volcanic activity extends to the extreme southwestern part of the fissure swarm. Seismic monitoring of the Bárdarbunga central volcano could provide an early warning of renewed activity on the Veidivötn fissure *swarm. A major rifting episode resulting in eruption on its southwestern part can be expected during the next 100 to 300 years.*

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— (2005) "Explosive volcanism in Iceland: Three examples of hydromagmatic basaltic eruptions on long volcanic fissures within the past 1200 years": Geophysical Research Abstracts, v. **7**(10158).

Larsen, G., and Dugmore, A. (2001) Unstable tephra dammed lakes in the Veiðivötn volcanic area, Iceland, Earth System Processes: Abstracts: Edinburgh, p. 44.

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Vilmundardóttir, E.G., and Larsen, G. (1986) Productivity Pattern of the Veidivötn Fissure Swarm, South Iceland, in Postglacial Time, 17e Nordiska Geologmötet: Abstracts: Helsingfors, Finland, p. 214.

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5.9.3 Eldgjá

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— (1999) The Lakagígar crater row; Katla volcanic system and Eldgjá fissure; Hekla, *in* Arnórsson, S., and Gíslason, S.R., eds., The Fifth International Symposium on the Geochemistry of the Earths Surface Field Guide: Iceland, p. 27-28, 38-40, 51-53.

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Þórdarson, T., Miller, D.J., Larsen, G., Self, S., and Sigurðsson, H. (2001) "New estimates of sulfur degassing and atmospheric mass-loading by the 934 AD Eldgjá eruption, Iceland": Journal of Volcanology and Geothermal Research, v. **108**(1-4): p. 33-54.

The 934 AD Eldgjá basaltic flood lava eruption in southern Iceland is the largest on Earth in the last millennium. The Eldgjá fissures produced 19.6 km3 of transitional basalt in a prolonged eruption that featured at least eight distinct episodes and may have lasted for 3-8 years. The atmospheric SO2 mass loading by Eldgjá is determined by new measurements of pre-eruption and residual sulfur contents in the products from all phases of the eruption. A pre-eruption sulfur content of ~2150 ppm indicates that the magma carried 232 Mt of SO2 to the surface, where vent and lava flow degassing released 219 Mt into the atmosphere. This value corresponds to a potential H2SO4-aerosol yield of ~450 Mt, increasing previous H2SO4-aerosol mass estimates by a

factor of 2.6-4.5. Approximately 79% of the original sulfur mass was released at the vents, indicating ~185 Mt SO2 were discharged into the atmosphere above the Eldgjá fissures and carried aloft by the eruption columns to upper tropospheric and lower stratospheric altitudes (~15 km). Consequently, only ~35 Mt SO2 escaped from the lava into the lower troposphere. These estimates of the SO2 mass loading from Eldgjá make it the greatest known volcanic pollutant of recent history, exceeding that of 1783 AD Laki and 1815 AD Tambora eruptions by factors of 1.8 and 2.0-2.8, respectively. However, the intensity of climatic effects deduced by the Eldgja event are not thought to have surpassed that of Laki or Tambora because the eruption was prolonged and subsequently the sulfur emissions were drawn out over several years. The lack of detailed historic records for this period make estimates of the effects of long term but significant release of SO2 (30-70 Mt/yr) on the atmosphere uncertain.

5.9.4 Laki

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Guðmundsson, A.T. (1986) Íslandseldar : eldvirkni á Íslandi í 10.000 ár Reykjavík, Vaka-Helgafell, 168 s. : myndir, teikn., kort, línurit, töflur p.

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Þórðarson, Þ. (1990) Skaftáreldar 1783-1785. Gjóskan og framvinda gossins: Reykjavík, Háskóli Íslands.

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— (2001) "Real-time observations of the Laki sulfuric aerosol cloud in Europe during 1783 as documented by Professor S. P. van Swinden at Franeker, Holland." Jökull v. **50**: p. 65-72.

Þórdarson, Self, S., Óskarsson, N., and Hulsebosch, T. (1996) "Sulfur, chlorine, and fluorine degassing and atmospheric loading by the 1783-1784 AD Laki (Skaftár Fires) eruption in Iceland": Bulletin of Volcanology, v. **58**: p. 205-225.

The 1783-1784 Laki tholeiitic basalt fissure eruption in Iceland was one of the greatest atmospheric pollution events of the past 250 years, with widespread effects in the northern hemisphere. The degassing history and volatile budget of this event are determined by measurements of pre-eruption and residual contents of sulfur, chlorine, and fluorine in the products of all phases of the eruption. In fissure eruptions such as Laki, degassing occurs in two stages: by explosive activity or lava fountaining at the vents, and from the lava as it flows away from the vents. Using the measured sulfur concentrations in glass inclusions in phenocrysts and in groundmass glasses of quenched eruption products, we calculate that the total accumulative atmospheric mass loading of sulfur dioxide was 122 Mt over a period of 8 months. This volatile release is sufficient to have generated ~250 Mt of H2SO4 aerosols, an amount which agrees with an independent estimate of the Laki aerosol yield based on atmospheric turbidity measurements. Most of this volatile mass (~60 wt.%) was released during the

first 1.5 months of activity. The measured chlorine and fluorine concentrations in the samples indicate that the atmospheric loading of hydrochloric acid and hydrofluoric acid was ~7.0 and 15.0 Mt, respectively. Furthermore, ~75% of the volatile mass dissolved by the Laki magma was released at the vents and carried by eruption columns to altitudes between 6 and 13 km. The high degree of degassing at the vents is attributed to development of a separated two-phase flow in the upper magma conduit, and implies that high-discharge basaltic eruptions such as Laki are able to loft huge quantities of gas to altitudes where the resulting aerosols can reside for months or even 1-2 years. The atmospheric volatile contribution due to subsequent degassing of the Laki lava flow is only 18 wt.% of the total dissolved in the magma, and these emissions were confined to the lowest regions of the troposphere and therefore important only over Iceland. This study indicates that determination of the amount of sulfur degassed from the Laki magma batch by measurements of sulfur in the volcanic products (the petrologic method) yields a result which is sufficient to account for the mass of aerosols estimated by other methods.

5.9.5 Sprungugos, ekki skilgreint nánar hvar

Jónsson, J. (1979) "Eldstöðvar og hraun í Skaftfellsþingi": Náttúrufræðingurinn, v. **48. árg**(3-4 hefti): p. 196-232.

Larsen, G. (1977) Þrjú stór sprungugos á Suðausturgosbelt, Ráðstefna um íslenska jarðfræði, ágrip erinda: Reykjavík, Jarðfræðafélag Íslands, p. 14.

Loftsson, M. (1999) Rit um jarðelda á Íslandi: Þorlákshöfn, Halla Kjartansdóttir.

Piper, J.D.A. (1979) "Outline volcanic history of the region west of Vatnajokull, Central Iceland": Journal of Volcanology and Geothermal Research, v. **5**(1-2): p. 87-98.

This paper outlines the structure and volcanic geology of a 25 x 50 km region of central Iceland including part of the eastern neovolcanic zone and its western margin. It includes an extinct Brunhes epoch silicic centre, the Hagangas, offset en echelon from a zone of major postglacial basaltic activity forming a northeasterly extension of the Torfajokull centre. Stratigraphic subdivisions restricted to the last 690,000 years comprise, in order of decreasing age, interglacial flood tholeiites, major centres of intraglacial hyaloclastite eruption, and postglacial lavas, which are mostly olivine basalts. The Hagangas centre and interglacial tholeiites lie on crust predominantly of Matuyama age (0.69-2.30 m.y.) but the bulk of the present volcanic activity may be taking place through crust belonging entirely to the present polarity epoch; this latter zone is characterised by normal faulting and extensive hydrothermal alteration. The widespread hydrothermal alteration and voluminous basaltic eruption distinguish this neovolcanic zone from the western zone, and the relationship of the region to growth of the upper crust in Iceland is briefly discussed.

5.10 Heitur reitur, möttulstrókur (hot spot, mantle plume)

Allen, R.M. (2001) The mantle plume beneath Iceland and its interaction with the North-Atlantic Ridge: a seismological investigation, Princeton University.

Allen, R.M., Nolet, G., Morgan, W.J., Vogfjörð, K., and Bergsson, B.H. (1999) "The thin hot plume beneath Iceland": International Geophysical Journal, v. **137**: p. 51-63.

Björnsson, S. (1967) "Iceland and Mid-Ocean Ridges : report of a symposium held in Reykjavík February 27 to March 8, 1967, under the sponsorship of the Geoscience Society of Iceland / edited by Sveinbjörn Björnsson": Societas Scientiarum Islandica (Vísindafélag Íslendinga) v. **Rit 38**: p. 209 s., [1] mbl., [1] kortabl. br. : myndir, kort, línurit, töflur.

Efni: Early history of the Scandic area and some chapters of the geology of Iceland / Trausti Einarsson: s. 13-28. - The Icelandic basalt plateau and the question of sial / Haraldur Sigurdsson: s. 32-46. - Chemistry of basalts from the Icelandic rift zone / Gudmundur E. Sigvaldason: s. 50-51. - Volcanic forms at the sea bottom / Gudmundur Kjartansson: s. 53-64. - Upper crustal structure in Iceland / Gudmundur Pálmason: s. 67-78. - Some problems of seismological studies on the Mid-Atlantic Ridge / Ragnar Stefánsson: s. 80-89. - Aeromagnetic surveys of Iceland and its neighbourhood / Thorbjörn Sigurgeirsson: s. 91-96. - Magnetic anomalies / Gudmundur Gudmundsson: s. 97-105. - Sub-crustal viscosity in Iceland / Trausti Einarsson: s. 109-110. - On heat flow in Iceland in relation to the Mid-Atlantic Ridge / Gudmundur Pálmason: s. 111-127 The Icelandic fracture system and the inferred causal stress field / Trausti Einarsson: s. 128-139. - The rift zone and the Reykjanes peninsula / Jón Jónsson: s. 142-147. - An outline of the structure of SW-Iceland / Kristján Sæmundsson: s. 151-159. - Dykes, fractures and folds in the basalt plateau of western Iceland / Haraldur Sigurdsson: s. 162-169. - The extent of the tertiary basalt formation and the structure of Iceland / Thorleifur Einarsson: s. 170-178. - Hekla's magma / Jens Tómasson: s. 180-188 Hekla and Katla / Sigurdur Thorarinsson: s. 190-197

Breddam, K. (2002) "Primitive melt from the Iceland mantle plume": Journal of Petrology, v. **43**: p. 345-373 (220).

This paper presents new geochemical data from Kistufell (64°48'N, 17°13'W), a monogenetic table mountain situated directly above the inferred locus of the Iceland mantle plume. Kistufell is composed of the most primitive olivine tholeiitic glasses found in central Iceland (MgO 10·56 wt %, olivine Fo89·7). The glasses are interpreted as near-primary, high-degree plume melts derived from a heterogeneous mantle source. Mineral, glass and bulk-rock (glass + minerals) chemistry indicates a low average melting pressure (15 kbar), high initial crystallization pressures and temperatures (10–15 kbar and 1270°C), and eruption temperatures (1240°C) that are among the highest observed in Iceland. The glasses have trace element signatures (Lan/Ybn <1, Ban/Zrn 0·55–0·58) indicative of a trace element depleted source, and the Sr–Nd–Pb isotopic ratios (87Sr/86Sr 0·70304–0·70308, 143Nd/144Nd 0·513058–0·513099, 206Pb/204Pb 18·343–18·361) further suggest a long-term trace element depletion relative to primordial mantle. High He isotopic ratios (15·3–16·8 R/Ra) combined with low 207Pb/204Pb (15·42–15·43) suggest that the mantle source of the magma is different from that of North Atlantic mid-ocean ridge basalt. Negative Pb anomalies,

and positive Nb and Ta anomalies indicate that the source includes a recycled, subducted oceanic crustal or mantle component. Positive Sr anomalies (Srn/Ndn = 1·39–1·50) further suggest that this recycled source component involves lower oceanic crustal gabbros. The 18O values (4·2–4·7), which are lower than those observed in mantle peridotites but similar to those observed in ophiolites and in situ oceanic gabbros, are consistent with this interpretation. The elevated 3He/4He ratios are primarily attributed to a primitive, relatively undegassed component in the Iceland mantle plume, which dominates the He isotope signature as a result of long-term depletion of U, Th and He in the recycled gabbroic component.

Burke, K., Kidd, W.S.F., and Tuzo Wilson, J. (1973) "Relative and Latitudinal Motion of Atlantic Hot Spots": Nature, v. **245**: p. 133-137.

Darbyshire, F.A., Bjarnason, I.T., White, R.S., and Flovenz, O.G. (1998) "Crustal structure above the Iceland mantle plume imaged by the ICEMELT refraction profile": Geophysical Journal International, v. **135**(3): p. 1131-1149.

The crustal structure of central Iceland is modelled using data from a 310 km long refraction profile shot during summer 1995. The profile traversed Iceland from the Skagi Peninsula an the north coast (surface rocks of age 8.5-0.8 Myr) to the southeast coast (surface rocks of age 8.5-3.3 Myr), crossing central Iceland (surface rocks of age 3.3-0 Myr) over the glacier Vatnajokull, below which the locus of the Iceland mantle plume is currently centred. The crustal thickness is 25 km at the north end of the profile, increasing to 38-40 km beneath southern central Iceland. The upper crust is characterized by seismic P-wave velocities from 3.2 to approximately 6.4 km s(-1). At the extreme ends of the profile, the upper crust can be modelled by a two-layered structure, within which seismic velocity increases with depth, with a total thickness of 5-6 km. The central highlands of Iceland have a single unit of upper crust, with seismic velocity increasing continuously with depth to almost 10 km below the surface. Below the central volcanoes of northern Vatnajokull, the upper crust is only 3 km thick. The lower-crustal velocity structure is determined from rays that turn at a maximum depth of 24 km below central Iceland, where the seismic velocity is 7.2 km s(-1). Below 24 km depth there are no first-arriving turning rays. The Moho is defined by P- and S-wave reflections observed from the shots at the extreme ends of the profile. P- to S-wave velocity ratios give a Poisson's ratio of 0.26 in the upper crust and 0.27 in the lower crust, indicating that, even directly above the centre of the mantle plume, the crust is well below the solidus temperature.

Du, Z.J., and Foulger, G.R. (2001) "Variation in the crustal structure across central Iceland": Geophysical Journal International, v. **145**(1): p. 246-264.

We determine the crustal structures beneath 12 broad-band seismic stations deployed in a swath across central Iceland along and around the ICEMELT explosion seismic profile by combining teleseismic receiver functions, surface wave dispersion curves and the waveforms of a large, local event in Iceland. By using teleseisms that approach fi om different backazimuths, we study lateral structural variability out of the line of the ICEMELT profile. Beneath Tertiary areas, the thickness of the upper crust, as defined by the 6.5 km s(-1) velocity horizon, is similar to8 km and the depth to the base of the lower crust, as defined by the 7.2 km s(-1) velocity horizon, is similar to 29-32 km. Beneath the currently active rift zone the upper crust thins to similar to 6.0 km and the *depth to the base of the lower crust increases to similar to 35-40 km. A substantial low-velocity zone underlies the Middle Volcanic Zone in the lower crust, which may indicate anomalously high geothermal gradients there. This suggests that the large-scale thermal centre of the hotspot may be more westerly than northwest Vatnajokull, where it is generally assumed to lie. Simplified description of the results notwithstanding, there is substantial variability in the overall style of crustal structure throughout Iceland, and a clear, tripartite division into upper and lower crusts and a sharp Moho is poorly supported by many of our results. The nature, distinctiveness and continuity of the Moho is variable and in many areas the crust-mantle transition is a zone with enhanced velocity gradients several kilometres thick.*

— (2004) "Surface wave waveform inversion for variation in upper mantle structure beneath Iceland": Geophysical Journal International, v. **157**(1): p. 305-314.

We study the structure of the upper mantle beneath Iceland using surface wave waveforms recorded at pairs of stations lying approximately on the same great circles as the sources used. We invert for local, path-average V-s variations between the station pairs. The method used in this study is an extension of an algorithm proposed by Kushnir et al. (1989), which uses only the phase of the seismograms. In our waveform inversion not only the phases but also the amplitudes of the surface waves are used as structural constraints. We illustrate the resolution power of the new algorithm with synthetic examples. We apply the method to study upper mantle structure beneath Iceland using recordings of three events with northerly, southsouthwesterly and easterly orientated paths and 19 station pairs. Depending on the separation distance of the stations, we invert waveforms in the frequency range 0.0166-0.08 Hz and 0.01-0.08 Hz. Resolution is limited by the penetration depth of the surface wave fundamental mode, and is good down to similar to 150 km for the narrower frequency band and similar to200 km for the wider band. Although the inversions of the differential waveforms only provide information on lateral V-s variations between station pairs, the main structural features of the upper mantle beneath Iceland are retrieved. We confirm that the strongest negative V-s anomalies of up to similar to -5 per cent underlie central Iceland, and extend down to the limit of our resolution at similar to200 km. The rift zones away from central Iceland are underlain by low velocities in the depth range similar to50-100 km and high velocities below this, indicating that they are shallowly sourced. Such a structure also underlies northwest Vatnajokull, where a mantle plume is traditionally assumed to lie. Beneath intraplate areas, mantle structural variations are small. Using our method, smaller-scale mantle structures are detectable than is possible with teleseismic tomography, which tends to smear anomalies throughout larger volumes.

Einarsson, P., Brandsdóttir, B., Guðmundsson, M., Björnsson, H., Grönvold, K., and Sigmundsson, F. (1997) "Centre of Iceland's hotspot experiences unrest": Eos, Transactions, American Geophysical Union, v. **78**(35): p. 369, 374-375.

Einarsson, T. (1967) The Extent of the Tertiary Basalt Formation and the Structure of Iceland, *in* Björnsson, S., ed., Societas Scientiarum Islandica 38: Iceland and Mid-Ocean Ridges: Reykjavík, Vísindafélag Íslendinga, p. 170-177.

Elliott, T.R., Hawkesworth, C.J., and Grönvold, K. (1991) "Dynamic melting of the Iceland plume": Nature, v. **351**: p. 201-206.

Icelandic high-magnesia basalts show striking correlations between major element abundances and incompatible element and radiogenic isotope ratios. The most MgO-rich lavas have the most depleted incompatible element ratios and among the least radiogenic lead isotopes recorded in Atlantic mid-ocean-ridge basalts, highlighting a decoupling of the major and trace element characteristics expected of plume melts. This paradox can be explained by the process that mixes melts segregated from different depths of the melting column. The resulting model provides insight into the processes governing melt compositions at spreading ridges.

Evans, J.R., and Sacks, I.S. (1979) "Deep Structure of the Iceland Plateau": Journal of Geophysical Research, v. **84**: p. 6859-6866.

Foulger, G.R., and Anderson, D.L. (2005) "A cool model for the Iceland hotspot": Journal of Volcanology and Geothermal Research, v. **141**(1-2): p. 1-22.

Several primary features of the Iceland region require a posteriori adaptions of the classical plume hypothesis to explain them, which erodes confidence in this model. These include the lack of a time-progressive volcanic track and the paucity of evidence for a seismic anomaly in the lower mantle. Diverse studies suggest a mantle potential temperature anomaly beneath the region of no more than 50-100 K, which is probably insufficient for a thermally buoyant plume. We suggest an alternative model that attributes the enhanced magmatism in the Iceland region to high local mantle fertility from subducted Iapetus oceanic crust trapped in the Laurasian continental mantle lithosphere within the collision zone associated with the Caledonian suture. This crust is recycled into the melt zone locally beneath the mid-Atlantic ridge where isentropic upwelling of eclogitized crust or a crust-peridotite mixture produces excess melt. The production of anomalously large volumes of melt on this part of the spreading ridge has built a zone of thick seismic crust that traverses the whole north Atlantic. A weak, downward continuation of the seismic low-velocity zone into the transition zone between the Charlie Gibbs and Jan Mayen fracture zones may correspond to a component of partial melt, too low to be extractable, that indicates the depth extent of enhanced fusibility or volatiles resulting from the recycled crust. The Iceland region separates two contrasting oceanic tectonic regions to its north and south that may behave independently to some degree. Perhaps as a result of this, it has persistently been characterized by complex and unstable tectonics involving spreading about a parallel pair of ridges, intervening microplates, ridge migrations, and local variations in the spreading direction. These tectonic complexities can explain a number of primary features observed on land in Iceland. A captured microplate that may contain oceanic crust up to ~30 m.y. old underlies central Iceland submerged beneath younger lavas. This may account for local thickening of the seismic crust to ~40 km there. Eastward-widening, fan-shaped extension about a west-east zone that traverses central Iceland culminates in northwest Vatnajökull and may cause the enhanced volcanism there that is traditionally assumed to indicate the center of a plume. The general locus of spreading has not migrated east as is often suggested in support of an eastward-migrating plume model. The model suggested here attributes the Iceland melting anomaly to structures and processes related to plate tectonics that are sourced in the shallow upper mantle. Similar models may explain other "hotspots." Such models suggest a simplifying view of mantle convection since they require only a single mode of convection, that associated with plate tectonics, and not an additional second independent mode associated with deep mantle plumes.

Guðmundsson, Á. (2000) "Dynamics of Volcanic Systems in Iceland: Example of Tectonism and Volcanism in Juxtaposed Hot Spot and MId-ocean Ridge Systems": Annual Review of the Earth and Planetary Sciences, v. **28**: p. 107-140.

Helmberger, D.V., Wen, L., and Ding, X. (1998) "Seismic evidence that the source of the Iceland hotspot lies at the core-mantle boundary": Nature, v. **396**(6708): p. 251-254.

Although Morgan proposed in 1971 that hotspots such as Iceland were the result of hot, rising mantly plumes, it is still debated whether plumes originate from a thermal boundary just above the core-mantle boundary or at the base of the upper mantle.

Hemond, C., Arndt, N.T., Lichtenstein, U., Hofmann, A.W., Óskarsson, N., and Steinthorsson, S. (1993) "The Heterogeneous Iceland Plume: Nd-Sr-O Isotopes and Trace Element Constraints": Journal of Geophysical Research, v. **98**(15): p. 833-850.

Jacoby, W., and Gudmundsson, M.T. (in press) "Hotspot Iceland: An introduction": Journal of Geodynamics, v. **In Press, Corrected Proof**.

Jacoby, W.R., Björnsson, A., and Möller, D. (1980) "Iceland: Evolution, Active Tectonics, and Structure. A Preface": Journal of Geophysics v. **47**(1-6).

Johnson, G.L., Southall, J.R., Young, P.W., and Vogt, P.R. (1972) "Origin and Structure of the Iceland Plateau and Kolbeinsey Ridge": Journal of Geophysical Research, v. **77**: p. 5688-5696.

Jónsdóttir, K., and Hjörleifsdóttir, V. (1998) Heitur reitur: rannsókn á gosstöðvunum í Vatnajökli með skjálftamælingum: skýrsla til Nýsköpunarsjóðs haust 1998, p. 67, myndir, gröf, kort.

Kincald, C., Ito, G., and Gable, C. (1995) "Laboratory investigation of the interaction of off-axis mantle plumes and spreading centres": Nature, v. **376**(6543): p. 758-761.

MANTLE plumes and mid-ocean ridge spreading centres are the dominant phenomena through which mass and heat are transported from the mantle to the Earth's surface. It now seems that the dispersion of near-ridge plumes beneath the lithosphere is modulated strongly by mid-ocean ridges; in particular, geochemical and geophysical observations have suggested that rising plumes are diverted towards and feed nearby ridges 1-7 . Here we confirm the feasibility of this model with laboratory experiments that incorporate the essential physical and fluid dynamic aspects of a plume-ridge upper mantle system. Our results indicate that an off-axis plume may communicate thermally and chemically with a spreading ridge through a narrow, sub-horizontal conduit instead of a broader, radially spreading plume head. A necessary condition for this communication is the presence of a lithospheric or rheological boundary layer that thickens away from the ridge axis owing to conductive cooling. Interestingly, we find that for high plume temperatures, increasing the plume thermal buoyancy may inhibit *rather than enhance plume-ridge interaction, as a result of increased erosion of the overlying lithosphere.*

Lacasse, C., Sigurdsson, H., Carey, S., Paterne, M., and Guichard, F. (1996) "North Atlantic deep-sea sedimentation of Late Quaternary tephra from the Iceland hotspot": Marine Geology, v. **129**(3-4): p. 207-235.

