NATURAL ENVIRONMENT RESEARCH COUNCIL

APPLICATION FOR CONSENT TO CONDUCT MARINE SCIENTIFIC RESEARCH Greenland

Date: 14th January 2010

Ship Name	Cruise Number	Dates of Cruise	Country applied for	Port Calls	Dates
RRS James Cook	JC050	16/7/10-10/8/10	Iceland	Rekjavik	15 – 16 July 2010
			Greenland	None	
			UK	Clyde	10 – 15th Aug 2010

COASTAL STATE: Greenland **PORT CALL**: None **DATES**:

List Scientific Work by Function e.g.: Magnetometry Gravity, Diving, Seismic, Bathymetry, Seabed Sampling, Trawling, Echo Sounding, Water Sampling U/W T.V.: Moored and Towed instrument	Water Column Incl. Sediment Sampling on the Seabed	Fisheries Research within Fishing Limits	Research Concerning the Natural Resources of the Continental Shelf or its Physical Characteristics	Distance from Coast Between Within 12 NM ** UP TO COAST **	12 - 200 NM
Seismic reflection surveying	Y	N/A	N/A	N/A	Y
magnetometry	Y	N/A	N/A	N/A	Y
Gravity surveying	Y	N/A	N/A	N/A	Y
Swath bathymetry	Y	N/A	N/A	N/A	Y
Seabed sampling	Y	N/A	N/A	N/A	Y
Sonobuoy deployment	Y	N/A	N/A	N/A	Y

1. *General Information*

1.1 **Cruise name and/or number:** RRS JAMES COOK Cruise **JC050**

1.2 **Sponsoring institution**:

Name: Natural Environment Research Council
Address: Polaris House, North Star Avenue, Swindon, SN2 1EU
Name of director: Professor Alan Thorpe

1.3 **Scientist in charge of the project**:

Name: Dr Nicholas Jeremiah White
Address: Bullard Laboratories, Madingley Rise, Madingley Road, Cambridge, CB3 0EZ
Telephone: 01223 337063
Telefax: 01223 360779

1.4 **Scientist(s) from** Greenland **informed of the planning of the project**

Name:
Address:
Telephone:

NATURAL ENVIRONMENT RESEARCH COUNCIL

1.4 Submitting officer:

Name: R. Plumley, NERC NMF SS, National Oceanography Centre, European Way, Empress Dock, Southampton, SO14 3ZH
Telephone: 02380 596800
Telefax: 02380 635130

2. *Description of project* *(Attach additional pages as necessary)*

2.1 Nature of objectives of the project:

Acquire 1400-2800 km of seismic reflection data in a region south of Iceland which is located primarily in international waters but also in the Exclusive Economic Zones of both Iceland and Greenland.

2.2 Relevant previous or future research cruises:

See attached Research Description.

2.3 Previously published research data relating to the project:

See attached Research Description.

3. *Methods and means to be used*

3.1 Particulars of vessel

Name: RRS James Cook
Nationality: British
Owner: NERC
Operator: NMF SS
Overall Length: 86.20 metres
Maximum draught: 6.7 metres
Net tonnage: 1620 **Gross tonnage:** 5401
Propulsion: Motor
Cruising Speed: 11 knots **Maximum speed:** 15 knots
Call sign: MLRM6
Method of capability of communication (including telex, frequencies):
Inmarsat Voice: 764538468 Fax: 764538470 Telex: 423501712=jame x
SAT C Number: 423501712
Name of Master: TBA
Number of Crew: 23
Number of Scientists on board: 31
MMSI: 235010700

3.2 Aircraft or other craft to be used in the project: N/A

3.3 Particulars of methods and scientific instruments

Types of samples and data	Methods to be used	Instruments to be used
Sub-sea imaging	Seismic profiling, sonobuoys	2-3 km streamer, airgun array, sonobuoys
geophysics/bathymetry	Attached to ship	Gravimeter, magnetometer, swath bathymetry
Geological samples	Seabottom dredging	Dredge basket

3.4 **Indicate whether harmful substances will be used:** N/A

3.5 **Indicate whether drilling will be carried out:** N/A

3.6 **Indicate whether explosives will be used:** N/A

4. *Installations and equipment*

Details of installations and equipment (dates of laying, servicing, recovery; exact locations and depth):

airgun array and streamer towed at 5-15 m depth behind vessel. Locations determined by survey plan shown in attached Research Description.

5. *Geographical areas*

5.1 **Indicate geographical areas in which the project is to be conducted (with reference in latitude and longitude):**

60-64 degrees north, 21-37 degrees west.

5.2 **Attach chart (s) at an appropriate scale showing the geographical areas of the intended work and, as far as practicable, the positions of intended stations, the tracks of survey lines, and the locations of installations and equipment.**

See figures in attached Research Description.

6. *Dates*

6.1 **Expected dates of first entry into** Greenland **and final departure from research area of the research vessel:**

Expected first entry: 16th July 2010
Expected final departure: 8th August 2010

6.2 **Indicate if multiple entry is expected:** No

7. *Port calls*

7.1 **Dates and names of intended ports of call in:** Greenland

None

7.2 **Any special logistical requirements at ports of call:** No

7.3 **Name/Address/Telephone of shipping agent (if available):** N/A

8. *Participation*

8.1 **Extent to which** Greenland **will be enabled to participate or to be represented in the research project:** None

8.2 **Proposed dates and ports for embarkation/disembarkation:**

Embark: Reykjavik, Iceland 15 – 16 July 2010
Disembark: Clyde, UK 10 – 15th August 2010

9. Access to data, samples and research results

9.1 **Expected dates of submission to** Greenland **of preliminary reports which should include the expected dates of submission of the final results:**

Six months after completion of Cruise

9.2 **Proposed means for access by** Greenland **to data and samples:** N/A

9.3 **Proposed means to provide** Greenland **with assessment of data, samples and research results or provide assistance in their assessment or interpretation:** N/A

9.4 **Proposed means of making research results internationally available:**

Publication in international journals.

N J White......(On behalf of the Principal Scientist)

DISTRIBUTION
FCO LONDON
RNWS TAUNTON
SUBMARINE CABLE SYSTEMS
CTF 311
PRINCIPAL SCIENTIST
MASTER
CRUISE FILE

NATURAL ENVIRONMENT RESEARCH COUNCIL

APPLICATION FOR CONSENT TO CONDUCT MARINE SCIENTIFIC RESEARCH Greenland

Date: 14th January 2010

Ship Name	Cruise Number	Dates of Cruise	Country applied for	Port Calls	Dates
RRS James Cook	JC050	16/7/10-10/8/10	Iceland	Rekjavik	15 – 16 July 2010
			Greenland	None	
			UK	Clyde	10 – 15th Aug 2010

COASTAL STATE: Greenland **PORT CALL**: None **DATES**: None

List Scientific Work by Function e.g.: Magnetometry Gravity, Diving, Seismic, Bathymetry, Seabed Sampling, Trawling, Echo Sounding, Water Sampling U/W T.V.: Moored and Towed instrument	Water Column Incl. Sediment Sampling on the Seabed	Fisheries Research within Fishing Limits	Research Concerning the Natural Resources of the Continental Shelf or its Physical Characteristics	Distance from Coast Between Within 12 NM ** UP TO COAST **	12 - 200 NM
Seismic reflection surveying	Y	N/A	N/A	N/A	Y
magnetometry	Y	N/A	N/A	N/A	Y
Gravity surveying	Y	N/A	N/A	N/A	Y
Swath bathymetry	Y	N/A	N/A	N/A	Y
Seabed sampling	Y	N/A	N/A	N/A	Y
Sonobuoy deployment	Y	N/A	N/A	N/A	Y

1. *General information*

1.1 Cruise name and/or number: RRS JAMES COOK Cruise **JC050**

1.2 Sponsoring institution:

Name: Natural Environment Research Council
Address: Polaris House, North Star Avenue, Swindon, SN2 1EU
Name of director: Professor Alan Thorpe

1.3 Scientist in charge of the project:

Name: Dr Nicholas Jeremiah White
Address: Bullard Laboratories, Madingley Rise, Madingley Road, Cambridge, CB3 0EZ
Telephone: 01223 337063
Telefax: 01223 360779

1.4 Scientist(s) from Greenland **informed of the planning of the project**

Name:
Address:
Telephone:

NATURAL ENVIRONMENT RESEARCH COUNCIL

1.4 Submitting officer:

Name: R. Plumley, NERC NMF SS, National Oceanography Centre, European Way, Empress Dock, Southampton, SO14 3ZH
Telephone: 02380 596800
Telefax: 02380 635130

2. *Description of project* *(Attach additional pages as necessary)*

2.1 Nature of objectives of the project:

Acquire 1400-2800 km of seismic reflection data in a region south of Iceland which is located primarily in international waters but also in the Exclusive Economic Zones of both Iceland and Greenland.