Piston cores recovered from the North Atlantic were used to study the sedimentation of Holocene and Pleistocene volcanic ash in the Irminger and Iceland Basins. Ash Zones 1 (≈ 11,100 yr B.P.), 2 (≈ 55,000 yr B.P.) and 3 (≈ 305,000 yr B.P.) were identified from their major element glass composition. The silicic and alkalic Ash Zones 1 and 2 originate from the Southeastern Volcanic Zone of Iceland, where they correlate with the Sólheimar ignimbrite from Katla volcano and the Thórsmörk ignimbrite from Tindfjallajökull volcano, respectively. The low-alkali composition of silicic Ash Zone 3 indicates a source from one of the silicic centers in the active rift system. Ash Zones 2 and 3 occur in the Irminger Basin as dispersed glass shards over a depth interval of several tens of centimeters. Their compositional and granulometric characteristics reflect an initial fallout on pack-ice north of Iceland, followed by ice-rafting sedimentation in the Denmark Strait, prior to bioturbation. δ18O stratigraphy of foraminifera in the cores indicates that the ash zones were deposited during a cold interval, at the time when seas north of Iceland were ice-covered. Sedimentary features indicate that turbidity currents were also involved in the dispersal of Ash Zones 1 and 2 south of Iceland. The initiation of these gravity currents from the shelf can be attributed to either glacier bursts (jökulhlaups) carrying tephra, or the entrance of pyroclastic flows into the ocean.

Larsen, G., Gudmundsson, M.T., and Bjornsson, H. (1998) "Eight centuries of periodic volcanism at the center of the Iceland hotspot revealed by glacier tephrostratigraphy": Geology, v. **26**(10): p. 943-946.

A record of volcanic activity within the Vatnajokull ice cap has been obtained by combining data from three sources: tephrostratigraphic studies of two outlet glaciers, a 415-m-long ice core from northwestern Vamajokull, and written records. The record extends back to A.D. 1200 and shows that the volcanic activity has a 130-140 yr period, Intervals of frequent eruptions with recurrence times of three to seven years alternate with intervals of similar duration having much lower eruption frequency, In comparison with other parts of the plate boundary in Iceland, eruption frequency is greater, episodes of unrest are longer, and intervals of low activity are shorter. The high eruption frequency may be the result of a more sustained supply of magma, owing to the area's location above the center of the Iceland mantle plume. When combined with historical data on eruptions and earthquakes, our data indicate that rifting-related activity in Iceland as a whole is periodic and broadly in phase,vith the volcanic activity within Vatnajokull.

Maclennan, J., McKenzie, D., and Grönvold, K. (2001) "Plume-driven upwelling under central Iceland": Earth and Planetary Science Letters, v. **194**: p. 67-82.

A suite of 70 basaltic samples from the Herdubreid region of the Northern Volcanic Zone (NVZ) in central Iceland has been analysed for major and trace element compositions. The average light rare earth element concentration of these basalts is more than a factor of 2 higher than that of basalts from the Theistareykir volcanic system near the northern end of the NVZ. Seismic surveys of the NVZ have shown that the crustal *thickness increases from 20 km near Theistareykir to 32–40 km in central Iceland. The observed REE composition and crustal thickness of the Theistareykir area can be reproduced by a melting model where mantle with a potential temperature of 1480°C upwells under the spreading ridge and the mantle upwelling is driven by plate separation alone. However, plate-driven upwelling models cannot simultaneously reproduce the composition of the Herdubreid region lava and the observed crustal thickness. Forward and inverse techniques show that plate-driven models that match the crustal thickness underestimate the La concentration by more than a factor of 2, and models that reproduce the compositions underestimate the crustal thickness by a factor of 4–5. Therefore one of the assumptions involved in the plate-driven upwelling models is not appropriate for central Iceland. A new set of models was developed in which mantle upwelling rates are allowed to differ from those of plate-driven upwelling in order to investigate the role of plume-driven mantle upwelling. The lava composition and crustal thickness of the Herdubreid region can be reproduced by models where the upwelling rates near the base of the melting region (>100 km depth) are 10 times higher than those expected from plate-driven upwelling alone and the mantle potential temperature is 1480–1520°C. About half of the melt generation under central Iceland results from plume-driven upwelling, with the remainder caused by plate-driven upwelling of hot material. This result is in agreement with numerical models of ridge-centred plumes.*

McNutt, M. (1990) "Deep causes of hotspots": Nature, v. **346**(6286): p. 701-702.

Momme, P., Oskarsson, N., Keays, R.R., Tegner, C., and Brooks, C.K. (2003) "Platinum-Group Elements in basalts derived from the Iceland plume: implications for metallogenesis": GAGMAC, Geological Society of America Abstracts with Programs, v. **35**.

Morgan, W.J. (1983) "Hotspot Tracks and the Early Rifting of the Atlantic": Tectonophysics, v. **94**: p. 123-139.

Nichols, A.R.L., Carroll, M.R., and Höskuldsson, Á. (2002) "Is the Icelandic hot spot also wet? Evidence from the water contents of undegassed submarine and subglacial pillow basalts": Earth and Planetary Science Letters, v. **6297**: p. 1-11.

Water contents have been measured in basaltic glasses from submarine and subglacial eruption sites along the Reykjanes Ridge and Iceland, respectively, in order to evaluate the hypothesis of Schilling et al. [Phil. Trans. R. Soc. London A 56 (1980) 147–178] that hot spots are also wet spots. Having erupted under pressure the water contents measured in these samples are potentially unaffected by degassing. After correcting these water contents for the effects of crystallisation (to give H2O(8) values) they indicate that the concentration of water in the source regions increases from 165 ppm at the southern end of the Reykjanes Ridge to between 620 and 920 ppm beneath Iceland. This suggests that Iceland is a wet spot and the H2O(8) values indicate that its influence on basalt compositions increases northwards along the Reykjanes Ridge from 61°N (650 km from the plume centre) towards Iceland. The existence of wetter Icelandic source regions have important implications for mantle melting, as enrichments of this magnitude depress the mantle solidus, increasing the *degree of melting at a given temperature. Therefore the enhanced rates of volcanism on Iceland may be a result of wetter sources in addition to a thermal anomaly beneath Iceland.*

Nielsen, T.F.D., Turkov, V.A., Solovova, I.P., Kogarko, L.N., and Ryabchikov, I.D. (2006) "A Hawaiian beginning for the Iceland plume: Modelling of reconnaissance data for olivine-hosted melt inclusions in Palaeogene picrite lavas from East Greenland": Lithos, v. **92**(1-2): p. 83-104.

Compositions of parental and primary melts are modelled for olivine-hosted melt inclusions in three, Palaeogene, proto-Iceland plume picrite samples from East Greenland. The samples represent three stages in the magmatic evolution: (1) the early pre-spreading volcanics of the Lower Basalts, (2) the early plateau basalts in the Milne Land Formation and (3) the steady stage plateau basalt of the Geikie Plateau Formation. The observations suggest that the host lavas are variably mixed with melts and material from the wall rocks of the feeder system. Pressure estimates based on KD between olivine and reconstructed melt composition suggests the melts to be trapped in their hosts during ascent from magma chambers near the base of the East Greenland crust. CaO/Al2O3 ratios suggest initiation of melting in the proto-Iceland plume at pressures up to 5-6[no-break space]GPa and segregation depths mainly between 3 and 4[no-break space]GPa. Early melts show marked similarities in major and trace elements with primary Hawaiian type melts. It is proposed that the continental separation in the North Atlantic was influenced by a pre-seafloor spreading rise of a "Hawaiian" type plume with a significant component of recycled basalt.

O'Hara, M.J. (1973) "Non-Primary Magmas and Dubious Mantle Plume beneath Iceland": Nature, v. **243**.

Óskarsson, N., Grönvold, K., and Sigvaldason, G.E. (1994) "Compositions of basalts above the Iceland mantle plume": Mineralogical Magazine, v. **58a**: p. 676-678.

Parkin, C.J., Lunnon, Z.C., White, R.S., and Christie, P.A.F. (2007) "Imaging the pulsing Iceland mantle plume through the Eocene": Geology, v. **35**(1): p. 93–96.

The temperature of mantle plumes may vary on geologic time scales, from a few million years to tens of millions of years. In special circumstances such as near Iceland in the North Atlantic, where the plume underlies an oceanic spreading center, temporal variations in the oceanic crustal thickness provide a sensitive proxy for the mantle temperature if, as is likely, the crustal thickness is controlled primarily by passive decompression of mantle rising beneath the spreading center. We show from both seismic reflection imaging and wide-angle ocean bottom seismometer data from the Norwegian Sea that the temperature of the Iceland mantle plume decreased by 50 °C over the first 5 m.y. following continental breakup and then oscillated by 25 °C over an 3 m.y. period. Similar temperature variations on a 3–6 m.y. time scale, creating strong lineations in the gravity field, are inferred from the regional North Atlantic. They occur both in the period immediately following breakup and at the present-day Reykjanes Ridge south of Iceland, where they create V-shaped ridges as the mantle thermal anomalies propagate away from the center of the plume beneath Iceland. We propose that mantle plume temperature variations of 25 °C have occurred in the Iceland plume *with a similar amplitude and frequency since at least 49 Ma, and are likely to be a feature of all mantle plumes.*

Pálmason, G. (1974) Insular Margins of Iceland, *in* Burk, C.A., and Drake, C.L., eds., The Geology of Continental Margins.

Prestvik, T., Goldberg, S., Karlsson, H., and Gronvold, K. (2001) "Anomalous strontium and lead isotope signatures in the off-rift Oraefajokull central volcano in south-east Iceland : Evidence for enriched endmember(s) of the Iceland mantle plume?" Earth and Planetary Science Letters, v. **190**(3-4): p. 211-220.

The currently active off-rift central volcano Öræfajökull in south-east Iceland sits unconformably on much older (~10-12 Ma) and eroded crust. The composition of recent volcanics ranges from basalt to rhyolite, but the series is more sodic alkaline than the common rift zone tholeiitic suites. In this study we present Sr, Nd, Pb and O isotopic data for a suite of Öræfajökull samples. The complete suite shows typical mantle values for oxygen isotopes. The 87Sr/86Sr ratios (average of 15 SAMPLES=0.703702) of the modern Öræfajökull rocks (basalts as well as rhyolites) are much higher than observed so far for any other Icelandic rocks. The 143Nd/144Nd ratios (average=0.512947; n=15) are lower than for rift rocks, but similar to rocks of the off-rift Snaefellsnes volcanic zone. Furthermore, the Öræfajökull rocks are enriched in the 207Pb/204Pb and 208Pb/204Pb isotope ratios compared to Icelandic rift basalts. The enriched nature of the suite indicates that Öræfajökull samples a source component that has characteristics common with EM2 type mantle. Furthermore, it is concluded that the silicic rocks of Öræfajökull formed by fractional crystallization from mafic melts rather than by partial melting of older crust.

Schilling, J.G. (1973) "Iceland Mantle Plume: Geochemical Study of Reykjanes Ridge": Nature, v. **242**: p. 565-571.

Schilling, J.G., and Noe-Nygaard, A. (1974) "Faeroe-Iceland plume: Rare-earth evidence": Earth and Planetary Science Letters, v. **24**(1): p. 1-14.

Rare-earth abundances through the 3000-m thick Faeroes Plateau basalt monitor the Faeroe-Iceland plume activity with time. An abrupt change from light Re-enriched to depleted patterns is observed naer the boundary of the middle and upper series of the Faeroes Plateau basalt. The discontinuity seems to reflect a change of volcanic regime from plume-derived to more akin to oceanic type. The change also coincides with field evidence for beginning of subsidence of the plateau. Using existing spreading rate history for the North Atlantic during the 50-60-m.y. B.P. period, which is one of deceleration, the change of volcanic regime suggests a decline of intensity of the Faeroe-Iceland plume during the late part of the period. Rising blobs, rather than a continuous plume, appears preferable for modeling the temporal plume activity.

Serson, P.H., Hannaford, W., and Haines, G.V. (1968) "Magnetic Anomalies over Iceland": Science, v. **162**: p. 355-356.

Shen, Y., Solomon, S.C., Bjarnason, I.T., and Wolfe, C.J. (1998) "Seismic evidence for a lower mantle origin of the Icelandic plume": Nature, v. **395**(6697): p. 62-65.

Iceland, one of the most thoroughly investigated hotspots, is generally accepted to be the manifestation of an upwelling mantle plume. Yet whether the plume originates from the lower mantle or from a convective instability at a thermal boundary layer between the upper and lower mantle near 660 km depth remains unconstrained.

Sigmarsson, O., Condomines, M., and Fourcade, S. (1992) "Mantle and crustal contribution in the genesis of Recent basalts from off-rift zones in Iceland: Constraints from Th, Sr and O isotopes": Earth and Planetary Science Letters, v. **110**(1-4): p. 149-162.

Along the two volcanic off-rift zones in Iceland, the Snaefellsnes volcanic zone (SNVZ) and the South Iceland volcanic zone (SIVZ), geochemical parameters vary regularly along the strike towards the centre of the island. Recent basalts from the SNVZ change from alkali basalts to tholeiites where the volcanic zone reaches the active rift axis, and their 87Sr/86Sr and Th/U ratios decrease in the same direction. These variations are interpreted as the result of mixing between mantle melts from two distinct reservoirs below Snaefellsnes. The mantle melt would be more depleted in incompatible elements, but with a higher 3He/4He ratio (R/Ra [approximate] 20) beneath the centre of Iceland than at the tip of the Snaefellsnes volcanic zone (R/Ra [approximate] 7.5).From southwest to northeast along the SIVZ, the basalts change from alkali basalts to FeTi basalts and quartz-normative tholeiites. The Th/U ratio of the Recent basalts increases and both (230Th/232Th) and [delta]18O values decrease in the same direction. This reflects an important crustal contamination of the FeTi-rich basalts and the quartz tholeiites. The two types of basalts could be produced through assimilation and fractional crystallization in which primary alkali basaltic and olivine tholeiitic melts `erode' and assimilate the base of the crust. The increasingly tholeiitic character of the basalts towards the centre of Iceland, which reflects a higher degree of partial melting, is qualitatively consistent with increasing geothermal gradient and negative gravity anomaly.The highest Sr isotope ratio in Recent basalts from Iceland is observed in Oraefajokull volcano, which has a 3He/4He ratio (R/Ra [approximate] 7.8) close to the MORB value, and this might represent a mantle source similar to that of Mauna Loa in Hawaii.

Sigurðsson, H. (1967) The Icelandic Basalt Plateau and the Question of Sial. A Review, *in* Björnsson, S., ed., Societas Scientiarum Islandica 38: Iceland and Mid-Ocean Ridges: Reykjavík, Vísindafélag Íslendinga, p. 32-45.

Sigvaldason, G. (1973) "Basalts from the Centre of the Assumed Icelandic Mantle Plume": Journal of Petrology, v. **15**(Part 3): p. 497- 524.

Sigvaldason, G.E., and Steinthórsson, S. (1974) Chemistry of tholeiitic basalts from Iceland and their relation to the Kverkfjöll hot spot, *in* Kristjansson, L., ed., Geodynamics of Iceland and the North Atlantic Area: Dordrecth-Holland, D. Reidel Publ. Company, p. 155-164.

Sigvaldason, G.E., Steinthórsson, S., Óskarsson, N., and Imsland, P. (1974) "Compositional variation in Recent Icelandic tholeiites and the Kverkfjöll hot spot": Nature, v. **251**: p. 579-582.

Geochemical studies of recent igneous rocks from Iceland lend support to the 'hot spot' theory. There is a geographical variation in basaltic composition between Iceland and the submerged parts of the Reykjanes Ridge and Mid-Atlantic Ridge, which suggests that the single-source model for basalts of this region may be correct.

Sleep, N.H. (2006) "Mantle plumes from top to bottom": Earth-Science Reviews, v. **77**(4): p. 231-271.

Hotspots include midplate features like Hawaii and on-axis features like Iceland. Mantle plumes are a well-posed hypothesis for their formation. Starting plume heads provide an explanation of brief episodes of flood basalts, mafic intrusions, and radial dike swarms. Yet the essence of the hypothesis hides deep in the mantle. Tests independent of surface geology and geochemistry to date have been at best tantalizing. It is productive to bare the current ignorance, rather than to dump the plume hypothesis. One finds potentially fruitful lines of inquiry using simple dynamics and observations. Ancient lithospheric xenoliths may reveal heating by plumes and subsequent thermal equilibration in the past. The effect at the base of the chemical layer is modest 50-100[no-break space]K for transient heating by plume heads. Thinning of nonbuoyant platform lithosphere is readily observed but not directly attributable to plumes. The plume history in Antarctica is ill constrained because of poor geological exposure. This locality provides a worst case on what is known about surface evidence of hotspots. Direct detection of plume tail conduits in the mid-mantle is now at the edge of seismic resolution. Seismology does not provide adequate resolution of the deep mantle. We do not know the extent of a chemically dense dregs layer or whether superplume regions are cooler or hotter than an adiabat in equilibrium with the asthenosphere. Overall, mid-mantle seismology is most likely to give definitive results as plume conduits are the guts of the dynamic hypothesis. Finding them would bring unresolved deep and shallow processes into place.

Smith, D.K., and Cann, J.R. (1993) "Building the crust at the Mid- Atlantic Ridge": Nature, v. **365**(6448): p. 707-714.

The morphology of the sea floor at mid-ocean-ridge spreading centers provides a key to understanding how ocean crust is constructed. Images of the axial zone of the Mid-Atlantic Ridge show that crustal construction is complex and variable according to corresponding tectonic, magmatic and hydrothermal processes.

Steintþórsson, S., Harðarson, B.S., Ellam, R.M., and Larsen, G. (2000) "Petrochemistry of the Gjálp-1996 subglacial eruption, Vatnajökull, SE Iceland": Journal of Volcanology and Geothermal Research, v. **98**(1-4): p. 79-90.

In October 1996 a subglacial fissure to the north of the Grimsvötn caldera in W-Vatnajökull produced about 0.4 km3 of Fe-rich basaltic andesite-icelandite--in an area characterized mostly by tholeiitic basalt. In this paper the chemical composition of volcanic systems in the region is discussed with the help of six new analyses and others from the literature, and a tentative model for their evolution is proposed, in which magma produced by the partial melting of a two-component mantle mixes with hydrous, silicic melt in the crust. The Vatnajökull 1996 magma belongs to a separate volcanic system, intermediate between Bárdarbunga and Grimsvötn.

Tegner, C., Lesher, C.E., Larsen, L.M., and Watt, W.S. (1998) "Evidence from the rare-earth-element record of mantle melting for cooling of the Tertiary Iceland plume": Nature, v. **395**(6702): p. 591- 594.

Widespread flood basalt volcanism and continental rifting in the northeast Atlantic in the early Tertiary period (about 55 Myr ago) have been linked to the mantle plume now residing beneath Iceland. Although much is known about the present-day Iceland plume, its thermal structure, composition and position in the early Tertiary period remain unresolved.

Vink, G.E. (1984) "A Hotspot Model for Iceland and the Vøring Plateau": Journal of Geophysical Research, v. **89**: p. 9949-9959.

Vogt, P.R. (1974) The Iceland Phenomenon: Imprints of a Hot Spot on the Ocean Crust, and Implications for Flow Beneath the Plates, Geodynamics of Iceland and the North Atlantic area: Dordrecht Reidel, p. 105-126.

— (1983) The Icelandic Mantle Plume: Status of the hypothesis after a decade of work, *in* Bott, ed., Structure and development of the Greenland-Scotland Ridge: New York, Plenum Press.

Wolfe, C.J., Bjarnason, I.T., VanDecar, J.C., and Solomon, S.C. (1997) "Seismic structure of the Iceland mantle plume": Nature, v. **385**(6613): p. 245-247.

Results of a regional broadband seismic experiment undertaken to determine the 3D velocity structure of the upper mantle beneath Iceland using relative travel times of body waves from teleseismic earthquakes are discussed in a study.

Wright, J.B. (1973) "Continental Drift, Magmatic Provinces and Mantle Plumes": Nature, v. **244**: p. 565-567.

Zhang, Y.-S.T., T. (1992) "Ridges, hotspots and their interaction as observed in seismic velocity maps": Nature, v. **355**(6355): p. 45-49.

A new global S-wave velocity model reveals that although mid-ocean ridges and hotspots are both underlain by low-velocity anomalies in the mantle, these have distinctly different structures. This implies that there are differences between the upwelling mechanisms under ridges and under hotspots. The velocity model also shows that there may be interactions between ridges and hotpots near Afar and St Helena.

5.11 Landrek (plate tectonics, rifting)

Beloussov, V.V., and Milanovsky, Y.Y. (1976) "On tectonics and tectonic position of Iceland ": Greinar (Vísindafélag Íslendinga): p. 96-118.

Björnsson, H., and Einarsson, P. (1990) "Volcanoes beneath Vatnajökull, Iceland: Evidence from radio echo-sounding earthquakes and jökulhlaups": Jökull, v. **40**: p. 147-168.

Integration of knowledge of subglacial topography, earthquake activity and jökulhlaups has contributed to more precise locations of the volcanic systems beneath Vatnajökull. Bárðarbunga is the centre of a volcanic system which includes the fissure swarms of Veiðivötn to the SW and Dyngjuháls to the NE. The Grímsvötn volcano is the centre of a system that comprises the Laki fissure swarm in the SW and extends for an unknown distance to the NE of the volcano. Þórðarhyrna is probably a separate central volcano within this system. The Kverkfjöll system can be traced 10 km to the SW of the Kverkfjöll volcano. It appears to be separated from the Grímsvötn volcano. The Askja fissure swarm extends beneath Dyngjujökull and can possibly be traced to the Grímsvötn volcano. Hamarinn and the ridge striking eastward from Hamarinn (Loki Ridge) are central volcanoes which together with the Fögrufjöll fissure swarm form a volcanic system. No support can be found in the topographic data for the existence of a central volcano near Breiðabunga. Volcanic activity in historical times has mainly been limited to the Grímsvötn and Bárðarbunga systems. Major rifting events have affected large sections of these volcanic systems but both have been remarkably quiet for the past decades. A few volcanic events are presumed to have occurred on the Hamarinn - Loki system and on the Askja fissure swarm beneath Dyngjujökull, but no event is known with certainty on the Kverkfjöll system. The rivers Skeiðará and Súla have the most frequent eruption-related jökulhlaups. They receive meltwater from the Grímsvötn caldera and the area to the SW of it, including Þórðarhyrna. Núpsvötn, Djúpá and Hverfisfljót drain the southwestern part of the Grímsvötn system, an area bounded by Þórðarhyrna, Geirvörtur, Hágöngur and Pálsfjall. Skaftá drains the Loki Ridge and the area west of Grímsvötn. Jökulhlaups in Kaldakvísl, and ultimately Þjórsá, must originate in the Bárðarbunga or the Hamarinn - Loki systems, and the only possible source for volcanic jökulhlaups in Skjálfandafljót is the northern part of the Bárðarbunga system. Jökulsá á Fjöllum may drain meltwater from activity in all the volcanic systems in northern Vatnajökull: Bárðarbunga, the Askja fissure swarm and Kverkfjöll. This includes the voluminous, ice-filled calderas of Bárðarbunga and Kverkfjöll. Activity in the northern part of the Grímsvötn system may cause floods in Jökulsá á Fjöllum. Meltwater from volcanic activity on the SE flank of a ridge that strikes south from Kverkfjöll may drain to Jökulsá á Brú. Volcanic activity farther north on the E flanks of this ridge would cause floods in Kreppa.

Björnsson, S. (1967) "Iceland and Mid-Ocean Ridges : report of a symposium held in Reykjavík February 27 to March 8, 1967, under the sponsorship of the Geoscience Society of Iceland / edited by Sveinbjörn Björnsson": Societas Scientiarum Islandica (Vísindafélag Íslendinga) v. **Rit 38**: p. 209 s., [1] mbl., [1] kortabl. br. : myndir, kort, línurit, töflur.