2.2 Relevant previous or future research cruises:

See attached Research Description.

2.3 Previously published research data relating to the project:

See attached Research Description.

3. *Methods and means to be used*

3.1 Particulars of vessel

Name: RRS James Cook
Nationality: British
Owner: NERC
Operator: NMF SS
Overall Length: 86.20 metres
Maximum draught: 6.7 metres
Net tonnage: 1620 **Gross tonnage:** 5401
Propulsion: Motor
Cruising Speed: 11 knots **Maximum speed:** 15 knots
Call sign: MLRM6
Method of capability of communication (including telex, frequencies):
Inmarsat Voice: 764538468 **Fax:** 764538470 **Telex:** 423501712=jame x
SAT C Number: 423501712
Name of Master: TBA
Number of Crew: 23
Number of Scientists on board: 31
MMSI: 235010700

3.2 Aircraft or other craft to be used in the project: N/A

3.3 Particulars of methods and scientific instruments

Types of samples and data	Methods to be used	Instruments to be used
Sub-sea imaging	Seismic profiling, sonobuoys	2-3 km streamer, airgun array, sonobuoys
geophysics/bathymetry	Attached to ship	Gravimeter, magnetometer, swath bathymetry
Geological samples	Seabottom dredging	Dredge basket

NATURAL ENVIRONMENT RESEARCH COUNCIL

3.4 Indicate whether harmful substances will be used: N/A

3.5 Indicate whether drilling will be carried out: N/A

3.6 Indicate whether explosives will be used: N/A

4. Installations and equipment

Details of installations and equipment (dates of laying, servicing, recovery; exact locations and depth):

airgun array and streamer towed at 5-15 m depth behind vessel. Locations determined by survey plan shown in attached Research Description.

5. Geographical areas

5.1 Indicate geographical areas in which the project is to be conducted (with reference in latitude and longitude):

60-64 degrees north, 21-37 degrees west.

5.2 Attach chart (s) at an appropriate scale showing the geographical areas of the intended work and, as far as practicable, the positions of intended stations, the tracks of survey lines, and the locations of installations and equipment.

See figures in attached Research Description.

6. Dates

6.1 Expected dates of first entry into Greenland **and final departure from research area of the research vessel:**

Expected first entry: 16th July 2010
Expected final departure: 8th August 2010

6.2 Indicate if multiple entry is expected: No

7. Port calls

7.1 Dates and names of intended ports of call in: Greenland

None

7.2 Any special logistical requirements at ports of call: No

7.3 Name/Address/Telephone of shipping agent (if available): N/A

8. Participation

8.1 Extent to which Greenland **will be enabled to participate or to be represented in the research project:** None

8.2 Proposed dates and ports for embarkation/disembarkation:

Embark: Reykjavik, Iceland 15 – 16 July 2010
Disembark: Clyde, UK 10 – 15th August 2010

9. *Access to data, samples and research results*

9.1 **Expected dates of submission to** Greenland **of preliminary reports which should include the expected dates of submission of the final results:**

Six months after completion of Cruise

9.2 **Proposed means for access by** Greenland **to data and samples:** N/A

9.3 **Proposed means to provide** Greenland **with assessment of data, samples and research results or provide assistance in their assessment or interpretation:** N/A

9.4 **Proposed means of making research results internationally available:**

Publication in international journals.

N J White......(On behalf of the Principal Scientist)