Efni: Early history of the Scandic area and some chapters of the geology of Iceland / Trausti Einarsson: s. 13-28. - The Icelandic basalt plateau and the question of sial / Haraldur Sigurdsson: s. 32-46. - Chemistry of basalts from the Icelandic rift zone / Gudmundur E. Sigvaldason: s. 50-51. - Volcanic forms at the sea bottom / Gudmundur Kjartansson: s. 53-64. - Upper crustal structure in Iceland / Gudmundur Pálmason: s. 67-78. - Some problems of seismological studies on the Mid-Atlantic Ridge / Ragnar Stefánsson: s. 80-89. - Aeromagnetic surveys of Iceland and its neighbourhood / Thorbjörn Sigurgeirsson: s. 91-96. - Magnetic anomalies / Gudmundur Gudmundsson: s. 97-105. - Sub-crustal viscosity in Iceland / Trausti Einarsson: s. 109-110. - On heat flow in Iceland in relation to the Mid-Atlantic Ridge / Gudmundur Pálmason: s. 111-127

The Icelandic fracture system and the inferred causal stress field / Trausti Einarsson: s. 128-139. - The rift zone and the Reykjanes peninsula / Jón Jónsson: s. 142-147. - An outline of the structure of SW-Iceland / Kristján Sæmundsson: s. 151-159. - Dykes, fractures and folds in the basalt plateau of western Iceland / Haraldur Sigurdsson: s. 162-169. - The extent of the tertiary basalt formation and the structure of Iceland / Thorleifur Einarsson: s. 170-178. - Hekla's magma / Jens Tómasson: s. 180-188 Hekla and Katla / Sigurdur Thorarinsson: s. 190-197

Blake, S. (1984) "Magma mixing and hybridization processes at the alkalic, silicic, Torfajökull central volcano triggered by tholeiitic Veiðivötn fissuring, south Iceland": Journal of Volcanology and Geothermal Research, v. **22**(1-2): p. 1-31.

Around 19°W64°N19, in the Eastern Volcanic Zone of south Iceland, the southwestern extremity of the tholeiitic Veiðivötn fissure swarm abuts the northern periphery of the mildly alkaline silicic central volcano Torfajökull. Effusive mixed-magma eruptions in this area have been initiated by crustal rifting associated with lateral injection of tholeiitic magma into the rhyolitic Torfajökull chamber. Mixed rocks, in which cm- to dm-sized mafic inclusions constitute ~ 10% of the rhyolite lava are distinguished from hybrid rocks which are thorough mixtures having an homogeneous fabric.Mapping of the Domadalshraun lava (0.05-0.1 km3) reveals the early eruption of hybrid spatter and lava followed by less thoroughly blended mixed lava. Geochemical study discloses the participation of three end-members. Plagioclase-phyric tholeiite containing ~ 10-20% pl + cpx + o1 precipitated at ~ 1140-1160[deg]C is typical of the Veiðivötn component. The Torfajökull rhyolite contains ~ 10% crystals, dominantly anorthoclase and oligoclase, and is found to be compositionally zoned. Early-late trends include SiO2: 71.6-70.1%, A.I.: 1.07-0.86, Sr: 61-86 ppm and result from feldspar fractionation. The third end-member is a transitional alkali basaltic andesite ([identical to] hawaiite) belonging to the mafic magma suite associated with Torfajökull. This intermediate magma resided at depth within the stratified Torfajökull chamber and contains xenocrystic feldspars which have settled out of the differentiating rhyolite. The calculated positions in tholeiite-rhyolite-basaltic andesite composition space of eight hybrid rocks show that hybridization was not a random process. No rhyolite/transitional alkali hybrids are present. The only two tholeiite/transitional alkali hybrids are both 0.45/0.55 blends of these two end-members. No rhyolite-bearing hybrid contains more than 20% transitional alkali magma. It is proposed that rhyolite/tholeiite hybrids are most likely to be generated where a shallow tholeiitic fissure has been laterally intruded into and above the roof of the rhyolitic chamber. Near the top of the fissure, tholeiite containing excess water may have been sufficiently vesicular for its bulk density to equal that of the rhyolitic magma. Calculations identify this critical depth as 0.75-1 km-coincident with calculated quenching pressures of small vesicular tholeiitic clots in the mixed lavas (assuming 1 wt.% water). Dense tholeiite at deeper levels in the dyke collapses into the chamber and is replaced by buoyantly rising rhyolite. Hybridization ensues where the rhyolite and vesicular tholeiite come together in the fissure. These and other relative-density controlled processes account for the selective nature of the hybridization process and the order in which hybrid and mixed magmas were erupted.The late 15th century Laugahraun and Sudurnamshraun flows at Landmannalaugar reveal participation of only tholeiitic and rhyolitic end-members. Hybrids are poorly represented and it is hypothesized that this is due to the deep ([greater-than or equivalent to] 1 km) intrusion of undersaturated tholeiite, which leads to the generation of mixed rather than hybrid magmas.These and other tholeiite/rhyolite mixed-magma eruptions in the area were triggered by lateral flow of tholeiite from the Veidivotn system, initiated by

the overfilling of the Veiðivötn magma chamber, 40 km to the NE, in the style recognized at Krafla and elsewhere in Iceland. Future concern over any renewed activity in Veiðivötn should not, therefore, prohibit consideration of rhyolitic or mixed-magma eruptions being induced in the Torfajokull region.

Bott, M.H.P. (1974) Deep Structure, Evolution and Origin of the Icelandic Transverse Ridge, Geodynamics of Iceland and the North Atlantic area: Dordrecht, Reidel, p. 33-47.

Burke, K., Kidd, W.S.F., and Tuzo Wilson, J. (1973) "Relative and Latitudinal Motion of Atlantic Hot Spots": Nature, v. **245**: p. 133-137.

Bödvarsson, G., and Walker, G.P.L. (1964) "Crustal Drift in Iceland": Geophysical Journal of the Royal Astrological Society, v. **8**: p. 285-300.

Carrivick, J.L., Russell, A.J., and Tweed, F.S. (2004) "Geomorphological evidence for jökulhlaups from Kverkfjöll volcano, Iceland": Geomorphology v. **63**: p. 81-102.

Jökulhlaups (glacial outburst floods) are known to have drained along the Jökulsá á Fjöllum river in Iceland during the Holocene. However, little is known about their number, age, source, and flow characteristics. This paper provides detailed geomorphological evidence for jökulhlaups that have routed from the Kverkfjöll ice margin and hence into the Jökulsá á Fjöllum. Erosional evidence of jökulhlaups from Kverkfjöll includes gorges, cataracts, spillways, subaerial lava steps, and valley-wide scoured surfaces. Depositional evidence includes wash limits, boulder bars, cataract-fill mounds, terraces, slackwater deposits, and outwash fans. Some of these landforms have been documented previously in association with jökulhlaups. However, subaerial lava surfaces that have been scoured of the upper clinker, gorges within pillow–hyaloclastite ridges, gorges between pillow–hyaloclastite ridges and subaerial lava flows, subaerial lava lobe steps, cataract-fill mounds, and boulder run-ups are previously undocumented in the literature. These landforms may therefore be diagnostic of jökulhlaups within an active volcanic rifting landscape. The nature and spatial distribution of these landforms and their stratigraphic association with other landforms suggest that there have been at least two jökulhlaups through Kverkfjallarani. The Biskupsfell eruption occurred between these two jökulhlaups. Kverkfjallarani jökulhlaups were very strongly influenced by topography, geology, and interevent processes that together determined the quantity and nature of sediment availability. Such controls have resulted in jökulhlaups that were probably fluidal, turbulent, and supercritical over large areas of the anastomosing channel bed. Kverkfjallarani jökulhlaups would have had highly variable hydraulic properties, both spatially and temporally. The knowledge of flow characteristics that can be gained from jökulhlaup impacts has implications for recognising jökulhlaups in the rock record and for hazard analysis and mitigation within similar landscapes and upon other glaciated volcanoes.

Carrivick, J.L., Russell, A.J., Tweed, F.S., and Twigg, D. (2004) "Palaeohydrology and sedimentary impacts of jokulhlaups from Kverkfjoll, Iceland": Sedimentary Geology, v. **172**(1-2): p. 19-40.

Jökulhlaups (glacial outburst floods) occur frequently within Iceland and within most glaciated regions of the world. The largest jökulhlaups known to have occurred within Iceland drained from the northern margin of the Vatnajökull and along the Jökulsá a Fjöllum during the Holocene. However, little is known about the number, age and flow characteristics of the Jökulsá a Fjöllum jokulhlaups. One source of meltwater into the Jökulsá a Fjöllum is Kverkfjöll, a glaciated stratovolcano. This paper provides detailed sedimentological evidence demonstrating that jokulhlaups have routed through Kverkfjallarani and hence from Kverkfjöll. Sedimentological evidence of jökulhlaups includes valley-fill deposits and slack water deposits. Lithofacies, which are indicative of high-magnitude fluvial sedimentation, show that these deposits cannot be the result of nonjökulhlaup processes. The situation and nature of the sediments permit palaeoflow reconstructions. Fine-grained deposits within slack water deposits mark a break in jökulhlaup deposition and suggest that at least three jökulhlaups have drained through Hraundalur, the predominant valley within Kverkfjallarani. Evidence of lava overrunning `wet' jökulhlaup deposits indicates that jokulhlaups occurred in close association with volcanic eruptions in the Biskupsfell fissure. The largest jökulhlaup was initially hyperconcentrated and subsequently became more fluid. Slope-area reconstructions indicate that the largest jokulhlaup had a probable average peak discharge of 45,000-50,000 m3 s-1; however, the peak discharge attenuated by 25-30% in just 25 km. These observations quantify the number, rheology, hydraulics and chronology of jokulhlaups from Kverkfjoll and hence within the Jökulsa a Fjöllum. This study presents a model of jökulhlaup impacts and characteristics from glaciated volcanoes and/or within volcanic rifting zones.

Dagley, P., Wilson, R.L., Ade-Hall, J.M., Walker, G.P.L., Haggerty, S.E., Sigurgeirsson, T., Watkins, N.D., Smith, P.J., Edwards, J., and Grasty, R.L. (1967) "Geomagnetic Polarity Zones for Icelandic Lavas": Nature, v. **216**: p. 25-29.

Dauteuil, O., and Brun, J.-P. (1993) "Oblique rifting in a slow-spreading ridge": Nature, v. **361**: p. 145-148

In oceanic rifts, the spreading direction is usually nearly perpendicular to the ridge axis, but at the Reykjanes and Mohns ridges in the Norwegian Sea this direction is highly oblique. It is argued that the oblique highs in this ridge are of tectonic origin. Laboratory experiments on brittle-ductile models which support this interpretation are examined.

Decker, R.W., Einarsson, P., and Mohr, P.A. (1971) "Rifting in Iceland: New Geodetic Data": Science, v. **173**: p. 530-532.

Decker, R.W., Plumb, R., and Einarsson, P. (1976) "Rifting in Iceland : measuring horizontal movements ": Greinar (Vísindafélag Íslendinga): p. 61-71, Myndir, töflur.

Du, Z.J., and Foulger, G.R. (2001) "Variation in the crustal structure across central Iceland": Geophysical Journal International, v. **145**(1): p. 246-264.

We determine the crustal structures beneath 12 broad-band seismic stations deployed in a swath across central Iceland along and around the ICEMELT explosion seismic profile by combining teleseismic receiver functions, surface wave dispersion curves and the waveforms of a large, local event in Iceland. By using teleseisms that approach fi om *different backazimuths, we study lateral structural variability out of the line of the ICEMELT profile. Beneath Tertiary areas, the thickness of the upper crust, as defined by the 6.5 km s(-1) velocity horizon, is similar to8 km and the depth to the base of the lower crust, as defined by the 7.2 km s(-1) velocity horizon, is similar to 29-32 km. Beneath the currently active rift zone the upper crust thins to similar to 6.0 km and the depth to the base of the lower crust increases to similar to 35-40 km. A substantial low-velocity zone underlies the Middle Volcanic Zone in the lower crust, which may indicate anomalously high geothermal gradients there. This suggests that the large-scale thermal centre of the hotspot may be more westerly than northwest Vatnajokull, where it is generally assumed to lie. Simplified description of the results notwithstanding, there is substantial variability in the overall style of crustal structure throughout Iceland, and a clear, tripartite division into upper and lower crusts and a sharp Moho is poorly supported by many of our results. The nature, distinctiveness and continuity of the Moho is variable and in many areas the crust-mantle transition is a zone with enhanced velocity gradients several kilometres thick.*

— (2004) "Surface wave waveform inversion for variation in upper mantle structure beneath Iceland": Geophysical Journal International, v. **157**(1): p. 305-314.

We study the structure of the upper mantle beneath Iceland using surface wave waveforms recorded at pairs of stations lying approximately on the same great circles as the sources used. We invert for local, path-average V-s variations between the station pairs. The method used in this study is an extension of an algorithm proposed by Kushnir et al. (1989), which uses only the phase of the seismograms. In our waveform inversion not only the phases but also the amplitudes of the surface waves are used as structural constraints. We illustrate the resolution power of the new algorithm with synthetic examples. We apply the method to study upper mantle structure beneath Iceland using recordings of three events with northerly, southsouthwesterly and easterly orientated paths and 19 station pairs. Depending on the separation distance of the stations, we invert waveforms in the frequency range 0.0166-0.08 Hz and 0.01-0.08 Hz. Resolution is limited by the penetration depth of the surface wave fundamental mode, and is good down to similar to 150 km for the narrower frequency band and similar to200 km for the wider band. Although the inversions of the differential waveforms only provide information on lateral V-s variations between station pairs, the main structural features of the upper mantle beneath Iceland are retrieved. We confirm that the strongest negative V-s anomalies of up to similar to -5 per cent underlie central Iceland, and extend down to the limit of our resolution at similar to200 km. The rift zones away from central Iceland are underlain by low velocities in the depth range similar to50-100 km and high velocities below this, indicating that they are shallowly sourced. Such a structure also underlies northwest Vatnajokull, where a mantle plume is traditionally assumed to lie. Beneath intraplate areas, mantle structural variations are small. Using our method, smaller-scale mantle structures are detectable than is possible with teleseismic tomography, which tends to smear anomalies throughout larger volumes.

Einarsson, T. (1962) "Upper tertiary and pleistocene rocks in Iceland : a stratigraphic-paleomagnetic-morphologic-tectonic analysis ": Societas Scientiarum Islandica (Vísindafélag Íslendinga) v. **Rit 36**: p. 196, [1] s., [5] kortabl. br. : kort, uppdr. .

— (1967) The Extent of the Tertiary Basalt Formation and the Structure of Iceland, *in* Björnsson, S., ed., Societas Scientiarum Islandica 38: Iceland and Mid-Ocean Ridges: Reykjavík, Vísindafélag Íslendinga, p. 170-177.

Foulger, G.R., and Anderson, D.L. (2005) "A cool model for the Iceland hotspot": Journal of Volcanology and Geothermal Research, v. **141**(1-2): p. 1-22.

Several primary features of the Iceland region require a posteriori adaptions of the classical plume hypothesis to explain them, which erodes confidence in this model. These include the lack of a time-progressive volcanic track and the paucity of evidence for a seismic anomaly in the lower mantle. Diverse studies suggest a mantle potential temperature anomaly beneath the region of no more than 50-100 K, which is probably insufficient for a thermally buoyant plume. We suggest an alternative model that attributes the enhanced magmatism in the Iceland region to high local mantle fertility from subducted Iapetus oceanic crust trapped in the Laurasian continental mantle lithosphere within the collision zone associated with the Caledonian suture. This crust is recycled into the melt zone locally beneath the mid-Atlantic ridge where isentropic upwelling of eclogitized crust or a crust-peridotite mixture produces excess melt. The production of anomalously large volumes of melt on this part of the spreading ridge has built a zone of thick seismic crust that traverses the whole north Atlantic. A weak, downward continuation of the seismic low-velocity zone into the transition zone between the Charlie Gibbs and Jan Mayen fracture zones may correspond to a component of partial melt, too low to be extractable, that indicates the depth extent of enhanced fusibility or volatiles resulting from the recycled crust. The Iceland region separates two contrasting oceanic tectonic regions to its north and south that may behave independently to some degree. Perhaps as a result of this, it has persistently been characterized by complex and unstable tectonics involving spreading about a parallel pair of ridges, intervening microplates, ridge migrations, and local variations in the spreading direction. These tectonic complexities can explain a number of primary features observed on land in Iceland. A captured microplate that may contain oceanic crust up to ~30 m.y. old underlies central Iceland submerged beneath younger lavas. This may account for local thickening of the seismic crust to ~40 km there. Eastward-widening, fan-shaped extension about a west-east zone that traverses central Iceland culminates in northwest Vatnajökull and may cause the enhanced volcanism there that is traditionally assumed to indicate the center of a plume. The general locus of spreading has not migrated east as is often suggested in support of an eastward-migrating plume model. The model suggested here attributes the Iceland melting anomaly to structures and processes related to plate tectonics that are sourced in the shallow upper mantle. Similar models may explain other "hotspots." Such models suggest a simplifying view of mantle convection since they require only a single mode of convection, that associated with plate tectonics, and not an additional second independent mode associated with deep mantle plumes.

Fram, M.S., and C.E., L. (1993) "Geochemical constraints on mantle melting during creation of the North Atlantic basin": Nature, v. **363**(6431): p. 712-713.

Major- and trace-element data for lavas erupted during rifting of the Greenland-European continent about 60 million years ago are discussed. It is inferred that the earliest rift lavas can largely account for their high contents of incompatible elements.

Gibson, I.L. (1966) "The Crustal Structure of Eastern Iceland": Geophysical Journal of the Royal Astronomical Society, v. **12**: p. 99-102.

— (1969) "A comparative Account of the Flood Basalt Volcanism of the Columbia Plateau and Eastern Iceland": Bulletin of Volcanology, v. **33**(2): p. 419-437.

Gibson, I.L., and Gibb, A.D. (1987) "Accretionary volcanic processes and the crustal structure of Iceland": Tectonophysics, v. **133**: p. 57-64.

Gibson, I.L., and Piper, J.D.A. (1972.) "Structure of the Icelandic plateau and the process of drift": Phil. Trans. Royal Soc. London, v. **A271**: p. 141-150.

Hards, V.L., Kempton, P.D., Thompson, R.N., and Greenwood, P.B. (2000) "The magmatic evolution of the Snaefell volcanic centre; an example of volcanism during incipient rifting in Iceland": Journal of Volcanology and Geothermal Research, v. **99**(1-4): p. 97-121.

The Snaefell volcanic centre is situated in central-east Iceland, at the northern end of a short flank volcanic zone. Its products represent a typical suite of Icelandic volcanics and comprise a bimodal suite of alkalic lavas: a series from basaltic to mugearitic compositions and a small cluster of peralkaline rhyolites. Compositional variations across the whole series can be broadly explained by fractional crystallisation of a family of related parental/primary magmas in a magma chamber at mid-crustal (~13 km) levels, that has been subject to periodic replenishment and periodic tapping, with sufficient repose times for extreme differentiation. Interaction with the crust appears minimal, although some crustal input into the rhyolites is indicated by their isotopic characteristics. The Snaefell volcanics therefore represent largely new additions to the Icelandic crust.The apparent depth of the magma chamber appears significant and sets Snaefell apart from the axial rift zones at centres such as Krafla, where seismic studies (e.g. Brandsdottir, B., Menke, W., Einarsson, P., White, R.S., Staples, R.K., 1997. Faeroe-Iceland ridge experiment. 2. Crustal structure of Krafla central volcano. J. Geophys. Res. 102 (B4), 7867-7886) have detected the presence of magma bodies at depths of around 3 km beneath centres in the northern volcanic zone. Comparing Snaefell with volcanic centres in the propagating eastern volcanic zone suggests that, in terms of its stage of evolution, Snaefell is approximately equivalent to Torfajokull. Thus, the Oraefajokull-Snaefell volcanic zone may have represented a site of incipient rifting.

Helgason, J. (1988) Fjallgarðagoskerfið á Norðausturlandi: Útkulnuð plötumót á frumstigi eða óvirkt eldgosabelti?, Vorráðstefna 1988: ágrip erinda: Reykjavík.

Helmberger, D.V., Wen, L., and Ding, X. (1998) "Seismic evidence that the source of the Iceland hotspot lies at the core-mantle boundary": Nature, v. **396**(6708): p. 251-254.

Although Morgan proposed in 1971 that hotspots such as Iceland were the result of hot, rising mantly plumes, it is still debated whether plumes originate from a thermal boundary just above the core-mantle boundary or at the base of the upper mantle.

Herron, E.M., Dewey, J.F., and Pitman, W.C.I. (1974) " Plate Tectonics Model for the Evolution of the Arctic": Geology v. **2**(no. 8): p. 377-380.

Hofton, M.A., and Foulger, G.R. (1996) "Postrifting anelastic deformation around the spreading plate boundary, north Iceland .2. Implications of the model derived from the 1987-1992 deformation field": Journal of Geophysical Research-Solid Earth, v. **101**(B11): p. 25423-25436.

A decade-long rifting episode that began in the Krafla volcanic system, north Iceland, in 1975 caused substantial, regional, postevent anelastic deformation. This was modeled as viscous relaxation in an elastic/viscoelastic structure by Hofton and Foulger [this issue]. The results from modeling the deformation detected in north Iceland have far-reaching implications both for local and regional processes and for the fundamental behavior of deformation around spreading plate boundaries in general. Tilt in the vicinity of the Krafla volcano fits the model well after 1988/1989 which suggests that the volcano magma chamber stopped inflating/deflating in 1988. A viscosity of 0.8 x 10(18) Pa s was required to match the local tilt data, less than that predicted for north Iceland as a whole. Vertical motion measured using the Global Positioning System (GPS) 1987-1992 around the ice cap Vatnajokull is inconsistent with isostatic uplift. Using the elastic-viscoelastic model to predict motion in other regions of Iceland suggests that the deformation effects of the Krafla episode are significant in many parts of Iceland and should be taken into account when modeling deformation there. Though not a realistic plate boundary model, interesting complexities of the elastic-viscoelastic model are highlighted by deformation modeling of an infinitely long dike. This predicts that the amount of horizontal displacement close to the dike may exceed the amount of initial dike opening early in the spreading cycle. A more realistic approximation to the plate boundary in north Iceland, involving five overlapping segments that experience dike emplacements at discrete intervals, suggests that the width of the zone within which transient, time-dependent deformation occurs may be several hundred kilometers wide, considerably wider than the neovolcanic zone. A kinematic approach to describing plate motions is not appropriate close to spreading plate boundaries and elsewhere where the viscosity of the Earth is low.

Jacoby, W.R., Björnsson, A., and Möller, D. (1980) "Iceland: Evolution, Active Tectonics, and Structure. A Preface": Journal of Geophysics v. **47**(1-6).

Johnson, G.L., and Heezen, B.C. (1967) "Morphology and evolution of the Norwegian-Greenland Sea": Deep Sea Research, v. **14**: p. 755- 771.

Johnson, G.L., Southall, J.R., Young, P.W., and Vogt, P.R. (1972) "Origin and Structure of the Iceland Plateau and Kolbeinsey Ridge": Journal of Geophysical Research, v. **77**: p. 5688-5696.

Kincald, C., Ito, G., and Gable, C. (1995) "Laboratory investigation of the interaction of off-axis mantle plumes and spreading centres": Nature, v. **376**(6543): p. 758-761.

MANTLE plumes and mid-ocean ridge spreading centres are the dominant phenomena through which mass and heat are transported from the mantle to the Earth's surface. It now seems that the dispersion of near-ridge plumes beneath the lithosphere is modulated strongly by mid-ocean ridges; in particular, geochemical and geophysical observations have suggested that rising plumes are diverted towards and feed nearby ridges 1-7 . Here we confirm the feasibility of this model with laboratory experiments that incorporate the essential physical and fluid dynamic aspects of a plume-ridge upper mantle system. Our results indicate that an off-axis plume may communicate thermally and chemically with a spreading ridge through a narrow, sub-horizontal conduit instead of a broader, radially spreading plume head. A necessary condition for this communication is the presence of a lithospheric or rheological boundary layer that thickens away from the ridge axis owing to conductive cooling. Interestingly, we find that for high plume temperatures, increasing the plume thermal buoyancy may inhibit rather than enhance plume-ridge interaction, as a result of increased erosion of the overlying lithosphere.

Klausen, M.B. (2006) "Similar dyke thickness variation across three volcanic rifts in the North Atlantic region: Implications for intrusion mechanisms": Lithos, v. **92**(1-2): p. 137-153.

The thicknesses of 1935 mafic dykes have been recorded through meticulous mapping across (1) the East Greenland coastal dyke swarm, (2) an extinct rift zone in SE Iceland and (3) an obducted dyke swarm segment within the Swedish Caledonides. In all three cases, the thickness of almost every dyke along well-exposed and coherent profile segments could be measured and analyzed. Statistics show that dyke thickness distributions more often are negative exponential (i.e., random) than log-normal within any given segment, with a regression's inverse exponential coefficient representing a more sophisticated average thickness. For all three dyke profiles, there is a similar decrease in average thickness from thicker dykes along the margin of the swarm to narrower dykes along its axis. Cross cutting relationships within two profiles, furthermore, suggest that the average dyke thickness decreased with time.The random thickness distribution of dykes is most likely governed by dyke initiations, releasing differential stresses at random time intervals during constant rates of plate separation. It is argued that the thickness of a dyke does not change significantly within the depth ranges that these dyke swarms are exposed, allowing systematic spatial and temporal changes in average dyke thicknesses to be related to other factors. Results are primarily related to the depth of an underlying sub-crustal magma reservoir, which progressively rose to shallower elevations beneath an active volcanic rift. As an alternative, or in conjunction with this model, stress concentrations towards the rising crest of a sub-crustal magma reservoir might increase the average frequency of randomly released differential stresses, leading to move rapid injections of thinner dyke toward swarm centres and with time. Correlating average dyke thicknesses to crustal depths, I end up with an empirical dyke thickness/height ratio of ~ 2 x 10-[no-break space]4, yet variable thickness/length ratio in order to accommodate the elliptical surface outline of swarms.

Larsen, G. (1984) "Recent volcanic history of the Veidivötn fissure swarm, southern Iceland- an approach to volcanic risk assessment": Journal of volcanology and geothermal research, v. **22**(1-2): p. 33-58.

The recent volcanic history of the southwestern part of the Veiðivötn fissure swarm, southern Iceland, provides a basis for assessment of volcanic risk in an area of large

hydropower potential. Local tephrastratigraphy and regional tephrochronology provide relative and absolute dating of individual eruptions as well as information on the volume and distribution of the products formed in each eruption. Three large eruptions took place in this area in 1480 A.D., 900 A.D. and 150 A.D., respectively. Each eruption produced approx. 1 km3 (DRE) of basaltic, and minor amounts of silicic lava and tephra on fissures up to 42 km long. No evidence is found of smaller eruptions during this period. The estimated eruption frequency, one eruption every 600–800 years, implies that this part of the Veidivötn fissure swarm is inactive for long periods between relatively large volcanic events. A change in the mode of eruption from effusive to explosive took place during this period. The hazards posed by this area include far-reaching lava flows, widespread heavy tephra fall with thicknesses in excess of 2 m at distances of 10 km, and damming of a large glacial river with the consequent formation of unstable lakes. A volcano-tectonic model, which explains the observed eruption frequency and provides a basis for a long-term monitoring program, is proposed. Eruptions on the Veidivötn fissure swarm are interpreted as corollaries of rifting episodes initiated in the Bárdarbunga central volcano. Volcano-tectonic episodes affect the fissure swarm at an average interval of 100 years. Minor episodes are limited to the central volcano and adjacents parts of the fissure swarm. During the less frequent major episodes, rifting and volcanic activity extends to the extreme southwestern part of the fissure swarm. Seismic monitoring of the Bárdarbunga central volcano could provide an early warning of renewed activity on the Veidivötn fissure swarm. A major rifting episode resulting in eruption on its southwestern part can be expected during the next 100 to 300 years.

Larsen, G., Gudmundsson, M.T., and Bjornsson, H. (1998) "Eight centuries of periodic volcanism at the center of the Iceland hotspot revealed by glacier tephrostratigraphy": Geology, v. **26**(10): p. 943-946.

A record of volcanic activity within the Vatnajokull ice cap has been obtained by combining data from three sources: tephrostratigraphic studies of two outlet glaciers, a 415-m-long ice core from northwestern Vamajokull, and written records. The record extends back to A.D. 1200 and shows that the volcanic activity has a 130-140 yr period, Intervals of frequent eruptions with recurrence times of three to seven years alternate with intervals of similar duration having much lower eruption frequency, In comparison with other parts of the plate boundary in Iceland, eruption frequency is greater, episodes of unrest are longer, and intervals of low activity are shorter. The high eruption frequency may be the result of a more sustained supply of magma, owing to the area's location above the center of the Iceland mantle plume. When combined with historical data on eruptions and earthquakes, our data indicate that rifting-related activity in Iceland as a whole is periodic and broadly in phase,vith the volcanic activity within Vatnajokull.

Laughton, A.S. (1971) "South Labrador Sea and the Evolution of the North Atlantic": Nature, v. **232**: p. 612-616.

Le Pichon, X., and Fox, P.J. (1971) "Marginal Offsets, Fracture Zones, and the Early Opening of the North Atlantic": Journal of Geophysical Research, v. **76**: p. 6294-6307.

Macdonald, K., and Fox, P.J. (1990) "The Mid-Ocean Ridge": Scientific American.

Maclennan, J., McKenzie, D., and Grönvold, K. (2001) "Plume-driven upwelling under central Iceland": Earth and Planetary Science Letters, v. **194**: p. 67-82.

A suite of 70 basaltic samples from the Herdubreid region of the Northern Volcanic Zone (NVZ) in central Iceland has been analysed for major and trace element compositions. The average light rare earth element concentration of these basalts is more than a factor of 2 higher than that of basalts from the Theistareykir volcanic system near the northern end of the NVZ. Seismic surveys of the NVZ have shown that the crustal thickness increases from 20 km near Theistareykir to 32–40 km in central Iceland. The observed REE composition and crustal thickness of the Theistareykir area can be reproduced by a melting model where mantle with a potential temperature of 1480°C upwells under the spreading ridge and the mantle upwelling is driven by plate separation alone. However, plate-driven upwelling models cannot simultaneously reproduce the composition of the Herdubreid region lava and the observed crustal thickness. Forward and inverse techniques show that plate-driven models that match the crustal thickness underestimate the La concentration by more than a factor of 2, and models that reproduce the compositions underestimate the crustal thickness by a factor of 4–5. Therefore one of the assumptions involved in the plate-driven upwelling models is not appropriate for central Iceland. A new set of models was developed in which mantle upwelling rates are allowed to differ from those of plate-driven upwelling in order to investigate the role of plume-driven mantle upwelling. The lava composition and crustal thickness of the Herdubreid region can be reproduced by models where the upwelling rates near the base of the melting region (>100 km depth) are 10 times higher than those expected from plate-driven upwelling alone and the mantle potential temperature is 1480–1520°C. About half of the melt generation under central Iceland results from plume-driven upwelling, with the remainder caused by plate-driven upwelling of hot material. This result is in agreement with numerical models of ridge-centred plumes.

McDougall, I., and Wensink, H. (1966) "Paleomagnetism and Geochronology of the Pliocene-Pleistocene Lavas in Iceland": Earth and Planetary Science Letters, v. **1**: p. 232-236.

Maclennan, J., Jull, M., McKenzie, D., Slater, L., and Grönvold, K. (2002) "The link between volcanism and deglaciation in Iceland": GEOCHEMISTRY GEOPHYSICS GEOSYSTEMS, v. **3**(11, 1062): p. 1-25.

Temporal variation in the eruption rate and lava composition in the rift zones of Iceland is associated with deglaciation. Average eruption rates after the end of the last glacial period, ~12 kyr BP, were up to 100 times higher than those from both the glacial period and recent times (<5 kyr BP). This peak in volcanic activity finished less than 2 kyr after the end of deglaciation. New geochemical data from ~80 basalt and picrite samples from the Theistareykir and Krafla volcanic systems show that there is a temporal variation in both the major and trace element composition of the eruptions. Early postglacial eruptions show a greater range in MgO contents than eruptions from other times, and at a fixed MgO content, the concentration of incompatible elements in subglacial eruptions is higher than that in early postglacial eruptions. Recent eruptions from the Krafla system have similar compositions to subglacial eruptions. The high eruption rates and low rare earth element (REE) concentrations in the lava from early postglacial times can be accounted for by increased melt generation rates in the

shallow mantle caused by unloading of an ice sheet. Magma chamber processes such as crystallization and assimilation can produce the temporal variation in REE contents if garnet is present. However, garnet is not observed as a phenocryst or xenocryst phase and is not required to match the variation in major element contents observed at Krafla and Theistareykir. If the increase in eruption rates reflects increased melt production rates in the mantle, then the relative timing of deglaciation and the burst in eruption rates can be used to estimate the rate of melt transport in the mantle. The observed duration of enhanced eruption rates after deglaciation can be reproduced if the vertical melt extraction velocity is >50 m yr−1.

McNutt, M. (1990) "Deep causes of hotspots": Nature, v. **346**(6286): p. 701-702.

Morgan, W.J. (1983) "Hotspot Tracks and the Early Rifting of the Atlantic": Tectonophysics, v. **94**: p. 123-139.

Nilsen, T.H. (1978) "Lower Tertiary laterite on the Iceland-Faeroe Ridge and the Thulean land bridge": Nature, v. **274**: p. 786-788.

O'Hara, M.J. (1973) "Non-Primary Magmas and Dubious Mantle Plume beneath Iceland": Nature, v. **243**.

Pálmason, G. (1974) Insular Margins of Iceland, *in* Burk, C.A., and Drake, C.L., eds., The Geology of Continental Margins.

Ross, J.G., and others (1976) "40Ar/39Ar dates for spreading rates in Eastern Iceland": Nature, v. **259**: p. 36-38.

Schilling, J.G. (1973) "Iceland Mantle Plume: Geochemical Study of Reykjanes Ridge": Nature, v. **242**: p. 565-571.

Serson, P.H., Hannaford, W., and Haines, G.V. (1968) "Magnetic Anomalies over Iceland": Science, v. **162**: p. 355-356.

Shen, Y., Solomon, S.C., Bjarnason, I.T., and Wolfe, C.J. (1998) "Seismic evidence for a lower mantle origin of the Icelandic plume": Nature, v. **395**(6697): p. 62-65.

Iceland, one of the most thoroughly investigated hotspots, is generally accepted to be the manifestation of an upwelling mantle plume. Yet whether the plume originates from the lower mantle or from a convective instability at a thermal boundary layer between the upper and lower mantle near 660 km depth remains unconstrained.

Sigmarsson, O., Condomines, M., and Fourcade, S. (1992) "Mantle and crustal contribution in the genesis of Recent basalts from off-rift zones in Iceland: Constraints from Th, Sr and O isotopes": Earth and Planetary Science Letters, v. **110**(1-4): p. 149-162.

Along the two volcanic off-rift zones in Iceland, the Snaefellsnes volcanic zone (SNVZ) and the South Iceland volcanic zone (SIVZ), geochemical parameters vary regularly along the strike towards the centre of the island. Recent basalts from the SNVZ change from alkali basalts to tholeiites where the volcanic zone reaches the active rift axis, and their 87Sr/86Sr and Th/U ratios decrease in the same direction. These variations are interpreted as the result of mixing between mantle melts from two distinct reservoirs below Snaefellsnes. The mantle melt would be more depleted in incompatible elements, but with a higher 3He/4He ratio (R/Ra [approximate] 20) beneath the centre of Iceland than at the tip of the Snaefellsnes volcanic zone (R/Ra [approximate] 7.5).From southwest to northeast along the SIVZ, the basalts change from alkali basalts to FeTi basalts and quartz-normative tholeiites. The Th/U ratio of the Recent basalts increases and both (230Th/232Th) and [delta]18O values decrease in the same direction. This reflects an important crustal contamination of the FeTi-rich basalts and the quartz tholeiites. The two types of basalts could be produced through assimilation and fractional crystallization in which primary alkali basaltic and olivine tholeiitic melts `erode' and assimilate the base of the crust. The increasingly tholeiitic character of the basalts towards the centre of Iceland, which reflects a higher degree of partial melting, is qualitatively consistent with increasing geothermal gradient and negative gravity anomaly.The highest Sr isotope ratio in Recent basalts from Iceland is observed in Oraefajokull volcano, which has a 3He/4He ratio (R/Ra [approximate] 7.8) close to the MORB value, and this might represent a mantle source similar to that of Mauna Loa in Hawaii.

Sigmundsson, F. (2005) Glacial isostasy and sea-level change: rapid vertical movements and changes in volcanic production rates, Iceland Geodynamics- crustal deformation and divergent plate tectonics, Springer, p. 151-173.

Sigurðsson, H. (1967) The Icelandic Basalt Plateau and the Question of Sial. A Review, *in* Björnsson, S., ed., Societas Scientiarum Islandica 38: Iceland and Mid-Ocean Ridges: Reykjavík, Vísindafélag Íslendinga, p. 32-45.

Sigurðsson, H., and Sparks, S.R.J. (1978) "Lateral magma flow within rifted Icelandic Crust": Nature, v. **274**: p. 126-130.

Sigvaldason, G. (1973) "Basalts from the Centre of the Assumed Icelandic Mantle Plume": Journal of Petrology, v. **15**(Part 3): p. 497- 524.

Sigvaldason, G.E. (2002) "Volcanic and tectonic processes coinciding with glaciation and crustal rebound: an early Holocene rhyolitic eruption in the Dyngjufjöll volcanic centre and the formation of the Askja caldera, north Iceland": Bulletin of Volcanology v. **64**: p. 192-205.

A pronounced volcanic production maximum on the rift zones through Iceland coincided with rapid crustal rebound during and after glacier melting at the Pleistocene/Holocene boundary. At peak glaciation, ice thickness over central Iceland may have reached 1,500–2,000 m, causing 400–500-m depression of the crust. Rapid climatic improvement caused glacier melting and removal of the ice load within about 1,000

years. Low mantle viscosity resulted in rapid crustal rebound which was completed in about 1,000 years, with an average rate of uplift on the order of nearly half a metre per year over central Iceland. High volcanic production rate is documented by tephrachronological dating and volume estimates of several large-volume monogenetic lava shields and polygenetic volcanic centres along the plate boundary. A Plinian rhyolitic eruption, dated at about 10 ka within the Askja caldera in the Dyngjufjöll volcanic centre, left a pumice deposit which serves as a marker horizon during this remarkable, high-intensity period in the history of the volcano. At the time of the eruption, glaciers had retreated from the coastal areas of the country but the central, elevated parts were covered with a thinning glacier. The Plinian eruption (1–2 km3 dense rock equivalent) was triggered by pressure release caused by glacier melting and volatile supersaturation. Distal deposits of rhyolitic pumice are found in soil sections in coastal areas of eastern and northern Iceland where the pumice occurs between tephra layers from other sources which have been dated by independent methods. A few proximal deposits are preserved within the Dyngjufjöll centre. These provide age constraints on major tectonic and volcanic events during the period of crustal rebound, before and after complete glacier removal. The rhyolitic pumice is sandwiched between thick layers of phreatomagmatic basaltic tephra formed in an open melt-water lake. Sharp contacts between the deposits suggest quick succession of events, but lack of mixing between magmas indicates separate vent locations. The vent location for the 10-ka Plinian eruption has been obliterated by later events but available evidence, supported by a gravity survey, suggests its location in the central part of the Dyngjufjöll volcano. The eruption formed a subsidence structure, presently seen as an embayment in the hyaloclastite mountain block in the southern part of the Askja caldera where a second Plinian eruption occurred in 1875 A.D. The Plinian 10-ka eruption occurred while thinning glaciers were still present over central Iceland, but the Askja caldera formed after lavas started to flow over ice-free surfaces. The morphology of the caldera faults suggests non-simultaneous movement, and the tectonics are not easily compatible with conventional caldera models. A model is proposed involving uplift of tectonically well-defined crustal blocks to the north and west of the Askja caldera, combined with downsagging caused by voluminous outpouring of basaltic lava. The southern and eastern borders of the caldera are remnants of a subsidence following the 10-ka Plinian eruption, partly reactivated by the 1875 A.D. Plinian eruption. The model provides a satisfactory explanation for the enigmatic Öskjuop pass, and it is in agreement with a gravity survey of the Dyngjufjöll centre. The uplift coincided with rapid crustal rebound which was amplified by crustal deformation (doming) of the volcanic centre caused by high magmatic pressure in the plumbing system of the volcano. This is supported by emission of very large lava flows produced in the first millennia of the Holocene.

Sigvaldason, G.E., Annertz, K., and Nilsson, M. (1992) "Effect of glacier loading/deloading on volcanism: postglacial volcanic production rate of the Dyngjufjöll area, central Iceland": Bulletin of Volcanology, v. **54**(5): p. 385-392.

Tephrochronological dating of postglacial volcanism in the Dyngjufjöll volcanic complex, a major spreading center in the Icelandic Rift Zone, indicates a high production rate in the millennia following deglaciation as compared to the present low productivity. The visible and implied evidence indicates that lava production in the period 10 000–4500 bp was at least 20 to 30 times higher than that in the period after 2900 bp but the results are biased towards lower values for lava volumes during the earlier age periods since multiple lava layers are buried beneath younger flows. The higher production rate during the earlier period coincides with the disappearance of glaciers

of the last glaciation. Decreasing lithostatic pressure as the glacier melts and vigorous crustal movements caused by rapid isostatic rebound may trigger intense volcanism until a new pressure equilibrium has been established.

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Widespread flood basalt volcanism and continental rifting in the northeast Atlantic in the early Tertiary period (about 55 Myr ago) have been linked to the mantle plume now residing beneath Iceland. Although much is known about the present-day Iceland plume, its thermal structure, composition and position in the early Tertiary period remain unresolved.

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The Sydra Formation is a widespread interglacial complex in the North Volcanic Zone, Iceland, from the sector of the Askja volcano down to Öxarfjördur at the north coast. It probably corresponds to OIS 5e, 5d and 5c. Subsequently, the region was covered by the Weichselian ice cap. It is significant as well for the understanding of the OIS 6 deglaciation and its relations to volcanism as also for the erosional budget of the Saalian, warm based and Weichselian, cold based, glaciations. A topographic bulge linked with a rapid glacio-isostatic rebound, downstream of the Jökulsá á Fjöllum river, is responsible for the development of the Sydra lacustrine deposits. An early abrupt event (Sy2), the Sydra ash probably corresponds to ash zone B as on the northern Iceland shelf and possibly an abrupt cooling. It presents no similarity with the Fossvogur formation in the Reykjavik district. The meaning of the formation is significant in term of rift activity and of palaeoclimate for OIS5.

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A new global S-wave velocity model reveals that although mid-ocean ridges and hotspots are both underlain by low-velocity anomalies in the mantle, these have distinctly different structures. This implies that there are differences between the upwelling mechanisms *under ridges and under hotspots. The velocity model also shows that there may be interactions between ridges and hotpots near Afar and St Helena.*

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Handrit, hluti - hugsað til útgáfu sem sjálfstæð bók fyrir opinn almennan markað og ætlað til kennslu og fræðslu um myndun, mótun og breytingar lands og landnýtingarskilyrða á svæðum þar sem hraði náttúrufarslegra ferla verður hraðari en almennt gengur og gerist vegna sérstæðra skilyrða bæði af innrænum og útrænum toga

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During the Weichselian glaciation Iceland was covered with an ice cap which caused downward flexure of the Earth's surface. The post-glacial rebound in Iceland was very rapid, being completed in about 1000 years. The length of this time interval constrains the maximum value of asthenosphere viscosity in Iceland to be 1x10(19) Pa s or less. Further clarification of the ice retreat and uplift history may reveal lower viscosity. Current changes in the mass balance of Icelandic glaciers must lead to measureable elevation changes considering this low viscosity. Expected current elevation changes around the Vatnajökull ice cap are of the order of 1 cm per year, due to mass balance change in this century.

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Measurements of the lake level of Lake Langisjór at the SW edge of the Vatnajokull ice cap indicate a tilt of 0.26 +/- 0.06 murad/year away from the ice cap in the years 1959-1991. The tilt is too large to be explained as an elastic Earth response to ice, retreat this century, or to be caused by change in the gravitational pull of the ice cap, but it can be explained by sub-lithospheric viscous adjustment. Regional subsidence in historical times in SE Iceland can similarly be attributed to viscous adjustment resulting from the increased load of Vatnajökull during the Little Ice Age. The inferred sub-lithospheric viscosity is 1 x 10(18) - 5 x 10(19) Pa s.

Sigmundsson, F., Pagli, C., Sturkell, E., Geirsson, H., Einarsson, P., Árnadóttir, Þ. and Björnsson, H. (2005) Landris við Vatnajökul, Rannsóknir Vegagerðarinnar: Hótel Nordica, Reykjavík.

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A pronounced volcanic production maximum on the rift zones through Iceland coincided with rapid crustal rebound during and after glacier melting at the Pleistocene/Holocene boundary. At peak glaciation, ice thickness over central Iceland may have reached 1,500–2,000 m, causing 400–500-m depression of the crust. Rapid climatic improvement caused glacier melting and removal of the ice load within about 1,000 years. Low mantle viscosity resulted in rapid crustal rebound which was completed in about 1,000 years, with an average rate of uplift on the order of nearly half a metre per year over central Iceland. High volcanic production rate is documented by tephrachronological dating and volume estimates of several large-volume monogenetic lava shields and polygenetic volcanic centres along the plate boundary. A Plinian rhyolitic eruption, dated at about 10 ka within the Askja caldera in the Dyngjufjöll volcanic centre, left a pumice deposit which serves as a marker horizon during this remarkable, high-intensity period in the history of the volcano. At the time of the eruption, glaciers had retreated from the coastal areas of the country but the central, elevated parts were covered with a thinning glacier. The Plinian eruption (1–2 km3 dense rock equivalent) was triggered by pressure release caused by glacier melting and volatile supersaturation. Distal deposits of rhyolitic pumice are found in soil sections in coastal areas of eastern and northern Iceland where the pumice occurs between tephra layers from other sources which have been dated by independent methods. A few proximal deposits are preserved within the Dyngjufjöll centre. These provide age constraints on major tectonic and volcanic events during the period of crustal rebound, before and after complete glacier removal. The rhyolitic pumice is sandwiched between thick layers of phreatomagmatic basaltic tephra formed in an open melt-water lake. Sharp contacts between the deposits suggest quick succession of events, but lack of mixing between magmas indicates separate vent locations. The vent location for the 10-ka Plinian eruption has been obliterated by later events but available evidence, supported by a gravity survey, suggests its location in the central part of the Dyngjufjöll volcano. The eruption formed a subsidence structure, presently seen as an embayment in the hyaloclastite mountain block in the southern part of the Askja caldera where a second Plinian eruption occurred in 1875 A.D. The Plinian 10-ka eruption occurred while thinning glaciers were still present over central Iceland, but the Askja caldera formed after lavas started to flow over ice-free surfaces. The morphology of the caldera faults suggests non-simultaneous movement, and the tectonics are not easily compatible with conventional caldera models. A model is proposed involving uplift of tectonically well-defined crustal blocks to the north and west of the Askja caldera, combined with downsagging caused by voluminous outpouring of basaltic lava. The southern and eastern borders of the caldera are remnants of a subsidence following the 10-ka Plinian eruption, partly reactivated by the 1875 A.D. Plinian eruption. The model provides a satisfactory explanation for the enigmatic Öskjuop pass, and it is in agreement with a gravity survey of the Dyngjufjöll centre. The uplift coincided with rapid crustal rebound which was amplified by crustal *deformation (doming) of the volcanic centre caused by high magmatic pressure in the plumbing system of the volcano. This is supported by emission of very large lava flows produced in the first millennia of the Holocene.*

Sigvaldason, G.E., Annertz, K., and Nilsson, M. (1992) "Effect of glacier loading/deloading on volcanism: postglacial volcanic production rate of the Dyngjufjöll area, central Iceland": Bulletin of Volcanology, v. **54**(5): p. 385-392.

Tephrochronological dating of postglacial volcanism in the Dyngjufjöll volcanic complex, a major spreading center in the Icelandic Rift Zone, indicates a high production rate in the millennia following deglaciation as compared to the present low productivity. The visible and implied evidence indicates that lava production in the period 10 000–4500 bp was at least 20 to 30 times higher than that in the period after 2900 bp but the results are biased towards lower values for lava volumes during the earlier age periods since multiple lava layers are buried beneath younger flows. The higher production rate during the earlier period coincides with the disappearance of glaciers of the last glaciation. Decreasing lithostatic pressure as the glacier melts and vigorous crustal movements caused by rapid isostatic rebound may trigger intense volcanism until a new pressure equilibrium has been established.