DISTRIBUTION
FCO LONDON
RNWS TAUNTON
SUBMARINE CABLE SYSTEMS
CTF 311
PRINCIPAL SCIENTIST
MASTER
CRUISE FILE

Research Description

Underlying Rational

The V-shaped ridges, which straddle the mid-oceanic ridges either side of Iceland, are the world's best window into transient convective circulation of the mantle (Figure 1). Since Vogt's (1971) important insight, it has been widely recognized that these ridges transgress magnetic anomalies and enable the temporal and spatial evolution of the Icelandic plume to be determined (e.g. White et al., 1995; Ito, 2001; Jones et al., 2002). Adjacent to the Reykjanes Ridge, these V-shaped ridges have a clear bathymetric and gravitational expression which reflects crustal thickness changes at depth. Indeed, limited wide-angle seismic data show that V-shaped ridges and troughs are produced by small (2 km) changes in crustal thickness which probably reflect temperature variations within the spreading plume (White et al., 1995). The inferred chronology of these temperature changes supports the notion that the Icelandic plume has played a central role in varying regional uplift, which in turn moderates Neogene overflow of North Atlantic Deep Water across the Greenland-Scotland Ridge (Wright & Miller, 1996; Poore et al., 2006). Despite their potential significance, these reconstructions rely on very old, poor quality, seismic reflection profiles (Talwani et al., 1971). Furthermore, V-shaped ridge formation is still debated: are they generated by radial or channelized flow? Do they represent primarily compositional or temperature variations? These debates together with the palaeoceanographic angle have prompted an IODP proposal whose cornerstone is a set of drill sites located along a flowline which crosses a series of V-shaped ridges and troughs (Murton et al., 2004).

We intend to acquire 1400-2800 km of high resolution seismic reflection profiles in support of this IODP proposal (Figure 2). The survey configuration serves two related purposes. First, orthogonal cross-line coverage is provided at 10 key drilling sites. Secondly, one long flowline, from the mid-oceanic ridge to the east coast of Greenland, will be used to analyse in detail the basement structure of Neogene and older V-shaped ridges. Seismic images will constrain the thickness and internal structure of sedimentary rocks which drape older V-shaped ridges and infill intervening troughs. Structure of the sediment-basement interface within the drilling corridor will be mapped. We will carefully distinguish between the effects of normal faulting and crustal thickness variations using the methodology of Poore (2008) who used the old profiles to analyze the sediment-basement interface and free-air gravity anomalies (Figure 3). Predicted crustal thicknesses will be compared with those determined from geochemical modelling of rocks dredged from the mid-oceanic ridge (Murton et al., 2002). Multibeam bathymetry, gravity and magnetic data will be acquired and integrated with the results of seismic reflection imaging. Our site survey proposal is significantly complemented by a comprehensive dredging expedition funded by the Marine Institute of Ireland and carried out in April-May 2008. A combined study of seismic profiles, dredged rocks and legacy data will transform our understanding of the chronology and formation of the V-shaped ridges. In this way, the long-standing debate about the palaeoceanographic significance of temporal variations within the Icelandic plume can also be addressed.

Scientific and Technological Issues to be addressed

The wider scientific issue concerns the temporal dynamics of the Earth's convecting mantle about which surprisingly little is known. The IODP Initial Science Plan (2003-2013) has identified the investigation of transient processes associated with plumes and large igneous provinces as a high priority (see also Neal et al. (2007) IODP Workshop Report). Plume-ridge interactions are a key objective since they enable us to infer temperature and compositional variations associated with upwelling plumes. The Iceland-Reykjanes system is regarded as the type example of plume-ridge interaction by the InterRidge community. This recognition has led to formulation of an IODP proposal to drill basement rocks along and across the V-shaped ridges which flank the Reykjanes Ridge. An improved understanding of Icelandic plume dynamics has a wider significance: vertical motion of Greenland-Scotland Ridge is now recognized as having played an important role in modulating palaeoceanography of the North Atlantic and Arctic Oceans (e.g. Haley et al., 2008). Although this proposal was formulated with the IODP proposal in mind, it will also play a key role in estimating transient vertical motion associated with the plume. (Figure 3) Recent attempts to analyze legacy seismic profiles in conjunction with gravity anomalies are compromised by the poor quality of acoustic imaging, especially of the detailed structure of the sediment-basement interface (Figure 4; Poore, 2008). Modern seismic imaging will transform this analysis and place the history of transient motion on a more solid basis. This proposal will act as a scientific stimulus which will help to draw together disciplines ranging from igneous petrology to palaeoceanography. Colleagues at Cambridge and Southampton have considerable experience in both of these fields and we expect close collaboration.