Sjöberg, L.E., Pan, M., Asenjo, E., and Erlingsson, S. (2000) "Glacial rebound near Vatnajökull, Iceland, studied by GPS campaigns in 1992 and 1996": Journal of Geodynamics, v. **29**(1-2): p. 63-70.

Since about 1920 the Vatnajokull ice cap in Iceland has experienced a significant retreat, corresponding to a volume reduction of more than 180 km3. With two GPS campaigns in 1992 and 1996 along the southern border of the glacier preliminary results reveal land uplift rates of 1-6 mm/yr, after a one-parameter (bias) fit with recent earth rheology models. The best fit model suggests that the lithosphere in the area is about 30 km thick and the viscosity of the asthenosphere 5 x 1018 Pa s. The rms fit of uplift rate at all GPS sites is +/-1.4 mm/yr. As the GPS data alone cannot provide the absolute uplift rates, the one-parameter fit to the theoretical modelling implies that the absolute rates were estimated by the matching of the GPS data and model. The resulting uplift rate at station Hofn (1 mm/yr) is not consistent with two independent sources, and we therefore conclude that further GPS epoch and permanent GPS site data are needed to confirm the present geodynamic processes near Vatnajokull.

Sjöberg, L.E., Pan, M., Erlingsson, S., Asenjo, E., and Árnason, K. (2004) "Land uplift near Vatnajokull, Iceland, as observed by GPS in 1992, 1996 and 1999": Geophysical Journal International, v. **159**(3): p. 943-948.

Warming of the climate in the 20th century has been manifested by an ablation of Europe's largest ice cap, Vatnajokull in Iceland. The thin elastic lithosphere and the low-viscosity asthenosphere are responding to the reduction in mass by current land uplift in the vicinity of the ice cap suggested to be of the order of 5-10 mm yr(-1): lithosphere thickness and asthenosphere viscosities compatible with these values have been inferred. From our repeated GPS epoch campaigns in 1992, 1996 and 1999 uplift rates are estimated to be of the order of 5-19 mm yr(-1), and the uplift rate is decreasing by -0.11 +/- 0.01 mm yr(-1) km(-1) with radial distance from the centre of the ice cap. These results deviate from previous Earth rheology models estimated for the region. Our data indicate that the lithosphere thickness might be of the order of 10-

20 km and the asthenosphere viscosity may be as low as 5 x 10(17) Pa s, but these parameters need a careful fitting to the estimated uplift rates.

Sturkell, E., H. Geirsson, et al. (2005). Landris við Vatnajökul, Áfangaskýrsla til Vegagerðarinnar, Nordic Volcanological Center**:** 12 pp.

Thoma, M. and D. Wolf (2001). Inverting land uplift near Vatnajökull, Iceland, in terms of lithosphere thickness and viscosity stratification. Gravity, Geoid, and Geodynamics 2000. M. S. Sideris. Berlin, Springer-Verlag**:** 97-102.

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Þórsdóttir, H. (2005) "Fjörðurinn yngri en áður var talið": Morgunblaðið156. tbl. 93. árg.(sunnudaginn 21. júní 2005): p. baksíða.

Viðtal við Pál Imsland og frétt Hrundar Þórsdóttur um niðurstöður fyrirlesturs á strandráðstefnu á Hornafirði

5.13 Aldursgreining m.a. með fléttum eða öskulögum (dating, lichenometry, tephrachronology)

5.13.1 Aldursgreining með fléttum (Lichenometry)

Bingham, R.G. (1998) An assessment of rare, large magnitude (catastrophic) events in landscape evolution: a study of jökulhlaups in Öræfi, south-east Iceland. , University of Edinburgh.

Argument continues today over the relative significance of rare, large magnitude (a.k.a. catastrophic) events in landscape evolution. This project develops the debate by examination of the proglacial foregrounds of Falljökull and Kotárjökull, Öræfi, south-east Iceland. 'Catastrophic' jökulhlaups (large-scale glacier floods) inundated these neighbouring foregrounds in the years 1362 and 1727 as a result of sudden drainages of the Öræfajökull caldera during Plinian-style volcanic eruptions. The proglacial landscapes today preserve much of the geomorphology created by these jökulhlaups, but they have also experienced 'gradual' modification due to glacial and fluvial activity. The proglacial foregrounds of Falljökull and Kotárjökull are mapped geomorphologically, thus showing in more detail than has previously been published the courses followed by the 1362 and 1727 jökulhlaups. The distribution of the landforms produced by the jökulhlaups is explained using an analogue from the

Skeidarársandur 1996 jökulhlaup studied by Russell and Knudsen (in press). In front of Falljökull, modification to the landscape since the 1727 jökulhlaup has mostly been directly related to glacier movement. Moraines left behind by glacier retreat are dated using lichenometry, basing the dating on an age/size relationship produced by Thompson and Jones (1986). Since 1727, Falljökull advanced until the late 19th century, and then retreated until the early 1970s. In front of Kotárjökull, modification to the landscape since the 1727 jökulhlaup may mostly be a result of fluvial action. Thompson and Jones (1986) believed that a sequence of river terraces had been cut over many years following 1727 due to gradual fluvial downcutting, but it is possible that the terraces were formed catastrophically during the jökulhlaup. These terraces were surveyed and mapped. Lichenometric dating was found to be impossible to carry out on the terraces owing to a thick moss cover. This means that the lichen dates recorded by Thompson and Jones (1986) may not reflect the true date of exposure of the terraces but merely when they were last free of moss. The results suggest that the Kotárjökull foreground preserves better the catastrophic landscape created by the jökulhlaups, whilst the Falljökull foreground has been modified to a greater degree by gradual land-forming processes. The unconfined nature of Falljökull's snout compared with the confined location of Kotárjökull's snout may have played a major role in producing these contrasting outcomes.

Bradwell, T. (2001) Glacier fluctuations, lichenometry and climate change in Iceland. Unpublished PhD thesis: Edinburgh, University of Edinburgh.

— (2001) "A new lichenometric dating curve for southeast Iceland": Geografiska Annaler v. **83 A**: p. 91-101.

This paper presents a new lichenometric dating curve for southeast Iceland. The temporal framework for the curve is based on reliably dated surfaces covering the last 270 years, making it the best constrained study of this nature conducted in Iceland. The growth of lichen species within Rhizocarpon Section Rhizocarpon is non-linear over time, with larger (older) thalli apparently growing more slowly. The linear 'growth' curves derived previously by former authors working in Iceland represent only part of a curve which has an overall exponential form. Reasons for the non-linearity of the new dating curve are probably physiological, although climatic change over the last three centuries cannot be ruled out. Use of linear 'growth' curves in Iceland is problematic over time-spans of more than c. 80 years. Pre-20th century moraines dated using a constant, linear relationship between lichen size and age are probably older than previously believed. Those moraines lichenometrically 'dated' to the second half of the 19th century in Iceland may actually pre-date this time by several decades (30–100 years), thus throwing doubt on the exact timing of maximum glaciation during the 'Little Ice Age'.

— (2004) "Lichenometric dating in southeast Iceland- the size-frequency approach." Geografiska Annaler v. **86 A**: p. 31-41.

The age of recent deposits can be determined using an intrinsic characteristic of the lichen 'population' growing on their surface. This paper presents a calibrated dating curve based on the gradient of the size-frequency distribution of yellow-green Rhizocarpon lichens. The dating potential of this new curve is tested on surfaces of known age in southeast Iceland. This particular size—frequency technique is also compared with the more traditional largest-lichen approach. The results are very encouraging and

suggest that the gradient can be used as an age indicator, at least on deposits formed within the last c. 150 years – and probably within the last c. 400 years – in the maritime subpolar climate of southeast Iceland. Using both lichenometric techniques, revised dates for moraines on two glacier forelands are presented which shed new light on the exact timing of the Little Ice Age glacier maximum in Iceland.

Bradwell, T., Dugmore, A.J., and Sugden, D.E. (2006) "The Little Ice Age glacier maximum in Iceland and the North Atlantic Oscillation: evidence from Lambatungnajökull, southeast Iceland": Boreas, v. **35**(1): p. 61-80.

This article examines the link between late Holocene fluctuations of Lambatungnajökull, an outlet glacier of the Vatnajökull ice cap in Iceland, and variations in climate. Geomorphological evidence is used to reconstruct the pattern of glacier fluctuations, while lichenometry and tephrostratigraphy are used to date glacial landforms deposited over the past ~400 years. Moraines dated using two different lichenometric techniques indicate that the most extensive period of glacier expansion occurred shortly before c. AD 1795, probably during the 1780s. Recession over the last 200 years was punctuated by re-advances in the 1810s, 1850s, 1870s, 1890s and c. 1920, 1930 and 1965. Lambatungnajökull receded more rapidly in the 1930s and 1940s than at any other time during the last 200 years. The rate and style of glacier retreat since 1930 compare well with other similar-sized, non-surging, glaciers in southeast Iceland, suggesting that the terminus fluctuations are climatically driven. Furthermore, the pattern of glacier fluctuations over the 20th century broadly reflects the temperature oscillations recorded at nearby meteorological stations. Much of the climatic variation experienced in southern Iceland, and the glacier fluctuations that result, can be explained by secular changes in the North Atlantic Oscillation (NAO). Advances of Lambatungnajökull generally occur during prolonged periods of negative NAO index. The main implication of this work relates to the exact timing of the Little Ice Age in the Northeast Atlantic. Mounting evidence now suggests that the period between AD 1750 and 1800, rather than the late 19th century, represented the culmination of the Little Ice Age in Iceland.

Dabski, M. (2002) "Dating of the Fláajökull moraine ridges, SE-Iceland; comparison of the glaciological, cartographic and lichenometric data": Jökull, v. **51**: p. 17-24.

Evans, D.J.A., Archer, S., and Wilson, D.J.H. (1999) "A comparison of the lichenometric and Schmidt hammer dating techniques based on data from the proglacial areas of some Icelandic glaciers": Quaternary Science Reviews, v. **18**(1): p. 13-41.

Measurements of Rhizocarpon section and Schmidt hammer R-values are reported from the proglacial geomorphic features on the forelands of the Icelandic glaciers of Kvíárjökull, Hólárjökull and Heinabergsjökull (Öræfi and south Vatnajökull), Sandfellsjökull and Öldufellsjökull (east Mýrdalsjökull), and Brúárjökull, Eyjabakkajökull and west Snæfell (north Vatnajökull). These data are used in reconstructions of patterns of glacier recession since the Little Ice Age maximum, and the geomophic signals of climatic versus non-climatic events are discussed. Age control was obtained from various dated substrates by utilizing historical accounts, aerial photographs and grave stones. Three lichen growth rates are calculated: (a) 0.51 mm a^{-1} (corrected to 0.50 mm a^{-1}) with a colonization lag time of < 16 yr for the arid forelands of north Vatnajökull; (b) 0.56 mm a^{-1} with a colonization lag time of 5 yr for the Icelandic southeast coast; and (c) 0.80 mm a^{-1} with a colonization lag time of 6.5 yr for the south Vatnajökull and

east Mýrdalsjökull forelands. These compare favourably with a previously published growth rate of 0.44 mm a−1 for the arid north of Iceland. This regional coverage of data allows a comparison between annual precipitation totals and lichen growth rates and the construction of a growth rate prediction curve for Iceland. The success of the Schmidt hammer in differentiating moraines based upon age varied according to the geomorphological setting. Reasonable R-value/lichen size correlations were obtained on the east Mýrdalsjökull and Heinabergsjökull forelands where unrestricted glacier advance into lowlands allows for a higher degree of debris surface freshening by direct glacial processes. Weak correlations were obtained at Kvíárjökull, where the glacier was restricted by a precursor latero-frontal moraine loop and therefore the debris comprising the Little Ice Age recessional moraines was diluted with material of various ages being reworked by mass movement from the precursor moraine loop. Similar problems arise in areas affected by surging glaciers, such as Brúárjökull and Eyjabakkajökull. It appears that an accurate R-value age-prediction curve can not be constructed for a timescale of < 100 yr in Iceland.

Everest, J., and Bradwell, T. (2003) "Buried glacier ice in southern Iceland and its wider significance": Geomorphology, v. **52**(3-4): p. 347-358.

Geo-electrical resistivity surveys have been carried out at recently deglaciated sites in front of three glaciers in southern Iceland: Skeiðarárjökull, Hrútarjökull, and Virkisjökull. The results show the presence of old glacier ice beneath debris mantles of various thickness. We conclude that buried glacier ice has survived for at least 50 years at Virkisjökull and Hrútarjökull, and probably for over 200 years at Skeiðarárjökull. Additional data from a further site have identified a discontinuous ice core within 18th-century jokulhlaup deposits. Photographic and lichenometric evidence show that the overlying debris has been relatively stable, and hence melting of the ice at all four sites is proceeding slowly due to the heat-shielding properties of the overburden. The geomorphic implications are pertinent when considering the potential longevity of buried ice. The possible implications for dating techniques, such as lichenometry, radiocarbon dating and cosmogenic surface-exposure dating are also important, as long-term readjustments of surface forms may lead to dating inaccuracy. Finally, it is recognised that landscape development in areas of stagnant ice topography may post-date initial deglaciation by a considerable degree

Gordon, J.E., and Sharp, M. (1983) "Lichenometry in dating recent glacial landforms and deposits, southeast Iceland": Boreas, v. **12**: p. p. 191-200.

Kirkbride, M.P., and Dugmore, A.J. (2001) "Can lichenometry be used to date the Little Ice Age glacial maximum in Icelands? " Climatic Change v. **48**: p. p. 151-167.

McKinzey, K.M., Orwin, J.F., and Bradwell, T. (2004) "Re-dating the moraines at Skálafellsjökull and Heinabergsjökull using different lichenometric methods: implications for the timing of the Icelandic Little Ice Age Maximum": Geografiske Annaler, v. **86A**: p. p.319-335.

Little Ice Age (LIA) moraines along the margins of Skálafellsjökull and Heinabergsjökull, two neighbouring outlet glaciers flowing from the Vatnajökull ice-cap, have been re-dated to test the reliability of different lichenometric approaches. During 2003, 12 000 lichens were measured on 40 moraine fragments at Skálafellsjökull and Heinabergsjökull to *provide surface age proxies. The results are revealing. Depending on the chosen method of analysis, Skálafellsjökull either reached its LIA maximum in the early 19th century (population gradient) or the late 19th century (average of five largest lichens), whereas the LIA maximum of Heinabergsjökull occurred by the mid-19th century (population gradient) or late-19th century (average of 5 largest lichens). Discrepancies (c. 80 years for Skálafellsjökull and c. 40 years for Heinabergsjökull) suggest that the previously cited AD 1887 LIA maxima for both glaciers should be reassessed. Dates predicted by the lichen population gradient method appear to be the most appropriate, as mounting evidence from other geochronological reconstructions and sea-ice records throughout Iceland tends to support an earlier LIA glacier maximum (late 18th to mid-19th century) and probably reflects changes in the North Atlantic Oscillation. These revised chronologies shed further light on the precise timing of the Icelandic LIA glacier maximum, whilst improving our understanding of glacier-climate interactions in the North Atlantic.*

— (2005) "A revised chronology of key Vatnajökull outlet glaciers during the little ice age": Annals of Glaciology, v. **Vol. 42**(1): p. 171-179.

Glacier fluctuations from key Vatnajökull outlets have been redated using tephrochronology coupled with two lichenometric techniques to ascertain the timing of the Little Ice Age (LIA) maximum in southeast Iceland. An updated tephrochronology for southeast Iceland (both the number of tephra layers present and their geochemical signatures) indicates a LIA maximum for both glaciers between AD 1755 and 1873. Based on a population gradient approach, lichenometrically dated moraines along the margins of Skálafellsjökull and Heinabergsjökull narrow this window to the early to mid-19th century respectively. These revised chronologies, in addition to emerging evidence from elsewhere in Iceland, support a late 18th- to early 19th-century LIA glacier maximum. In contrast, the Norwegian LIA glacial maximum is strongly centred around AD 1750. This implies differing glaciological responses to secular shifts in the North Atlantic Oscillation. Such revisions to the Vatnajökull record are crucial, as accurately identifying the timing and delimiting the spatial extent of the Icelandic LIA glacier maximum will allow further light to be shed on glacier-climate interactions in the North Atlantic.

Orwin, J.F., McKinzey, K.M., Stephens, M.A., and Dugmore, A.J. (submitted) "Mapping former ice margins using moraine lichen size distributions and the U2 statistic, southeast Iceland": Arctic, Antarctic and Alpine Researh.

Thompson, A., and Jones, A. (1986) "Rates and causes of proglacial river terrace formation in southeast Iceland: an application of lichenometric dating techniques": Boreas v. **15**: p. p. 231-246.

5.13.2 Aldursgreining með hjálp öskulaga, öskulagatímatal (Tephrachronology)

Bradwell, T., Dugmore, A.J., and Sugden, D.E. (2006) "The Little Ice Age glacier maximum in Iceland and the North Atlantic Oscillation: evidence from Lambatungnajökull, southeast Iceland": Boreas, v. **35**(1): p. 61-80.

This article examines the link between late Holocene fluctuations of Lambatungnajökull, an outlet glacier of the Vatnajökull ice cap in Iceland, and variations in climate. Geomorphological evidence is used to reconstruct the pattern of glacier fluctuations, while lichenometry and tephrostratigraphy are used to date glacial landforms deposited over the past ~400 years. Moraines dated using two different lichenometric techniques indicate that the most extensive period of glacier expansion occurred shortly before c. AD 1795, probably during the 1780s. Recession over the last 200 years was punctuated by re-advances in the 1810s, 1850s, 1870s, 1890s and c. 1920, 1930 and 1965. Lambatungnajökull receded more rapidly in the 1930s and 1940s than at any other time during the last 200 years. The rate and style of glacier retreat since 1930 compare well with other similar-sized, non-surging, glaciers in southeast Iceland, suggesting that the terminus fluctuations are climatically driven. Furthermore, the pattern of glacier fluctuations over the 20th century broadly reflects the temperature oscillations recorded at nearby meteorological stations. Much of the climatic variation experienced in southern Iceland, and the glacier fluctuations that result, can be explained by secular changes in the North Atlantic Oscillation (NAO). Advances of Lambatungnajökull generally occur during prolonged periods of negative NAO index. The main implication of this work relates to the exact timing of the Little Ice Age in the Northeast Atlantic. Mounting evidence now suggests that the period between AD 1750 and 1800, rather than the late 19th century, represented the culmination of the Little Ice Age in Iceland.

Larsen, G. (1984) "Recent volcanic history of the Veidivötn fissure swarm, southern Iceland- an approach to volcanic risk assessment": Journal of volcanology and geothermal research, v. **22**(1-2): p. 33-58.

The recent volcanic history of the southwestern part of the Veiðivötn fissure swarm, southern Iceland, provides a basis for assessment of volcanic risk in an area of large hydropower potential. Local tephrastratigraphy and regional tephrochronology provide relative and absolute dating of individual eruptions as well as information on the volume and distribution of the products formed in each eruption. Three large eruptions took place in this area in 1480 A.D., 900 A.D. and 150 A.D., respectively. Each eruption produced approx. 1 km3 (DRE) of basaltic, and minor amounts of silicic lava and tephra on fissures up to 42 km long. No evidence is found of smaller eruptions during this period. The estimated eruption frequency, one eruption every 600–800 years, implies that this part of the Veidivötn fissure swarm is inactive for long periods between relatively large volcanic events. A change in the mode of eruption from effusive to explosive took place during this period. The hazards posed by this area include far-reaching lava flows, widespread heavy tephra fall with thicknesses in excess of 2 m at distances of 10 km, and damming of a large glacial river with the consequent formation of unstable lakes. A volcano-tectonic model, which explains the observed eruption frequency and provides a basis for a long-term monitoring program, is proposed. Eruptions on the Veidivötn fissure swarm are interpreted as corollaries of rifting episodes initiated in the Bárdarbunga central volcano. Volcano-tectonic episodes affect the fissure swarm at an average interval of 100 years. Minor episodes are limited to the central volcano and adjacents parts of the fissure swarm. During the less frequent major episodes, rifting and volcanic activity extends to the extreme southwestern part of the fissure swarm. Seismic monitoring of the Bárdarbunga central volcano could provide an early warning of renewed activity on the Veidivötn fissure swarm. A major rifting episode resulting in eruption on its southwestern part can be expected during the next 100 to 300 years.

Larsen, G., Gudmundsson, M.T., and Björnsson, H. (1998) Dating of Vatnajökull by ash layers. Report on the Workshop on Vatnajökull, 20-25 June 1998, 9-10. European Science Foundation and European Ice Sheet Modelling Initiative (EISMINT): Skaftafell, Iceland.

— (2005) "Increased eruption frequency in volcanoes below Vatnajökull ice cap, Iceland, predicted by tephrochronology": Geophysical Research Abstracts, v. **7**(10066).

Larsen, G., Guðmundsson, M.T., and Björnsson, H. (1996) Gjóskulög í Tungnaárjökli: gossaga, aldur íss og dvalartími gjósku í jökli, Vorráðstefna 1996: "Eldgos í Vatnajökli 1996", ágrip erinda og veggspjalda: Reykjavík, Jarðfræðafélag Íslands, p. 33-35.

McKinzey, K.M., Orwin, J.F., and Bradwell, T. (2005) "A revised chronology of key Vatnajökull outlet glaciers during the little ice age": Annals of Glaciology, v. **Vol. 42**(1): p. 171-179.

Glacier fluctuations from key Vatnajökull outlets have been redated using tephrochronology coupled with two lichenometric techniques to ascertain the timing of the Little Ice Age (LIA) maximum in southeast Iceland. An updated tephrochronology for southeast Iceland (both the number of tephra layers present and their geochemical signatures) indicates a LIA maximum for both glaciers between AD 1755 and 1873. Based on a population gradient approach, lichenometrically dated moraines along the margins of Skálafellsjökull and Heinabergsjökull narrow this window to the early to mid-19th century respectively. These revised chronologies, in addition to emerging evidence from elsewhere in Iceland, support a late 18th- to early 19th-century LIA glacier maximum. In contrast, the Norwegian LIA glacial maximum is strongly centred around AD 1750. This implies differing glaciological responses to secular shifts in the North Atlantic Oscillation. Such revisions to the Vatnajökull record are crucial, as accurately identifying the timing and delimiting the spatial extent of the Icelandic LIA glacier maximum will allow further light to be shed on glacier-climate interactions in the North Atlantic.

Sigvaldason, G.E. (2002) "Volcanic and tectonic processes coinciding with glaciation and crustal rebound: an early Holocene rhyolitic eruption in the Dyngjufjöll volcanic centre and the formation of the Askja caldera, north Iceland": Bulletin of Volcanology v. **64**: p. 192-205.

A pronounced volcanic production maximum on the rift zones through Iceland coincided with rapid crustal rebound during and after glacier melting at the Pleistocene/Holocene boundary. At peak glaciation, ice thickness over central Iceland may have reached 1,500–2,000 m, causing 400–500-m depression of the crust. Rapid climatic improvement caused glacier melting and removal of the ice load within about 1,000 years. Low mantle viscosity resulted in rapid crustal rebound which was completed in about 1,000 years, with an average rate of uplift on the order of nearly half a metre per year over central Iceland. High volcanic production rate is documented by tephrachronological dating and volume estimates of several large-volume monogenetic lava shields and polygenetic volcanic centres along the plate boundary. A Plinian rhyolitic eruption, dated at about 10 ka within the Askja caldera in the

Dyngjufjöll volcanic centre, left a pumice deposit which serves as a marker horizon during this remarkable, high-intensity period in the history of the volcano. At the time of the eruption, glaciers had retreated from the coastal areas of the country but the central, elevated parts were covered with a thinning glacier. The Plinian eruption (1–2 km3 dense rock equivalent) was triggered by pressure release caused by glacier melting and volatile supersaturation. Distal deposits of rhyolitic pumice are found in soil sections in coastal areas of eastern and northern Iceland where the pumice occurs between tephra layers from other sources which have been dated by independent methods. A few proximal deposits are preserved within the Dyngjufjöll centre. These provide age constraints on major tectonic and volcanic events during the period of crustal rebound, before and after complete glacier removal. The rhyolitic pumice is sandwiched between thick layers of phreatomagmatic basaltic tephra formed in an open melt-water lake. Sharp contacts between the deposits suggest quick succession of events, but lack of mixing between magmas indicates separate vent locations. The vent location for the 10-ka Plinian eruption has been obliterated by later events but available evidence, supported by a gravity survey, suggests its location in the central part of the Dyngjufjöll volcano. The eruption formed a subsidence structure, presently seen as an embayment in the hyaloclastite mountain block in the southern part of the Askja caldera where a second Plinian eruption occurred in 1875 A.D. The Plinian 10-ka eruption occurred while thinning glaciers were still present over central Iceland, but the Askja caldera formed after lavas started to flow over ice-free surfaces. The morphology of the caldera faults suggests non-simultaneous movement, and the tectonics are not easily compatible with conventional caldera models. A model is proposed involving uplift of tectonically well-defined crustal blocks to the north and west of the Askja caldera, combined with downsagging caused by voluminous outpouring of basaltic lava. The southern and eastern borders of the caldera are remnants of a subsidence following the 10-ka Plinian eruption, partly reactivated by the 1875 A.D. Plinian eruption. The model provides a satisfactory explanation for the enigmatic Öskjuop pass, and it is in agreement with a gravity survey of the Dyngjufjöll centre. The uplift coincided with rapid crustal rebound which was amplified by crustal deformation (doming) of the volcanic centre caused by high magmatic pressure in the plumbing system of the volcano. This is supported by emission of very large lava flows produced in the first millennia of the Holocene.