The main technological issue is the ability of a high resolution seismic acquisition system to image the sedimentary structure and the sediment-basement interface. The University of Aarhus acquisition system consists of a 600 m, 96 channel digital streamer and either a single Generator-Injector (GI) gun or a 4 sleeve gun array. The troughs between the V-shaped ridges have sedimentary strata which vary in thickness from 100-300 m. Occasionally, on the east side of the Reykjanes Ridge, strata are up to 500 m thick. During our visit to Aarhus, we examined their seismic database and are highly impressed at the ability of this system to image sediment-basement interfaces through several kilometres of sediment. We are also impressed at the ability to resolve sedimentary structure in exquisite detail . We are confident, therefore, that this acquisition system can easily fulfill the technological requirements of an IODP site survey.

Relevance to Users and Potential Benefits

seismic The most direct and obvious beneficiary will be the IODP community. We will acquire, process, interpret and evaluate the required geophysical datasets to fulfill IODP requirements. The most important component is a set of crossing seismic reflection profiles at each of the 10 proposed drillings locations (Murton et al., 2004). These profiles will image the sediment-basement interface as well as the detailed structure of the sedimentary section. They will be complemented by swath bathymetric surveys, by gravity and magnetic data, and by dredge samples. The final data pack will be forwarded to IODP.

Secondly, there is increasing awareness in the hydrocarbon industry of the importance of understanding the temporal and spatial history of convective circulation within the Earth's mantle. In the North Atlantic realm, there is excellent evidence that convective flow has generated periodic, rapid transient uplift/subsidence events. These events punctuate otherwise uniform thermally-driven subsidence, generating disconformities and clastic deposition. Within the hydrocarbon-producing Paleogene strata of the Faroe-Shetland and northern North Sea basins, there is excellent evidence for a series of transient events whose magnitude, duration and cause is of direct interest to industry. BP Exploration are funding a separate project to investigate these events throughout the North Atlantic and Arctic Oceans. Our study of the V-shaped ridges will have a direct impact upon this work, hence BP and Schlumberger interest.

Thirdly, analysis of the V-shaped ridges associated with the Icelandic plume will be of direct relevance to the wider academic community. We lack direct observations which would help to constrain the temporal variation of convection on timescales of 1-10 million years. Recently, it has become increasingly clear that the Phanerozoic stratigraphic record contains important albeit indirect information about the details of time-dependent convective circulation. (Rudge et al.2008). An understanding of the Neogene behaviour of the Icelandic plume will considerably improve our ability to interpret plume-related transient events in the fringing sedimentary basins and margins. This approach will benefit stratigraphers and convection modellers alike. Our results will also help to constrain Neogene overflow of Northern Component Water across the Greenland-Scotland Ridge and we anticipate close collaboration with colleagues such as Dr Alex Piotrowski at Cambridge.

Specific Objectives of Project

(i) Acquire and process a high resolution seismic reflection survey which fulfills the site survey requirements of IODP.
(ii) Acquire and process other geophysical and geological datasets which aid sub-surface characterization (e.g. nature of seabed, presence of unconformities, nature of basement).
(iii) Detailed mapping of sedimentary structure and velocity analysis.
(iv) Detailed mapping of faulting and sediment-basement interface.
(v) Infer temperature and compositional anomalies associated with Icelandic plume by combining residual bathymetric estimates with geochemistry of dredged samples.
(vi) Compare a revised plume chronology with estimated Neogene overflow of Northern Component Water.
(vii) Develop dynamical model of plume evolution.
(viii) Exploit fresh understanding in fringing sedimentary basins and margins of North Atlantic realm.

Methodology and Approach

The seismic reflection survey will comprise at least one flowline which traverses the Neogene-age V-shaped ridges on either side of the Reykjanes Ridge. A series of shorter profiles will be shot at right angles to this flowline at each of the proposed drill sites. If conditions are good, it may be possible to acquire a second flowline. We will image the sediment-basement interface within the corridor of interest. Basement topography is generated in two ways. First, temperature and compositional variations within the plume conduit sweep southward within the convecting asthenosphere and, through the process of seafloor spreading, give rise to diachronous changes in crustal thickness. Isostatic considerations mean that the primary manifestations of crustal thickness changes are medium-wavelength basement swells and depressions. Secondly, basement topography at shorter wavelengths is generated by normal faulting. Our methodology is designed to isolate the component of basement variation which is generated by variations of crustal thickness. We will calculate the water-loaded basement subsidence and then remove the well-known age-depth cooling relationship. An appropriate filter will be used to remove the effects of faulting. The calculated crustal thickness variation will be calibrated using legacy spot measurements of crustal thickness (Poore, 2008). This result will be used to calibrate free-air gravity anomalies along the length of the Reykjanes Ridge. In order to obtain the temporal variation, the residual depth curve will be compared with intersecting magnetic anomaly data which will be placed on an astronomical timescale.

The newly calibrated proxy for crustal thickness variation will be exploited in two ways. First, we shall link this variation with the petrological and geochemical understanding of the V-shaped ridges (Poore, 2008). The key datasets are rock samples dredged by Murton et al. (2002), by the April-May 2008 cruise led by Jones and Murton, and by the proposed cruise. Our experience in April-May shows that off-axis dredging of the V-shaped ridges is both viable and productive. Major, trace element and isotopic data place important constraints upon the composition and temperature of the source region flowing beneath the Reykjanes Ridge. We will use existing quantitative models to explore the relationship between predicted crustal thickness, melt geochemistry and vertical motion. This seismic experiment will help to determine the origin of the V-shaped ridges and troughs: Are they related to ridge jumps on Iceland? Are they related to the migration of convection cells driven by deep mantle flow away from Iceland?

NATURAL ENVIRONMENT RESEARCH COUNCIL

What is the dominant mechanism of flow away from Iceland: along-axis transport or radial flow? What is the flux within, and the width of, the plume conduit? What is relationship between Iceland itself and Reykjanes Ridge?

The methodology and approach described above is contingent upon successful acoustic imaging of the sub-surface from the sea-bed down to the sediment-basement interface. Previous experience shows that the University of Aarhus high resolution seismic acquisition system provides excellent signal penetration through several kilometres of sedimentary cover. In the site survey area, strata are generally much thinner (100-300 m). The streamer has 96 channels with 6.25 m spacing. The water depth is 1-2 km (i.e. 1-3 s two-way travel time) and if we record 3 s two-way travel time below the seabed (i.e. ~3 km) then we need a record length of 6 s two-way travel time. The gun recycling time is 2 seconds. If our speed is 5 knots these values constrain the shot point interval to be 20 m which yields a fold of cover of 15. This coverage will yield excellent records down to, and below, the sediment-basement interface. The airgun array will be towed at 6 m depth and the streamer at 12 m. In both cases, these towing depths ensure a broad-band frequency range. To optimize the detailed structure of strata and of the sediment-basement interface, careful processing will be carried out using Schlumberger's *Omega2* processing package. The salient aspects of our processing sequence will be decided once data have been acquired but will include filtering, gain, source signature deconvolution, dense velocity analysis, source/signature deghosting, and post-stack migration. If possible, source signature deconvolution will be applied by using a far-field recorded source signature. In the absence of a far-field source signature for each shot, this form of deterministic deconvolution should successfully remove the bubble pulse and considerably reduce reverberation if we opt for the sleeve gun array. If the GI gun is used, reverberation should not arise. A low-cut filter will help to reduce low-frequency noise. Velocity analyses will be carried out every kilometre. Deghosting will be applied after normal move-out correction and standard multiple energy suppression by assuming a constant source/receiver depth and a flat sea surface. A standard spherical divergence correction will remove amplitude transmission losses but otherwise we do not anticipate applying automatic gain control. We will experiment with pre-stack depth migration but suspect that a post-stack Stolt *f-k* migration followed by vertical stretch will suffice. This simple migration algorithm should successfully remove all significant diffraction events and enable us to image detailed faulting of the sediment-basement interface.

The final aspect of this research project is integration of the seismic reflection survey with the ancillary data acquired during the cruise and with legacy datasets. We shall acquire swath bathymetry, gravity and magnetic data and rock samples. The swath data will help to some extent during seismic processing although its principal value will be for the site survey planning. Gravity and magnetic data will enhance existing databanks and be used to isolate crustal thickness variation from normal faulting, as well as help to date V-shaped ridges. Dredged rock samples of basalts will constitute an important resource in its own right which will be of interest to igneous petrologists and geochemists elsewhere. We expect to collaborate with other groups in order to ensure that these samples are analyzed for major, trace and rare Earth elements and for isotopes such as Pb, Sr and Nd.