Sigvaldason, G.E., Annertz, K., and Nilsson, M. (1992) "Effect of glacier loading/deloading on volcanism: postglacial volcanic production rate of the Dyngjufjöll area, central Iceland": Bulletin of Volcanology, v. **54**(5): p. 385-392.

Tephrochronological dating of postglacial volcanism in the Dyngjufjöll volcanic complex, a major spreading center in the Icelandic Rift Zone, indicates a high production rate in the millennia following deglaciation as compared to the present low productivity. The visible and implied evidence indicates that lava production in the period 10 000–4500 bp was at least 20 to 30 times higher than that in the period after 2900 bp but the results are biased towards lower values for lava volumes during the earlier age periods since multiple lava layers are buried beneath younger flows. The higher production rate during the earlier period coincides with the disappearance of glaciers of the last glaciation. Decreasing lithostatic pressure as the glacier melts and vigorous crustal movements caused by rapid isostatic rebound may trigger intense volcanism until a new pressure equilibrium has been established.

Smith, K.T., and Dugmore, A.J. (2006) "Jökulhlaups circa Landnám: Mid- to late first millennium AD floods in South Iceland and their implications for landscapes of settlement": Geografiska Annaler Series a-Physical Geography, v. **88A**(2): p. 165-176.

This paper presents geomorphological and sedimentological evidence for three large-scale floods to the west of the ice-capped volcano Katla around the time of Norse settlement or Landnám (AD 870-930). These glacial outburst floods (jökulhlaups), the most recent prehistoric events in a series of Holocene floods in the Markarfljót valley, are securely dated by tephrochronology and radiocarbon dating to between c. AD 500 and c. AD 900. The environmental impact of these events would have been extensive, affecting both the highlands and about 40-50 km(2) of the coastal lowlands where about 15 of the 400 or so landnam farms in Iceland were sited. An awareness of environmental conditions and landscape stability around the time of the Norse colonisation of Iceland is important to understand the earliest settlement patterns because of the different constraints and opportunities that they represent.

Vilmundardóttir, E.G., and Larsen, G. (1986) Productivity Pattern of the Veidivötn Fissure Swarm, South Iceland, in Postglacial Time, 17e Nordiska Geologmötet: Abstracts: Helsingfors, Finland, p. 214.

5.13.3 Aldursgreining með geislakolaðferð

Kirkbride, M.P., Dugmore, A.J., and Brazier, V. (2006) "Radiocarbon dating of mid-Holocene megaflood deposits in the Jökulsá á Fjöllum, north Iceland": The Holocene, v. **16**(4): p. 605 - 609.

Two megafloods in the canyon of the Jökulsá á Fjöllum, the major northern routeway for glaciovolcanic floods from Vatnajökull, have been closely dated by 14C AMS dates from Betula macrofossils within peat immediately below beds of flood-deposited sand. Ages of c. 4415 and c. 4065 yr BP (5020 and 4610 cal. yr BP) are consistent with the presence of the Hekla 4 tephra (c. 3830 yr BP) resting on the upper surface of the younger flood sand. These sediments are correlated across the Jökulsá a Fjöllum canyon with the upper flood sands in a stack recording around 16 flood events. Deposits on both sides of the canyon were trimmed by the last megaflood after the Hekla 3 tephra fall at c. 2900 yr BP, and the highest Holocene flood stages were at the culmination of a series peaking at c. 3500 yr BP. These floods have wider palaeoclimatic significance because they require the formation of large subglacial reservoirs below Vatnajökull. Therefore, the dated floods indicate that a large composite ice cap covered volcanoes in the southeastern highlands through the early and middle Holocene, and that flood routeways largely switched to the south after c. 3500 yr BP.

Smith, K.T., and Dugmore, A.J. (2006) "Jökulhlaups circa Landnám: Mid- to late first millennium AD floods in South Iceland and their implications for landscapes of settlement": Geografiska Annaler Series a-Physical Geography, v. **88A**(2): p. 165-176.

This paper presents geomorphological and sedimentological evidence for three large-scale floods to the west of the ice-capped volcano Katla around the time of Norse settlement or Landnám (AD 870-930). These glacial outburst floods (jökulhlaups), the most recent prehistoric events in a series of Holocene floods in the Markarfljót valley, are securely *dated by tephrochronology and radiocarbon dating to between c. AD 500 and c. AD 900. The environmental impact of these events would have been extensive, affecting both the highlands and about 40-50 km(2) of the coastal lowlands where about 15 of the 400 or so landnam farms in Iceland were sited. An awareness of environmental conditions and landscape stability around the time of the Norse colonisation of Iceland is important to understand the earliest settlement patterns because of the different constraints and opportunities that they represent.*

5.13.4 Aldursgreining, annað en með fléttum, öskulögum eða geislakolaðferð

Helgason, J., and Duncan, R.A. (1996) Jarðlagaskipan Svínafells í Öræfum: bergsegulstefna, aldursgreiningar og jöklunarsaga, Vorráðstefna 1996: ágrip erinda og veggspjalda: Odda, Reykjavík, Jarðfræðifélag Íslands.

— (2001) "Glacial-interglacial history of the Skaftafell region, southeast Iceland, 0-5 Ma": Geology, v. **29**(2): p. 179–182

Volcanic strata in the Skaftafell region, southeast Iceland, record a sequence of at least 16 glacial and interglacial intervals since 5 Ma. Two composite sections of 2 to 2.8 km thickness have been constructed from multiple, overlapping, cliff profiles. The timing of alternating sequences of subaerial lava flows, pillow basalts, and hyaloclastite deposits is provided by magnetostratigraphic mapping and K-Ar radiometric dating. We find that the frequency and intensity of glaciations increased significantly at ca. 2.6 Ma, and particularly since 0.8 Ma, amplifying topographic relief in this area from <100 m to 2 km. These changes correlate with increases in global ice volume, ice-rafted debris, and development from local to regional glacial conditions in the North Atlantic.

Helgason, J., and Roberts, B. (1992) Skaftafell: Jarðlagaskipan, bergsegulstefna og K-Ar aldursgreiningar, Vorráðstefna 1992: ágrip erinda: Reykjavík.

Jóhannesson, H. (1983) "Skalf þá og nötraði bærinn ": Náttúrufræðingurinn, v. **53**(1.-2.h.): p. 1-4.

Jónsson, J. (1960) "Mórinn á Skeiðarársandi": Náttúrufræðingurinn, v. **30. árg.**(1.hefti): p. 36-38.

Moorbath, S., Sigurdsson, H., and Goodwin, R. (1968) " K-Ar Ages of the Oldest Exposed Rocks in Iceland": Earth and Planetary Science Letters, v. **4**: p. 197-205.

Þórarinsson, S. (1964) "On the age of the terminal moraines of Brúarjökull and Hálsajökull": Jökull, v. **14**: p. 67-75.

Þórðarson, T., and Larsen, G. (2007) "Volcanism in Iceland in historical time: Volcano types, eruption styles and eruptive history": Journal of Geodynamics, v. **43**(1): p. 118-152.

The large-scale volcanic lineaments in Iceland are an axial zone, which is delineated by the Reykjanes, West and North Volcanic Zones (RVZ, WVZ, NVZ) and the East Volcanic Zone (EVZ), which is growing in length by propagation to the southwest through pre-existing crust. These zones are connected across central Iceland by the Mid-Iceland Belt (MIB). Other volcanically active areas are the two intraplate belts of Oraefajokull (OVB) and Snaefellsnes (SVB). The principal structure of the volcanic zones are the 30 volcanic systems, where 12 are comprised of a fissure swarm and a central volcano, 7 of a central volcano, 9 of a fissure swarm and a central domain, and 2 are typified by a central domain alone.Volcanism in Iceland is unusually diverse for an oceanic island because of special geological and climatological circumstances. It features nearly all volcano types and eruption styles known on Earth. The first order grouping of volcanoes is in accordance with recurrence of eruptions on the same vent system and is divided into central volcanoes (polygenetic) and basalt volcanoes (monogenetic). The basalt volcanoes are categorized further in accordance with vent geometry (circular or linear), type of vent accumulation, characteristic style of eruption and volcanic environment (i.e. subaerial, subglacial, submarine).Eruptions are broadly grouped into effusive eruptions where >95% of the erupted magma is lava, explosive eruptions if >95% of the erupted magma is tephra (volume calculated as dense rock equivalent, DRE), and mixed eruptions if the ratio of lava to tephra occupy the range in between these two end-members. Although basaltic volcanism dominates, the activity in historical time (i.e. last 11 centuries) features expulsion of basalt, andesite, dacite and rhyolite magmas that have produced effusive eruptions of Hawaiian and flood lava magnitudes, mixed eruptions featuring phases of Strombolian to Plinian intensities, and explosive phreatomagmatic and magmatic eruptions spanning almost the entire intensity scale; from Surtseyan to Phreatoplinian in case of "wet" eruptions and Strombolian to Plinian in terms of "dry" eruptions. In historical time the magma volume extruded by individual eruptions ranges from ~1 m3 to ~20 km3 DRE, reflecting variable magma compositions, effusion rates and eruption durations.All together 205 eruptive events have been identified in historical time by detailed mapping and dating of events along with extensive research on documentation of eruptions in historical chronicles. Of these 205 events, 192 represent individual eruptions and 13 are classified as "Fires", which include two or more eruptions defining an episode of volcanic activity that lasts for months to years. Of the 159 eruptions verified by identification of their products 124 are explosive, effusive eruptions are 14 and mixed eruptions are 21. Eruptions listed as reported-only are 33. Eight of the Fires are predominantly effusive and the remaining five include explosive activity that produced extensive tephra layers. The record indicates an average of 20-25 eruptions per century in Iceland, but eruption frequency has varied on time scale of decades. An apparent stepwise increase in eruption frequency is observed over the last 1100 years that reflects improved documentation of eruptive events with time. About 80% of the verified eruptions took place on the EVZ where the four most active volcanic systems (Grimsvotn, Bardarbunga-Veidivotn, Hekla and Katla) are located and 9%, 5%, 1% and 0.5% on the RVZ-WVZ, NVZ, OVB, and SVB, respectively. Source volcano for ~4.5% of the eruptions is not known.Magma productivity over 1100 years equals about 87 km3 DRE with basaltic magma accounting for about 79% and intermediate and acid magma accounting for 16% and 5%, respectively. Productivity is by far highest on the EVZ where 71 km3 (~82%) were erupted, with three flood lava eruptions accounting for more than one half of that volume. RVZ-WVZ accounts for 13% of the magma and the NWZ and the intraplate belts for 2.5% each. Collectively the axi l zone (RVZ, WVZ, NVZ) has only erupted 15-16% of total magma volume in the last 1130 years.

Þórðarson, T., Miller, J., and Larsen, G. (1998) "New data on the age and origin of the Leiðólfsfell Cone Group in south Iceland": Jökull, v. **46**: p. 3-15.

5.14 Rannsóknir á öskulögum (tephrastratigraphy)

Barth, T.F.W. (1937) "Volcanic Ash from Vatnajökull (a Modern Formation of Sideroc.....)": Norsk Geologisk Tidsskrift, v. **17**: p. 31-38.

Bradwell, T., Dugmore, A.J., and Sugden, D.E. (2006) "The Little Ice Age glacier maximum in Iceland and the North Atlantic Oscillation: evidence from Lambatungnajökull, southeast Iceland": Boreas, v. **35**(1): p. 61-80.

This article examines the link between late Holocene fluctuations of Lambatungnajökull, an outlet glacier of the Vatnajökull ice cap in Iceland, and variations in climate. Geomorphological evidence is used to reconstruct the pattern of glacier fluctuations, while lichenometry and tephrostratigraphy are used to date glacial landforms deposited over the past ~400 years. Moraines dated using two different lichenometric techniques indicate that the most extensive period of glacier expansion occurred shortly before c. AD 1795, probably during the 1780s. Recession over the last 200 years was punctuated by re-advances in the 1810s, 1850s, 1870s, 1890s and c. 1920, 1930 and 1965. Lambatungnajökull receded more rapidly in the 1930s and 1940s than at any other time during the last 200 years. The rate and style of glacier retreat since 1930 compare well with other similar-sized, non-surging, glaciers in southeast Iceland, suggesting that the terminus fluctuations are climatically driven. Furthermore, the pattern of glacier fluctuations over the 20th century broadly reflects the temperature oscillations recorded at nearby meteorological stations. Much of the climatic variation experienced in southern Iceland, and the glacier fluctuations that result, can be explained by secular changes in the North Atlantic Oscillation (NAO). Advances of Lambatungnajökull generally occur during prolonged periods of negative NAO index. The main implication of this work relates to the exact timing of the Little Ice Age in the Northeast Atlantic. Mounting evidence now suggests that the period between AD 1750 and 1800, rather than the late 19th century, represented the culmination of the Little Ice Age in Iceland.

Brandt, O., Björnsson, H., and Gjessing, Y. (2005) "Mass balance rates derived by mapping internal tephra layers in Myrdalsjökull and Vatnajökull ice caps, Iceland": Annals of Glaciology, v. **Vol. 42**(1): p. 284-290.

Internal tephra layers of known age have been detected by radio-echo soundings within the Mýrdalsjökull and Vatnajökull ice caps in Iceland. Assuming steady state, the estimated strain rates since these isochrones were deposited on the glacier surface have been used to calculate past average specific net balance rates in the accumulation zones along three flowlines on Mýrdalsjökull and one on Vatnajökull. For the period 1918-91 the specific mass-balance rate has been estimated to 4.5 and 3.5 m a−1 at 1350 m a.s.l. on the southern and northern slopes of Mýrdalsjökull, respectively. At 1800 m elevation on the Bárdarbunga ice dome in Vatnajökull, the specific net balance averaged over the last three centuries is estimated to be about 2.1 m a−1. Given this specific net balance, a revised age-depth timescale is presented

for a 400 m deep ice core recovered in 1972 from Bárdarbunga. The ice at the bottom is estimated to be from AD 1750.

Dugmore, A.D. (1989) Tephrachronological studies of Holocene glacier fluctuations in south Iceland, *in* Oerlemans (ed.), ed., Glacier Fluctuations and Climatic Change: Dordrecht., Kluwer, p. pp.37-55. .

Grönvold, K., and Jóhannesson, H. (1984) "Eruption of Grímsvötn 1983; course of events and chemical studies of tephra (Grímsvatnagosið 1983, atburðarás og efnagreining á gjósku)": Jökull, v. **34**: p. 1-11.

A short eruption took place in the Grímsvötn volcano in May - June 1983. The eruption most probably started on May 28th. Activity was last observed on June 1st and by June 5th it was certainly over. The Grímsvötn volcano is situated within the western part of the Vatnajökull ice cap. It is almost totally ice covered and the caldera lake is covered by an ice chelf about 200 metres thick. The eruption site is within the caldera near the southern rim and a lake, about 500 m in diameter, formed in the ice shelf with a small island in the middle. The eruption was subaquatic and intermittent ash explosions were observed in the lake. Usually these were about 50-100 m high and a steam column rose up to about 5000 m height a. s. l. Three small ash fans formed on the surrounding ice sheet; two by explosions, one to the south early in the eruption and another to the east most likely on June 1st; the third to the north within the caldera was most likely caused mainly by an avalanche from the overhanging caldera wall into the lake. The glass phase of the ash was analyzed in a number of samples and found to be evolved basalt with a uniform chemical composition but minor variations are indicated. Samples from the 1934, 1922 and 1903 Grímsvötn eruptions were analyzed for comparison and show very similar chemical composition as the 1983 ash. This composition is also very similar to that of the glass phase of the eruption of the Laki craters 1783-84. The Grímsvötn volcano is also the site of a major geothermal system, stimated at 5000 MW. The heat source of this system is assumed to be magmatic intrusions, most likely with the same compostion as the ash. It appears unlikely that the heat extraction takes place in the same parts of the magmatic system as the evolution of the basalt.

Guðmundsson, H.J. (1998) Holocene glacier fluctuations and tephrochronology of the Öræfi district, Iceland [**PhD thesis**], University of Edinburgh, Scotland.

Hafliðason, H., Eiríksson, J., and VanKreveld, S. (2000) "The tephrochronology of Iceland and the North Atlantic region during the Middle and Late Quaternary: a review": Journal of Quaternary Science v. **15**: p. 3-22.

The tephrochronology of Iceland and the North Atlantic region is reviewed in order to construct a unified framework for the last 400 kyr BP. Nearly all of the tephra layers described are also characterised geochemically. A number of new tephra layers are analysed for the first time for their geochemical signature and a number of pre-Holocene tephra layers have been given an informal denotation. The tephrostratigraphy of Ash Zone II is highlighted. Where possible the rhyolitic tephra layers found outside Iceland have been correlated to known Icelandic tephra layers or to the volcanic source area. The application of tephra fallout in various depositional environments is described and discussed

Lacasse, C., Sigurdsson, H., Carey, S., Paterne, M., and Guichard, F. (1996) "North Atlantic deep-sea sedimentation of Late Quaternary tephra from the Iceland hotspot": Marine Geology, v. **129**(3-4): p. 207-235.

Piston cores recovered from the North Atlantic were used to study the sedimentation of Holocene and Pleistocene volcanic ash in the Irminger and Iceland Basins. Ash Zones 1 (≈ 11,100 yr B.P.), 2 (≈ 55,000 yr B.P.) and 3 (≈ 305,000 yr B.P.) were identified from their major element glass composition. The silicic and alkalic Ash Zones 1 and 2 originate from the Southeastern Volcanic Zone of Iceland, where they correlate with the Sólheimar ignimbrite from Katla volcano and the Thórsmörk ignimbrite from Tindfjallajökull volcano, respectively. The low-alkali composition of silicic Ash Zone 3 indicates a source from one of the silicic centers in the active rift system. Ash Zones 2 and 3 occur in the Irminger Basin as dispersed glass shards over a depth interval of several tens of centimeters. Their compositional and granulometric characteristics reflect an initial fallout on pack-ice north of Iceland, followed by ice-rafting sedimentation in the Denmark Strait, prior to bioturbation. δ18O stratigraphy of foraminifera in the cores indicates that the ash zones were deposited during a cold interval, at the time when seas north of Iceland were ice-covered. Sedimentary features indicate that turbidity currents were also involved in the dispersal of Ash Zones 1 and 2 south of Iceland. The initiation of these gravity currents from the shelf can be attributed to either glacier bursts (jökulhlaups) carrying tephra, or the entrance of pyroclastic flows into the ocean.

Larsen, G. (1977) Þrjú stór sprungugos á Suðausturgosbelt, Ráðstefna um íslenska jarðfræði, ágrip erinda: Reykjavík, Jarðfræðafélag Íslands, p. 14.

— (1979) "Um aldur Eldgjárhrauna": Náttúrufræðingurinn, v. **49**: p. 1-26.

— (1982) Gjóskutímatal Jökuldals og nágrennis, *in* Þórarinsdóttir, H., Óskarsson, H., Steinþórsson, S., and Einarsson, eds., Eldur er í norðri: Reykjavík, Sögufélag, p. 331-335.

— (1982) Volcanic history and prediction: The Veidivötn area, southern Iceland, IAVCEI-IAGC Scientific Assembly: Reykjavík, p. 118.

— (1984) "Recent volcanic history of the Veidivötn fissure swarm, southern Iceland-an approach to volcanic risk assessment": Journal of volcanology and geothermal research, v. **22**(1-2): p. 33-58.

The recent volcanic history of the southwestern part of the Veiðivötn fissure swarm, southern Iceland, provides a basis for assessment of volcanic risk in an area of large hydropower potential. Local tephrastratigraphy and regional tephrochronology provide relative and absolute dating of individual eruptions as well as information on the volume and distribution of the products formed in each eruption. Three large eruptions took place in this area in 1480 A.D., 900 A.D. and 150 A.D., respectively. Each eruption produced approx. 1 km3 (DRE) of basaltic, and minor amounts of silicic lava and tephra on fissures up to 42 km long. No evidence is found of smaller eruptions *during this period. The estimated eruption frequency, one eruption every 600–800 years, implies that this part of the Veidivötn fissure swarm is inactive for long periods between relatively large volcanic events. A change in the mode of eruption from effusive to explosive took place during this period. The hazards posed by this area include far-reaching lava flows, widespread heavy tephra fall with thicknesses in excess of 2 m at distances of 10 km, and damming of a large glacial river with the consequent formation of unstable lakes. A volcano-tectonic model, which explains the observed eruption frequency and provides a basis for a long-term monitoring program, is proposed. Eruptions on the Veidivötn fissure swarm are interpreted as corollaries of rifting episodes initiated in the Bárdarbunga central volcano. Volcano-tectonic episodes affect the fissure swarm at an average interval of 100 years. Minor episodes are limited to the central volcano and adjacents parts of the fissure swarm. During the less frequent major episodes, rifting and volcanic activity extends to the extreme southwestern part of the fissure swarm. Seismic monitoring of the Bárdarbunga central volcano could provide an early warning of renewed activity on the Veidivötn fissure swarm. A major rifting episode resulting in eruption on its southwestern part can be expected during the next 100 to 300 years.*

— (1984) Recent volcanic history of the Veiðivötn fissure swarm, Southern Iceland. A basis for volcanic risk assessment, NVI Research Report 8403, Nordic Volcanological Center, p. 46.

— (1987) The Dike of the 1480 A.D. Veidivötn Eruption, S-Iceland, IAVCEI-IUGG XiX General Assembly: Abstracts V2: Vancouver, Canada, p. 396.

— (1988) Veiðivötn og Veiðivatnagos á 15 öld, Árbók Ferðafélags Íslands 1988, p. 149-163.

— (1990) The 10th century Eldgjá-Katla eruption; its products and consequences, 19. Nordiske Geologiske Vintermöte. Geonytt 1/90: Stavanger, Norge, p. 71-72.

— (1993) "Tephra layer from the 10th century Eldgjá fissure eruption, South Iceland": EOS, Transactions, American Geophysical Union, v. **74**(43, supplement): p. 132.

— (1994) Gjóskulagatímatal og leiðarlög frá Eldgjárgosi og Vatnaöldugosi, RH-25-94: Reykjavik, Science Institute, p. 20.

— (1999) The Lakagígar crater row; Katla volcanic system and Eldgjá fissure; Hekla, *in* Arnórsson, S., and Gíslason, S.R., eds., The Fifth International Symposium on the Geochemistry of the Earths Surface Field Guide: Iceland, p. 27-28, 38-40, 51-53.

— (2000) The icebreakers: Historical eruptions of subglacial volcanoes in Iceland, Volcano/ice interaction on Earth and Mars: Abstracts: Reykjavík, Iceland, p. 13-15.

— (2002) A brief overview of eruptions from ice-covered and ice-capped volcanic systems in Iceland during the past 11 centuries: frequency, periodicity and implications, *in* Smellie, J.L., and Chapman, M.G., eds., Volcano-Ice Interactions on Earth and Mars, Special Publications 202: London, Geological Society, p. 81-90.

— (2005) "Explosive volcanism in Iceland: Three examples of hydromagmatic basaltic eruptions on long volcanic fissures within the past 1200 years": Geophysical Research Abstracts, v. **7**(10158).

Larsen, G., Guðmundsson, M.T., and Björnsson, H. (1998) "Eight centuries of periodic volcanism at the center of the Iceland hotspot revealed by glacier tephrostratigraphy": Geology, v. **26**(10): p. 943-946.

A record of volcanic activity within the Vatnajökull ice cap has been obtained by combining data from three sources: tephrostratigraphic studies of two outlet glaciers, a 415-m-long ice core from northwestern Vatnajökull, and written records. The record extends back to A.D. 1200 and shows that the volcanic activity has a 130-140 yr period, Intervals of frequent eruptions with recurrence times of three to seven years alternate with intervals of similar duration having much lower eruption frequency, In comparison with other parts of the plate boundary in Iceland, eruption frequency is greater, episodes of unrest are longer, and intervals of low activity are shorter. The high eruption frequency may be the result of a more sustained supply of magma, owing to the area's location above the center of the Iceland mantle plume. When combined with historical data on eruptions and earthquakes, our data indicate that rifting-related activity in Iceland as a whole is periodic and broadly in phase with the volcanic activity within Vatnajokull.

Larsen, G., Gudmundsson, M.T., and Björnsson, H. (1995) "Tephrastratigraphy of ablation areas of the Vatnajökull ice cap, Iceland": EOS, Transactions, American Geophysical Union v. **76** (45, supplement): p. 198.

— (1996) Tephrastratigraphy of ablation areas of Vatnajökull ice cap, Iceland, *in* Colbeck, S., ed., Glaciers, Ice Sheets and Volcanoes: A tribute to Mark F. Meier. : CRREL Special Report 96-27, p. 75-80.

— (1998) Dating of Vatnajökull by ash layers. Report on the Workshop on Vatnajökull, 20-25 June 1998, 9-10. European Science Foundation and European Ice Sheet Modelling Initiative (EISMINT): Skaftafell, Iceland.

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— (2004) Chronology of eruptions in ice-covered volcanic systems: Eruptions within the Vatnajökull glacier, Iceland, IAVCEI General Assembly: Abstracts: Pucon, Chile.

— (2005) "Increased eruption frequency in volcanoes below Vatnajökull ice cap, Iceland, predicted by tephrochronology": Geophysical Research Abstracts, v. **7**(10066).

Larsen, G., and Guðmundsson, M.T. (1997) Gos í eldstöðvum undir Vatnajökli eftir 1200 AD., *in* Haraldsson, H., ed., Vatnajökull. Gos og hlaup 1996: Reykjavík, Vegagerðin, p. 23-36.

Larsen, G., Guðmundsson, M.T., and Björnsson, H. (1996) Gjóskulög í Tungnaárjökli: gossaga, aldur íss og dvalartími gjósku í jökli, Vorráðstefna 1996: "Eldgos í Vatnajökli 1996", ágrip erinda og veggspjalda: Reykjavík, Jarðfræðafélag Íslands, p. 33-35.

— (1997) Gos í eldstöðvum undir Vatnajökli á sögulegum tíma: Vitnisburður gjóskulaga og ritaðra heimilda, Vorráðstefna 1997: "Eldgos í Vatnajökli 1996", ágrip erinda og veggspjalda: Reykjavík, Jarðfræðafélag Íslands, p. 7-9.

— (2004) "Elldr uppi i iij stodum fyrir sunnan". Gjóskulög og eldgos í Vatnajökli, Raunvísindaþing 2004: Reykjavík, p. 58.

Larsen, G., Thordarson, T., and Miller, J.D. (2004) Nature, style and magnitude of explosive activity in the 934-40 Eldgjá flood lava eruption in S-Iceland, IAVCEI General Assembly: Abstracts: Pucon, Chile.

www.free.cl/iavcei2004

Larsen, G., and Þórðarson, Þ. (1984) Gjóskan frá Skaftáreldum 1783, *in* Gunnlaugsson, G.A., and al, eds., Skaftáreldar: Reykjavík, Mál og Menning, p. 59-66.

McKinzey, K.M., Orwin, J.F., and Bradwell, T. (2005) "A revised chronology of key Vatnajökull outlet glaciers during the little ice age": Annals of Glaciology, v. **Vol. 42**(1): p. 171-179.

Glacier fluctuations from key Vatnajökull outlets have been redated using tephrochronology coupled with two lichenometric techniques to ascertain the timing of the Little Ice Age (LIA) maximum in southeast Iceland. An updated tephrochronology for southeast Iceland (both the number of tephra layers present and their geochemical signatures) indicates a LIA maximum for both glaciers between AD 1755 and 1873. Based on a population gradient approach, lichenometrically dated moraines along the margins of Skálafellsjökull and Heinabergsjökull narrow this window to the early to mid-19th century respectively. These revised chronologies, in addition to emerging evidence from elsewhere in Iceland, support a late 18th- to early 19th-century LIA glacier maximum. In contrast, the Norwegian LIA glacial maximum is strongly centred around AD 1750. This implies differing glaciological responses to secular shifts in the North Atlantic Oscillation. Such revisions to the Vatnajökull record are crucial, as accurately identifying the timing and delimiting the spatial extent of the Icelandic LIA glacier *maximum will allow further light to be shed on glacier-climate interactions in the North Atlantic.*

Miller, D.J., Þórdarson, T., and Larsen, G. (1996) "Sulphur degassing and nature of eruptive activity during the 935 AD Eldgjá eruption, S-Iceland": EOS, Transactions, American Geophysical Union, v. **77 (supplement)**.

Mouritzen, M.L., and others (1950) "Volcanic Ash from the Grímsvötn-eruption in 1903, Iceland": Meddelelser fra Dansk Geologisk Forening, v. **Bd. 11**(h. 5): p. 583-584.

Óladóttir, B.A. (2003) Gjóskulagið E2 úr Kötlu : kornalögun og kornastærð [**BSc thesis**]: Reykjavík, Háskóli Íslands.

Sharma, K., Self, S., Blake, S., and Larsen, G. (2004) Deposits, sequence of events and volatile degassing from the A.D. 1362 rhyolitic eruption of Öræfajökull, S.E. Iceland, IAVCEI General Assembly: Abstracts: Pucon, Chile.

Sigvaldason, G.E. (2002) "Volcanic and tectonic processes coinciding with glaciation and crustal rebound: an early Holocene rhyolitic eruption in the Dyngjufjöll volcanic centre and the formation of the Askja caldera, north Iceland": Bulletin of Volcanology v. **64**: p. 192-205.

A pronounced volcanic production maximum on the rift zones through Iceland coincided with rapid crustal rebound during and after glacier melting at the Pleistocene/Holocene boundary. At peak glaciation, ice thickness over central Iceland may have reached 1,500–2,000 m, causing 400–500-m depression of the crust. Rapid climatic improvement caused glacier melting and removal of the ice load within about 1,000 years. Low mantle viscosity resulted in rapid crustal rebound which was completed in about 1,000 years, with an average rate of uplift on the order of nearly half a metre per year over central Iceland. High volcanic production rate is documented by tephrachronological dating and volume estimates of several large-volume monogenetic lava shields and polygenetic volcanic centres along the plate boundary. A Plinian rhyolitic eruption, dated at about 10 ka within the Askja caldera in the Dyngjufjöll volcanic centre, left a pumice deposit which serves as a marker horizon during this remarkable, high-intensity period in the history of the volcano. At the time of the eruption, glaciers had retreated from the coastal areas of the country but the central, elevated parts were covered with a thinning glacier. The Plinian eruption (1–2 km3 dense rock equivalent) was triggered by pressure release caused by glacier melting and volatile supersaturation. Distal deposits of rhyolitic pumice are found in soil sections in coastal areas of eastern and northern Iceland where the pumice occurs between tephra layers from other sources which have been dated by independent methods. A few proximal deposits are preserved within the Dyngjufjöll centre. These provide age constraints on major tectonic and volcanic events during the period of crustal rebound, before and after complete glacier removal. The rhyolitic pumice is sandwiched between thick layers of phreatomagmatic basaltic tephra formed in an open melt-water lake. Sharp contacts between the deposits suggest quick succession of events, but lack of mixing between magmas indicates separate vent locations. The vent location for the 10-ka Plinian eruption has been obliterated by later events but *available evidence, supported by a gravity survey, suggests its location in the central part of the Dyngjufjöll volcano. The eruption formed a subsidence structure, presently seen as an embayment in the hyaloclastite mountain block in the southern part of the Askja caldera where a second Plinian eruption occurred in 1875 A.D. The Plinian 10-ka eruption occurred while thinning glaciers were still present over central Iceland, but the Askja caldera formed after lavas started to flow over ice-free surfaces. The morphology of the caldera faults suggests non-simultaneous movement, and the tectonics are not easily compatible with conventional caldera models. A model is proposed involving uplift of tectonically well-defined crustal blocks to the north and west of the Askja caldera, combined with downsagging caused by voluminous outpouring of basaltic lava. The southern and eastern borders of the caldera are remnants of a subsidence following the 10-ka Plinian eruption, partly reactivated by the 1875 A.D. Plinian eruption. The model provides a satisfactory explanation for the enigmatic Öskjuop pass, and it is in agreement with a gravity survey of the Dyngjufjöll centre. The uplift coincided with rapid crustal rebound which was amplified by crustal deformation (doming) of the volcanic centre caused by high magmatic pressure in the plumbing system of the volcano. This is supported by emission of very large lava flows produced in the first millennia of the Holocene.*

Smith, K.T., and Dugmore, A.J. (2006) "Jökulhlaups circa Landnám: Mid- to late first millennium AD floods in South Iceland and their implications for landscapes of settlement": Geografiska Annaler Series a-Physical Geography, v. **88A**(2): p. 165-176.

This paper presents geomorphological and sedimentological evidence for three large-scale floods to the west of the ice-capped volcano Katla around the time of Norse settlement or Landnám (AD 870-930). These glacial outburst floods (jökulhlaups), the most recent prehistoric events in a series of Holocene floods in the Markarfljót valley, are securely dated by tephrochronology and radiocarbon dating to between c. AD 500 and c. AD 900. The environmental impact of these events would have been extensive, affecting both the highlands and about 40-50 km(2) of the coastal lowlands where about 15 of the 400 or so landnam farms in Iceland were sited. An awareness of environmental conditions and landscape stability around the time of the Norse colonisation of Iceland is important to understand the earliest settlement patterns because of the different constraints and opportunities that they represent.

Steinthorsson, S., Hardarson, B.S., Ellam, R.M., and Larsen, G. (1998) Petrochemistry of the 1996 subglacial Vatnajökull eruption, RH-24-98: Reykjavík, Science Institute, p. 18

Steinþórsson, S. (1977) "Tephra layers in a drill core from Vatnajökull ice cap. (Gjóskulögin í Bárðarbungukjarnanum) ": Jökull, v. **27**: p. 2-27.

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Steinþórsson, S., Harðarson, B.S., and Larsen, G. (1997) Jarðefnafræði eldstöðvakerfa undir vestanverðum Vatnajökli, Vorráðstefna 1997: "Eldgos í Vatnajökli 1996", ágrip erinda og veggspjalda: Reykjavík, Jarðfræðafélag Íslands, p. 27-28.

Van Vliet-Lanoe, B., Van Cauwenberge, A.-S., Bourgeois, O., Dauteuil, O., and Schneider, J.-L. (2001) "A candidate for the Last Interglacial record in northern Iceland: the Sydra formation. Stratigraphy and sedimentology": Comptes Rendus de l'Academie des Sciences - Series IIA - Earth and Planetary Science, v. **332**(9): p. 577-584.

The Sydra Formation is a widespread interglacial complex in the North Volcanic Zone, Iceland, from the sector of the Askja volcano down to Öxarfjördur at the north coast. It probably corresponds to OIS 5e, 5d and 5c. Subsequently, the region was covered by the Weichselian ice cap. It is significant as well for the understanding of the OIS 6 deglaciation and its relations to volcanism as also for the erosional budget of the Saalian, warm based and Weichselian, cold based, glaciations. A topographic bulge linked with a rapid glacio-isostatic rebound, downstream of the Jökulsá á Fjöllum river, is responsible for the development of the Sydra lacustrine deposits. An early abrupt event (Sy2), the Sydra ash probably corresponds to ash zone B as on the northern Iceland shelf and possibly an abrupt cooling. It presents no similarity with the Fossvogur formation in the Reykjavik district. The meaning of the formation is significant in term of rift activity and of palaeoclimate for OIS5.

Vilmundardóttir, E.G., and Larsen, G. (1986) Productivity Pattern of the Veidivötn Fissure Swarm, South Iceland, in Postglacial Time, 17e Nordiska Geologmötet: Abstracts: Helsingfors, Finland, p. 214.

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Þorsteinsson, Jóhannesson, T., Larsen, G., and Sigurðsson, O. (2003) Ice core drilling on the ice shelf covering the Grímsvötn subglacial lake, Research Report, National Geographic Society, p. 13.

— (2003) Ice core study on the Grímsvötn ice shelf, FRISP Workshop on Ice Shelf Processes: Ágrip og fyrirlestur: British Antarctic Survey, Cambridge.

Þorsteinsson, Jóhannesson, T., Larsen, G., Sigurðsson, O., Schmidt, K.G., and Forwick, M. (2003) Dust flux into the Grímsvötn subglacial lake, Vatnajökull ice cap, Iceland, estimated from ice core data, Third International Conference on Mars Polar Science and Exploration: Abstract #8134: Alberta, Canada, Lunar and Planetary Institute, Houston.

Þórarinsson, S. (1944) "Tefrakronologiska strudier paa Island": Geografiska Annaler, v. **26A**: p. 1-217.

— (1949) "Some tephrachronological contributions to the volcanology and glaciology of Iceland": Geografiska Annaler, v. **21**: p. 239-256.

— (1980) "Langleiðir gjósku úr þremur Kötlugosum. (Distant transport of tephra in three Katla eruptions and one Grímsvötn (?) eruption)": Jökull v. **30**: p. 65-73.

Þórðarson, T., Self, S., Miller, D.J., Larsen, G., and Vilmundardóttir, E.G. (2003) "Sulphur release from flood lava eruptions in the Veidivötn, Grímsvötn and Katla volcanic systems, Iceland. In: "Volcanic Degassing"": Special Publications, v. **213**: p. 103-121.

5.15 Loftslagsbreytingar á sögulegum tíma, ísaldarjöklar (climate change, glaciation history)

Akhmetiev, M.A., Bratoeva, G.M., Giterman, R.E., Golubeva, L.V., and Moiseeya, A.I. (1978) "Late Cenozoic stratigraphy and flora of Iceland": Transactions of the Academy of Sciences of the USSR, v. **316**.

Akhmetiev, M.A. (1991) Flora, vegetation, and climate of Iceland during the Pliocene. Pliocene Climates of the Northern Hemisphere: abstracts of the Joint US/USSR Workshop on Pliocene Paleoclimates, Joint US/USSR Workshop on Pliocene Paleoclimates. Moscow, USSR U.S. Geological Survey Open-File Report 91-447, 8-9.

Áskelsson, J. (1934) "Kvartaergeologische Studien von Island.I." Geologiska Föreningens i Stockholm Forhandlingar, v. **Bd. 56**(H. 4): p. 596-618.

Boulton, G.S., Thors, K., and Jarvis, J. (1988) "Dispersal of glacially derived sediment over part of the continental shelf of south Iceland and the geometry of the resultant sediment bodies": Marine Geology, v. **83**(1-4): p. 193-223.

The southern continental shelf of Iceland is crossed by a series of troughs 200-300 m below sea level with intervening banks 100-120 m below sea level. The troughs were eroded by the Pleistocene ancestors of the large valley glaciers which descend from the Vatnajökull ice cap. A study of sedimentation and sediment history in one such trough, its flanking banks and the adjacent coastal belt is presented.Coarse sediments discharged from the glaciers have built out as a massive coastal sediment wedge which has filled up the mouth of an earlier fjord, of which the shelf trough is an extension. Strong bottom currents across the flanking banks transport sand to depths of 140 m. The proximal part of the trough is infilled by muddy sediments derived from gravity flows down the face of the coastal sediment wedge and by sediment transported over the bank to the west. The trough infill is strongly asymmetric, being banked up against the western flank of the trough. Deep turbidite channels occur in the middle part of the trough and on its flanks. Strong bottom currents over the shelf edge have denuded the outer part of the trough of sediments.A Pleistocene phase of sedimentation on the shelf is represented by very thick till accumulations on the banks. A major moraine which extends across the inner part of the trough reflects a phase of glacier stillstand during the last retreat of ice across the shelf, and forms a dam behind

which debris-flow sediments derived from the coastal sediment wedge have accumulated.

Böðvarsson, G. (1982) "Glaciation and geothermal processes in Iceland (Áhrif ísaldarjökla á jarðhitasvæði á Íslandi)": Jökull, v. **32**: p. 21-28.

Caseldine, C.J., Russell, A.J., Knudsen, Ó., and Harðardóttir, J. (2005) Iceland Modern Processes and Past Environments, Elsevier.

Included in series
Developments in Quaternary Science, 5

Description
Iceland provides an unique stage on which to study the natural environment, both past and present, and it is understanding both aspects of reconstructing the past and observing and interpreting the present that form the focus of the contributions to this volume.

The papers are all written by active researchers and incorporate both reviews and new data. Although concentrating largely on the recent Quaternary timescale a wide range of topics is explored including subglacial volcanism, onshore and offshore evidence for the Last Glacial Maximum and subsequent deglaciation, current glacial characteristics including jökulhlaups and glacial landsystems, soil development, Holocene ecosystem change, current oceanography, impacts of volcanic sulphur loading, chemical weathering and the CO2 budget and documentary evidence for historical climate.

Contents
Preface. 1. Iceland. modern processes, past environments: an introduction (C. Caseldine et al.). 2. Late Quaternary marine sediment studies of the Icelandic shelf-palaeoceanography, land/ice sheet/ocean interactions and deglaciation: a review (J.T. Andrews). 3. Relative sea level change in Iceland: new aspects of the Weichselian deglaciation of Iceland (H. Norddahl and H. Petursson). 4. Recent developments in oceanographic research in Icelandic waters (S. Jonsson, H. Valdimarsson). 5. The glacier-marginal landsystems of Iceland (D.J.A. Evans). 6. Subglacial volcanic activity in Iceland (M.T. Gudmundsson). 7. Icelandic jökulhlaup impacts (A.J. Russell et al.). 8. Environmental and climatic effects from atmospheric SO2 mass-loading by Icelandic flood lava eruptions (P. Pordarson). 9. Holocene glacier history (M. Wastl, J. Stotter). 10. Variations of termini of glaciers in Iceland in recent centuries and their connection with climate (O. Sigurdsson). 11. Local knowledge and travellers' tales: a selection of climatic observations in Iceland (A. Ogilvie). 12. Chemical weathering, chemical denudation and the CO2 budget for Iceland (S.R. Gislason). 13. Icelandic soils (O. Arnalds). 14. The Holocene vegetation history of Iceland, state-of-the-art and future research (M. Hallsdottir, C. Caseldine).

Ehlers, J., and Gibbard, P.L. (In Press) "The extent and chronology of Cenozoic Global Glaciation": Quaternary International, v. **Corrected Proof**.

The Quaternary is synonymous with extensive glaciation of Earth's mid- and high-latitudes. Although there were local precursors, significant glaciation began in the latest Eocene (ca 35 Ma) in eastern Antarctica. It was followed by glaciation in mountain areas through the Miocene (in Alaska, Greenland, Iceland and Patagonia), later in the Pliocene (e.g. in the Bolivian Andes and possibly in Tasmania) and in the earliest Pleistocene (e.g. in the Alps, New Zealand, Iceland and Greenland). Today, evidence *from both the land and the ocean floors demonstrates that the major continental glaciations, outside the polar regions, rather than occurring throughout the 2.6 Ma of the Quaternary, were markedly restricted to the last 1 Ma--800 ka or less. Marine Isotope Stage (MIS) 22 (ca 870-880 ka) included the first of the `major' worldwide events with substantial ice volumes that typify the Later Pleistocene glaciations (i.e. MIS 16, 12, 10, 6, 4-2).*

Eiríksson, J., and others (1994) Roadlog : Nordic geological excursion in Iceland : quaternary geology - glaciology Reykjavík, myndir, kort, línurit p.

Eiríksson, J., and Geirsdottír, A. (1991) "A record of Pliocene and Pleistocene glaciations and climatic changes in the north Atlantic based on variations in volcanic and sedimentary facies in Iceland": Marine Geology, v. **101**: p. 147-159.

The location of Iceland directly below the Arctic Circle and on the North Atlantic plate boundary gives the island a characteristic record of interbedded lavas, glacial deposits and other sediments, opening a window on the geological and climatic history of the North Atlantic. Frequently extruded lava flows tend to shield underlying sediments from subsequent erosion. Explosive volcanism keeps the sedimentation rate high and produces extensive time markers. Continuing studies of diamictites interbedded within basaltic lava suites of Cainozoic age in Iceland deal specifically with the problem of differentiating between glacial and non-glacial sediments that have very similar attributes. A multifaceted approach has been taken in order to differentiate these deposits. This includes both lateral and vertical lithofacies description and clast fabric studies based on extensive field work, a comparison with modern analogues, and detailed laboratory work (textural studies on thin sections and palaeomagnetic studies). The results suggest that both the nature and extent of late Pliocene and early Pleistocene glaciations can be inferred from the preserved record. The rock sequence offers excellent opportunities for pinning down the age of each event through palaeomagnetic correlation and radiometric dating of the lava flows. The oldest tillite along the north coast of Iceland has been bracketed down to approximately 2.1 Ma, and in inland mid-western Iceland to approximately 2.6 Ma. It is anticipated that continuing work elsewhere in Iceland can further define the trends of Pliocene glaciation in the North Atlantic. The significance of the frequency of identified glacial deposits in the Icelandic sections may be tested through comparison with the latest deep-sea record of glacial-interglacial cycles.

Evans, D.J.A., Lemmen, D.S., and Rea, B.R. (1999) "Glacial landsystems of the southwest Laurentide Ice Sheet: modern Icelandic analogues": Journal of Quaternary Science, v. **14**(7): p. 673-691.

Landform assemblages and associated stratigraphy, sedimentology and structure are used in the reconstruction of palaeo-ice-sheet dynamics in Alberta, western Canada. Interpretations are based upon the modern analogues from four outlet glaciers at the margins of Vatnajökull and Mýrdalsjökull, Iceland. In the area between Lloydminster and Lac la Biche, central Alberta, an extensive landform assemblage of megaflutings, crevasse-squeeze ridges and thrust-block-moraine arcs document the former surging of part of the margin of the Laurentide Ice Sheet during later stages of recession. This and form assemblage, including numerous exposures of glacitectonised bedrock and

Quaternary sediments, is comparable to the landsystem of the surging glaciers Eyjabakkajökull and Brúarjokull in Iceland. Near High River southern Alberta, the former existence of an ice lobe characterised by active recession is recorded by closely spaced, low-amplitude recessional push moraines that drape tunnel valleys. These are comparable in form and pattern to annual push moraines and fluted till surfaces produced by Breidamerkurjokull and Sandfellsjokull, Iceland, and also include rimmed depressions produced by the escape of artesian water during ice-marginal pushing. This study provides interpretations of the regional glacial geomorphology of Alberta based upon comparisons of form and stratigraphy with modern glacial analogues, and provides an alternative to recent models which invoke large floods of subglacial meltwater to explain many of these same features. Implications for ice dynamics and regional till stratigraphies are discussed.

Geirsdóttir, Á., Miller, G.H., and Andrews, J.T. (In Press) "Glaciation, erosion, and landscape evolution of Iceland": Journal of Geodynamics, v. **Corrected Proof**.

Stratigraphic and sedimentological studies indicate that Iceland has experienced over 20 glaciations during the last 4-5 Myr, in reasonable agreement with the number of glaciations reconstructed from the [partial differential]18O record in deep-sea sediment. The pattern of glacial erosion was to a large part controlled by constructive volcanic processes resulting in increased topographic relief after 2.5 Myr. Between 2.5 and 0.5 Ma valleys up to 400 m deep were excavated into the Tertiary basalts of eastern and south Iceland with an average erosion rate of 10-20 cm ka-1. During the last 0.5 million years rates of erosion increased to 50-175 cm ka-1, with an additional 200 to over 1000 m of valley excavation. Previous estimates of the rate of landscape erosion during the Holocene vary widely, from 5 to 70,000 cm ka-1. We present new studies that define the rates of landscape denudation during the major part of the Holocene (the last 10,200 years): one based on the Iceland shelf sediment record, the other from the sediment record in the glacier-fed lake, Hvitarvatn. Both studies indicate average Holocene erosion rates of about 5 cm ka-1 similar to our erosion rate estimate for 4-5 Ma old strata that has not been subjected to regional glaciation.

Guðmundsson, H.J. (1997) "A review of the Holocene environmental history of Iceland": Quaternary Science Reviews v. **16**: p. p. 81-92.

Habbe, K.A. (1996) "Considerations on the motion mechanism of advancing Pleistocene glaciers and on glacial erosion and overdeepening": Eclogae Geologicae Helvetiae, v. **89**(3): p. 1007-1022.

Recent field observations and the growing knowledge of the deeper subsoil of Quaternary deposits allow a new attempt to solve the old problems of the motion mechanism of Pleistocene glaciers and of glacial erosion and overdeepening. Observations in the frontal zone of Alpine Foreland glaciers of the last glaciation as well as of modern outlet glaciers of the Vatnajokull in Iceland show that advancing glaciers move in another way than stationary or backmelting ones. The motion mechanism of advancing glaciers is characterized by a summation of numerous thrust movements of fiat ice-shields on shear-planes over stagnant-ice of preceding advances, all of them of relatively short duration and range. They obviously originated in precipitation-caused mass surpluses in the feeding area. Glaciers advancing in this way can affect the subsoil only when being pushed forward beyond their stagnant-ice basement, i.e. immediately behind the glacier front. A larger amount of glacial erosion can be *expected only when the glacier after its advance remained in the maximum position reached for a longer time and, addtionally, (snow)meltwater under hydrostatic pressure could affect the underground. Further observations on meltwater movement within the glacier are presented from Iceland, on meltwater impact on the subsoil from the German Alpine Foreland.*

Hafliðason, H., Eiríksson, J., and VanKreveld, S. (2000) "The tephrochronology of Iceland and the North Atlantic region during the Middle and Late Quaternary: a review": Journal of Quaternary Science v. **15**: p. 3-22.

The tephrochronology of Iceland and the North Atlantic region is reviewed in order to construct a unified framework for the last 400 kyr BP. Nearly all of the tephra layers described are also characterised geochemically. A number of new tephra layers are analysed for the first time for their geochemical signature and a number of pre-Holocene tephra layers have been given an informal denotation. The tephrostratigraphy of Ash Zone II is highlighted. Where possible the rhyolitic tephra layers found outside Iceland have been correlated to known Icelandic tephra layers or to the volcanic source area. The application of tephra fallout in various depositional environments is described and discussed

Helgason, J., and Duncan, R.A. (1996) Jarðlagaskipan Svínafells í Öræfum: bergsegulstefna, aldursgreiningar og jöklunarsaga, Vorráðstefna 1996: ágrip erinda og veggspjalda: Odda, Reykjavík, Jarðfræðifélag Íslands.

— (2001) "Glacial-interglacial history of the Skaftafell region, southeast Iceland, 0-5 Ma": Geology, v. **29**(2): p. 179–182

Volcanic strata in the Skaftafell region, southeast Iceland, record a sequence of at least 16 glacial and interglacial intervals since 5 Ma. Two composite sections of 2 to 2.8 km thickness have been constructed from multiple, overlapping, cliff profiles. The timing of alternating sequences of subaerial lava flows, pillow basalts, and hyaloclastite deposits is provided by magnetostratigraphic mapping and K-Ar radiometric dating. We find that the frequency and intensity of glaciations increased significantly at ca. 2.6 Ma, and particularly since 0.8 Ma, amplifying topographic relief in this area from <100 m to 2 km. These changes correlate with increases in global ice volume, ice-rafted debris, and development from local to regional glacial conditions in the North Atlantic.

Hemming, S.R. (2004) "Heinrich events: Massive late pleistocene detritus layers of the North Atlantic and their global climate imprint": Reviews of Geophysics, v. **42**(1).

Millennial climate oscillations of the glacial interval are interrupted by extreme events, the so-called Heinrich events of the North Atlantic. Their near-global footprint is a testament to coherent interactions among Earth's atmosphere, oceans, and cryosphere on millennial timescales. Heinrich detritus appears to have been derived from the region around Hudson Strait. It was deposited over approximately 500 +/- 250 years. Several mechanisms have been proposed for the origin of the layers: binge-purge cycle of the Laurentide ice sheet, jokulhlaup activity from a Hudson Bay lake, and an ice shelf buildup/collapse fed by Hudson Strait. To determine the origin of the Heinrich events, I recommend (1) further studies of the timing and duration of the events, (2) further sedimentology study near the Hudson Strait, and (3) greater spatial and temporal *resolution studies of the layers as well as their precursory intervals. Studies of previous glacial intervals may also provide important constraints.*

Hjartarson, Á., and Ingólfsson, Ó. (1988) "Preboreal glaciation of southeastern Iceland. " Jökull, v. **38**: p. pp.1-16.

Hoppe, G. (1982) "The extent of the last inland ice sheet of Iceland (Stærð jökulskjaldar á Íslandi á síðasta jökulskeiði)": Jökull, v. **32**: p. 3-11.

Hubbard, A. (2006) "The validation and sensitivity of a model of the Icelandic ice sheet": Quaternary Science Reviews, v. **25**(17-18): p. 2297-2313.

The derivation and implementation of a three-dimensional model used to investigate the Last Glacial Maximum ice sheet across Iceland by Hubbard et al. [2006. A modelling insight into the Icelandic Last Glacial Maximum ice sheet. Quaternary Science Reviews] is described. It is applied at 2 km resolution and requires boundary distributions of topography, geothermal heat flux, surface air temperature and mass balance calculated using a temperature-index approach based on reference distributions of annual temperature and precipitation. The model enables the variables of ice thickness, stress, strain and temperature to evolve freely through time and caters for the coupling of thermally triggered basal sliding with non-local dynamics through the computation of longitudinal stresses. It is driven through perturbations in sea-level and annual precipitation and temperature. A series of contemporary experiments are initiated to validate the model against the present ice cover across Iceland. Forcing the model from ice-free conditions with the 1961-1990 (reference) climatology yields a good simulation of all the ice masses except for Vatnajokull, where the model falls well short of its present margins. However, an experiment forced from ice-free conditions for 1000 years with a 2 [deg]C cooling perturbation, followed by 100 years of reference climatology yields a good simulation of Vatnajokull (in addition to other ice masses), implying that it is a remnant icecap, inherited from the Little Ice Age and perpetuated through strong ice elevation/mass balance coupling. An ensemble of experiments are initiated to investigate the sensitivity of the optimum LGM model isolated in Hubbard et al. (2006). Ice sheet volume and aspect ratio (but not area) are found to be sensitive to basal boundary conditions, in particular to the choice of sliding parameter and the applied geothermal conditions. Due to strong topographic control, in particular the configuration of offshore bathymetry and shelf break, ice sheet volume and area is sensitive to the calving parameter and sea-level change. However, an asymmetrical response indicates that the ice sheet is effectively decoupled from further climatic deterioration once it advances to the continental shelf break. These experiments imply that there is little latitude in the selection of model parameters which yields an ice sheet compatible with the available evidence and that the optimum LGM experiment represents a sound result. By inference, at least 63% of the optimum LGM ice sheet was grounded below sea-level implying potential instability with the onset of deglaciation.

Hubbard, A., Sugden, D., Dugmore, A., Norddahl, H., and Petursson, H.G. (2006) "A modelling insight into the Icelandic Last Glacial Maximum ice sheet": Quaternary Science Reviews, v. **25**(17-18): p. 2283-2296.

A three-dimensional thermomechanical model is used to investigate the Last Glacial Maximum (LGM) Icelandic ice sheet and the climate responsible for it at about 21 ka BP. A series of sensitivity experiments reveal that Iceland is susceptible to the onset large-scale glaciation with only a 3 1C cooling perturbation relative to recent (1961–1990) climate. A 5 1C cooling perturbation is enough to force an ice sheet to beyond the present day coastline in virtually all sectors. A suite of 15 experiments driven by a GRIP d18O time-series for 15,000 years from a climatic optimum at 36 ka to 21 ka BP scaled with 5.0–15.0 1C maximum cooling perturbation are initiated in order to identify a best-fit LGM ice sheet configuration compatible with the available empirical evidence. The optimum LGM model isolated requires an annual cooling of 10.0–12.5 1C relative to the recent climatology with over 50% precipitation suppression across the north and yields an extensive offshore ice sheet with an area of 3:29 x 105 km2 and a volume of 3:09 x 105 km3. Over-extension of ice extent across the northern shelf is addressed by the introduction of strong aridity across this region but otherwise the ice-sheet is well pinned to the continental shelf-break in remaining sectors which tends to decouple it from further climatic forcing. The optimum LGM ice-sheet has a substantial proportion of its base grounded below sea-level and is dominated by basal sliding which activates extensive zones of fast flow. This results in a highly dynamic, low aspect ice sheet with a mean ice thickness of 940m and a plateau elevation of 2000m breached by numerous nunataks and ice-free zones providing potential, but spatially limited and frigid, ecological refugia through the vicissitudes of the LGM.

Imsland, P. (2005) Hversu gamall er Hornafjörður?, Alþjóðleg ráðstefna um strandrannsóknir: Nýheimum á Höfn.

Ingólfsson, Ó. (1991) A review of the late Weichselian and early Holocene glacial and environmental history of Iceland, *in* Caseldine, C.J., and Maizels, J.K., eds., Environmental Changes in Iceland, Past and Present: Dordrecht, Kluwer, p. 13-29.

Ingólfsson, Ó., and Hjort, C. (1988) Weichselian glaciation in Iceland, *in* Binazer, K., Marcussen, I., and Konradi, P., eds., Nordiske Geologiske Vintermöde. Abstracts, p. 178-179.

Ingólfsson, Ó., and Norðdahl, H. (1994) "A review of the environmental history of Iceland, 13,000-9000 yr BP": Journal of Quaternary Science, v. **9**: p. 147-150.

Knudsen, K.L., Jiang, H., Jansen, E., Eiríksson, J., Heinemeier, J., and Seidenkrantz, M.-S. (2003) "Environmental changes off North Iceland during the deglaciation and the Holocene: forminifera, diatoms and stable isotopes": Marine Micropaleontology, v. **50**: p. 273-305.

Lacasse, C., Sigurdsson, H., Carey, S., Paterne, M., and Guichard, F. (1996) "North Atlantic deep-sea sedimentation of Late Quaternary tephra from the Iceland hotspot": Marine Geology, v. **129**(3-4): p. 207-235.

Piston cores recovered from the North Atlantic were used to study the sedimentation of Holocene and Pleistocene volcanic ash in the Irminger and Iceland Basins. Ash Zones 1 (≈ 11,100 yr B.P.), 2 (≈ 55,000 yr B.P.) and 3 (≈ 305,000 yr B.P.) were identified *from their major element glass composition. The silicic and alkalic Ash Zones 1 and 2 originate from the Southeastern Volcanic Zone of Iceland, where they correlate with the Sólheimar ignimbrite from Katla volcano and the Thórsmörk ignimbrite from Tindfjallajökull volcano, respectively. The low-alkali composition of silicic Ash Zone 3 indicates a source from one of the silicic centers in the active rift system. Ash Zones 2 and 3 occur in the Irminger Basin as dispersed glass shards over a depth interval of several tens of centimeters. Their compositional and granulometric characteristics reflect an initial fallout on pack-ice north of Iceland, followed by ice-rafting sedimentation in the Denmark Strait, prior to bioturbation. δ18O stratigraphy of foraminifera in the cores indicates that the ash zones were deposited during a cold interval, at the time when seas north of Iceland were ice-covered. Sedimentary features indicate that turbidity currents were also involved in the dispersal of Ash Zones 1 and 2 south of Iceland. The initiation of these gravity currents from the shelf can be attributed to either glacier bursts (jökulhlaups) carrying tephra, or the entrance of pyroclastic flows into the ocean.*

Maclennan, J., Jull, M., McKenzie, D., Slater, L., and Grönvold, K. (2002) "The link between volcanism and deglaciation in Iceland": GEOCHEMISTRY GEOPHYSICS GEOSYSTEMS, v. **3**(11, 1062): p. 1-25.

Temporal variation in the eruption rate and lava composition in the rift zones of Iceland is associated with deglaciation. Average eruption rates after the end of the last glacial period, ~12 kyr BP, were up to 100 times higher than those from both the glacial period and recent times (<5 kyr BP). This peak in volcanic activity finished less than 2 kyr after the end of deglaciation. New geochemical data from ~80 basalt and picrite samples from the Theistareykir and Krafla volcanic systems show that there is a temporal variation in both the major and trace element composition of the eruptions. Early postglacial eruptions show a greater range in MgO contents than eruptions from other times, and at a fixed MgO content, the concentration of incompatible elements in subglacial eruptions is higher than that in early postglacial eruptions. Recent eruptions from the Krafla system have similar compositions to subglacial eruptions. The high eruption rates and low rare earth element (REE) concentrations in the lava from early postglacial times can be accounted for by increased melt generation rates in the shallow mantle caused by unloading of an ice sheet. Magma chamber processes such as crystallization and assimilation can produce the temporal variation in REE contents if garnet is present. However, garnet is not observed as a phenocryst or xenocryst phase and is not required to match the variation in major element contents observed at Krafla and Theistareykir. If the increase in eruption rates reflects increased melt production rates in the mantle, then the relative timing of deglaciation and the burst in eruption rates can be used to estimate the rate of melt transport in the mantle. The observed duration of enhanced eruption rates after deglaciation can be reproduced if the vertical melt extraction velocity is >50 m yr−1.

Molewski, P. (2005) REKONSTRUKCJA PROCESÓW GLACJALNYCH W WYBRANYCH STREFACH MARGINALNYCH LODOWCÓW ISLANDII - FORMY I OSADY. Reconstruction of glacial processes in the chosen marginal zones of the Icelandic glaciers - forms and deposits: Torun, Instytut Geografii UMK; Stowarzyszenie Geomorfologów Polskich, p. 148.

Norðdahl, H. (1991) "Late Weichselian and Early Holocene deglaciation history of Iceland": Jökull, v. **40**: p. 27-50.

Norðdahl, H., and Einarsson, o. (1988) "Hörfun jökla og sjávarstöðubreytingar í ísaldarlok á Austfjörðum [English summary: Late Weichselian Deglaciation and Sea-level Changes in East and Southeast Iceland]": Náttúrufræðingurinn, v. **58**: p. 59-80.

— (2001) "Concurrent changes of relative sea-level and glacier extent at the Weichselian-Holocene boundary in Berufjörður, eastern Iceland": Quaternary Science Reviews, v. **20**: p. 1607-1622.

Sigbjarnason, G. (1983) "The Quaternary alpine glaciation and marine erosion in Iceland (Alpajöklar og öldubrjótar)": Jökull, v. **33**: p. 87-98.

Sigmundsson, F. (1991) "Postglacial Rebound and Asthenosphere Viscosity in Iceland": Geophysical Research Letters, v. **18**(6): p. 1131-1134.

During the Weichselian glaciation Iceland was covered with an ice cap which caused downward flexure of the Earth's surface. The post-glacial rebound in Iceland was very rapid, being completed in about 1000 years. The length of this time interval constrains the maximum value of asthenosphere viscosity in Iceland to be 1x10(19) Pa s or less. Further clarification of the ice retreat and uplift history may reveal lower viscosity. Current changes in the mass balance of Icelandic glaciers must lead to measureable elevation changes considering this low viscosity. Expected current elevation changes around the Vatnajökull ice cap are of the order of 1 cm per year, due to mass balance change in this century.

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The Sydra Formation is a widespread interglacial complex in the North Volcanic Zone, Iceland, from the sector of the Askja volcano down to Öxarfjördur at the north coast. It probably corresponds to OIS 5e, 5d and 5c. Subsequently, the region was covered by the Weichselian ice cap. It is significant as well for the understanding of the OIS 6 deglaciation and its relations to volcanism as also for the erosional budget of the Saalian, warm based and Weichselian, cold based, glaciations. A topographic bulge linked with a rapid glacio-isostatic rebound, downstream of the Jökulsá á Fjöllum river, is responsible for the development of the Sydra lacustrine deposits. An early abrupt event (Sy2), the Sydra ash probably corresponds to ash zone B as on the northern Iceland shelf and possibly an abrupt cooling. It presents no similarity with the Fossvogur formation in the Reykjavik district. The meaning of the formation is significant in term of rift activity and of palaeoclimate for OIS5.

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Weichselian sandar in NE Poland show characteristics that are inconsistent with the commonly accepted alluvial-fan-like model for outwash deposition and sandur formation. Analysis of the lithofacies and their vertical and lateral transitions indicates that the Polish sandar developed as braidplains, not as alluvial fans. Analysis of the geomorphic conditions under which modern sandar form, indicates that these conditions (which are characterized by deposition in a narrow belt between ice-covered mountain ranges and the sea) cannot be considered representative of those that prevailed in the geological past when sandar developed as braidplains in confined valleys, to end up in a lowland area where the deposits could spread out further in lateral directions. The latter conditions have been found consistently for all Polish Weichselian sandar that were investigated in much sedimentological detail. This raises the question whether sandar are alluvial fans or not. Because the development of the sandar in NE Poland seems to be much more representative for outwash deposition than the present-day sandar in Iceland and elsewhere, the current alluvial-fan-like sandur model - based on the fairly exceptional present-day situation with deposition in a narrow belt - should therefore be replaced by the braidplain-like sandur model - based on deposition in a valley and in a wider lowland area in front - that has been established for the Polish examples.

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General survey, with particular reference to Vatnajökull and extent of inland ice during last glaciation

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A historical view of the translation and different editions of the Icelandic scriptures
An inquiry into the origin, progress, nature, and characteristic features of Icelandic poetry
Appendix no. 1: A historical view of the translation and different editions of the Icelandic scriptures: s. 247-306 (2.b.)
Appendix no. 2: Poem of thanks from Iceland to the British and Foreign Bible Society by Sira Jon Thorlaksson of Bægisa: s. 307-320 (2.b.)
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Inniheldur:
Gos í Öskju
Náttúran talar
Þeir, sem landið erfa
Skáld litanna
Í aftureldingu
Tveir Reykvíkingar
Gróður á gömlum akri
Litli víxlarinn af Skaga
Eyðibyggðir

Konungur fuglanna og þegnar hans
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Inniheldur:
Gos í Öskju
Náttúran talar
Þeir, sem landið erfa
Skáld litanna
Í afturelding u
Tveir Reykvíkingar
Gróður á gömlum akri
Litli víxlarinn af Skaga
Eyðibyggðir
Konungur fuglanna og þegnar hans
Vörn og sókn

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In Iceland, studies that integrate local perceptions about the landscape with scientific evidence of change have been few. This article presents a case study from southeast Iceland that has two main objectives. Firstly, ethnographic data is used to explore the human dimension of the Little Ice Age through perceptions of landscape and climatic change and to describe the impacts that these changes had on life and livelihood. Secondly, the paper critically assesses the coherence of the scientific record regarding the Little Ice Age glacial maximum with evidence gained from the ethnographic survey and the local historical record. Although climatic deterioration from the seventeenth through nineteenth centuries ultimately affected farming viability, it was the interplay of climate with concomitant cultural and socio-economic factors that ensured effective strategies were emplaced to preserve life and livelihood in southeast Iceland. Furthermore, despite different trajectories of perception emanating from either the scientific or the local points of view, data from all sources are strongly coherent and point to a Little Ice Age maximum during the late eighteenth to early nineteenth centuries. This study also illustrates that sensitive landscapes can 'store memories' through the cumulative accumulation of disturbances during periods of climatic *variability, eventually reaching a critical threshold and inducing landscape instability, such as occurred during the nineteenth century.*

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This paper presents geomorphological and sedimentological evidence for three large-scale floods to the west of the ice-capped volcano Katla around the time of Norse settlement or Landnám (AD 870-930). These glacial outburst floods (jökulhlaups), the most recent prehistoric events in a series of Holocene floods in the Markarfljót valley, are securely dated by tephrochronology and radiocarbon dating to between c. AD 500 and c. AD 900. The environmental impact of these events would have been extensive, affecting both the highlands and about 40-50 km(2) of the coastal lowlands where about 15 of the 400 or so landnam farms in Iceland were sited. An awareness of environmental conditions and landscape stability around the time of the Norse colonisation of Iceland is important to understand the earliest settlement patterns because of the different constraints and opportunities that they represent.

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Kárahnjúkavirkjun 470 MW [kort]
Virkjanir norðan Vatnajökuls [kort]
Áætlanir um virkjanir norðan Vatnajökuls í Jökulsá á Fjöllum, Jökulsá á Brú og Jökulsá í Fljótsdal [kort]

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The pre-industrial natural carrying capacity is believed to have limited the human population in Iceland to a maximum of fifty to sixty thousand inhabitants. Since AD 1800 the Icelandic population has gradually grown up to nearly 300 thousand in 2005. In this paper a simple approach is used to evaluate the potential population size that the pre-industrial Icelandic environment could possibly sustain. A dynamic model was constructed that simulates the population size according to potential biological production available for livestock. Biological production was determined by the extent of the total potential vegetation cover based on the Degree-Day concept. Fluctuations in the mean annual temperature causes changes in the potential vegetation cover and as a consequence change the biological production sustaining livestock and ultimately human population. The simulation's results indicate that the potential population that the Icelandic environments could sustain during the pre-industrial period fluctuated between 40 and 80 thousand. The results further indicate that the severe land degradation experienced after the Viking settlement period in AD 900 had a marginal impact on the population size. The pre-historical population did however overshoot the natural sustainability on several occasions.

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Inniheldur:
Gos í Öskju
Náttúran talar
Þeir, sem landið erfa
Skáld litanna
Í aftureldingu
Tveir Reykvíkingar
Gróður á gömlum akri
Litli víxlarinn af Skaga
Eyðibyggðir
Konungur fuglanna og þegnar hans
Vörn og sókn

Kristinsdóttir, R. (2004) Landið er fagurt og frítt : mat á íslensku landslagi og fegurð þess [**MSc thesis**]: Reykjavík, Háskóli Íslands.

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We have simulated the spatial relationship between temperature change and long-term potential vegetation cover dynamics. The results show that the potential vegetation and birch forest range is highly sensitive to the temperature conditions. Around 3000 BP the simulated potential vegetation cover began to decrease and at the time of the Viking settlement, in AD 874 (1076 BP), vegetation and forest cover was already in *decline. The climate driven decline continued to an unprecedented low potential for vegetation for the Holocene that lasted c. 600 years, i.e. between ADc. 1300 and 1900. These interpretations are further supported by geomorphological and pollen data.*

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Formálsorð / Páll Imsland: s. 7-10

Efni: Árdagar íslenskrar jarðfræði / Jón Eiríksson. - Vöxtur jarðfræðingastéttarinnar og rannsóknaviðfangsefni íslenskra jarðfræðinga ; Jarðfræðirannsóknir á hafsbotninum umhverfis Ísland/ Páll Imsland. - Framlag leikmanna til jarðfræðirannsókna á Íslandi / Elsa G. Vilmundardóttir. - Erlendir jarðfræðileiðangrar til Íslands á þessari öld / Leifur A. Símonarson. - Rit um íslenska bergfræði, steindafræði og jarðefnafræði síðan 1840 / Sveinn Jakobsson og Bjarni Gautason. - Um menntun, ritstörf og áhrif íslenzkra jarðvísindamanna í fræðunum / Sigurður Steinþórsson. - Tengsl íslenskra jarðvísindamanna við útlönd / Leó Kristjánsson. - Útflutningur á íslenskri jarðfræðiþekkingu / Ingvar Birgir Friðleifsson
Um jarðvísindi við íslenskar rannsóknastofnanir / Stefán Arnórsson. - Mat stjórnvalda á gagnsemi þekkingar / Guðmundur E. Sigvaldason. - Jarðfræðin í íslenskri náttúruvernd / Þorleifur Einarsson. - Jarðfræðikortlagning á Íslandi / Freysteinn Sigurðsson. - Jarðfræðirannsóknir í sambandi við vatnsfallsvirkjanir á Íslandi - "virkjanajarðfræði" / Birgir Jónsson

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