Modelling these analyses and those from the April-May 2008 dredging cruise will play a crucial role in separating and quantifying the effects of temperature and composition on V-shaped ridge formation. The major scientific question is whether V-shaped ridges are generated by compositional variation, by temperature variation, or by both. We will address this question in two ways. Our first task will be calculating the crustal thickness variation associated with the V-shaped ridges from the calculated residual bathymetry using Poore's (2008) technique where she calibrated residual bathymetry against measured crustal thickness from wide-angle seismic experiments which are mostly concentrated close to the mid-oceanic ridge. We will then determine the source compositions and asthenospheric temperatures required to match the geochemical measurements from V-shaped ridges where they intersect the mid-oceanic ridge and where they have been sampled off axis. Our preliminary attempts to model the geochemical variability along the mid-oceanic ridge does suggest that temperature fluctuations are more important than source compositional variability although we freely acknowledge that this may not be the case off axis. In our view, the key to unravelling source and temperature effects relies on closely integrating geophysical and geochemical measurements in a single quantitative model. We hope that any predictions we make about source and temperature changes through time can be tested by comparison with Icelandic basaltic geochemistry and volume fluxes.

Research Programme

Our research programme will follow a logical sequence of cruise planning, data acquisition, signal processing, interpretation and palaeoceanographic interpretation. This general strategy has grown out of a preliminary analysis of legacy seismic reflection gravity, swath bathymetric and dredge data which is being carried out this summer (see also Poore, 2008). Successive elements of the workflow are necessarily contingent upon preceding elements but overlap will occur.

Q1-2: Start-up and preliminary cruise planning meeting (University of Aarhus), advertise and select PDRA. Synthesis of legacy seismic profiles, gravity anomalies and geochemistry of dredged basalts. Re-examination of palaeoceanographic constraints for North Atlantic Deep Water overflow (Carbon, Neodymium and Oxygen isotopes).

Q3-4: Final cruise planning meeting (University of Aarhus). PDRA in place. 1 month cruise. Decide processing strategy. Provisional processing and interpretation of seismic reflection data. Start processing of swath bathymetric data. Analysis of dredged basalts.

Q5-6: Finalise processing of seismic reflection data. Detailed interpretation of seismic reflection profiles which includes mapping of sedimentary section, faulting and sediment-basement interfaces. Combined modelling of gravity, magnetic, seismic and geochemical data. Seismic velocity analysis and tomographic modelling of seismic data.

Q7-8: Preparation of site survey package for IODP: surface characterization, sub-surface mapping, other constraints. Dynamical modelling of Icelandic plume. Publication of seismic images and interpretations. Publication of temporal history of Icelandic plume and its implications.

Management of Project and Resources

The project, resources and personnel will be managed by Dr N White at Cambridge in close consultation with his Co-Is. He will arrange formal project meetings every 6 months and ensure that deadlines are met in accordance with outlined programme. We hope that the cruise will take place in summer 2009. The first two meetings will focus on cruise planning and will take place at the University of Aarhus. The second two meetings will focus on data processing, interpretation and modelling and will take place in Cambridge and Southampton. The PDRA will take charge of seismic processing but this work will be overseen by Drs Henstock and White who have relevant experience. S/he will be based at Cambridge but will spend extended periods at Southampton. Although much co-ordination can be achieved by email/telephone, regular formal and informal meetings will ensure a successful project.

NATURAL ENVIRONMENT RESEARCH COUNCIL

Stewardship of Resulting Datasets

The primary dataset consists of pre-stack and post-stack seismic reflection images. These images will be made available in *SEG-Y*, *PostScript* and *JPEG* formats through NERC and on the web. The results will also be documented in a set of publications which will be available as PDFs. Ancillary datasets, consisting of swath bathymetry, gravity and magnetic measurements, geochemical analyses of dredged rocks will also be documented in publications and archived with NERC, NOCS and Cambridge. An IODP data package will be prepared and lodged.

References

Haley, B.A., Fank, M., Spielhagen, R.F., and Eisenhauer, A., 2008. Influence of brine formation on Arctic Ocean circulation over the past 15 million years. Nature, Geoscience, 1, 68-72.
Ito, G., 2001. Reykjanes V-shaped ridges originating from a pulsing and dehydrating mantle plume. Nature, 411, 681-684.
Jones, S.M., White, N., and Maclennan, J., 2002. V-shaped ridges around Iceland: implications for spatial and temporal patterns of mantle convection. G-cubed, 3, doi:10.1029/2002GC000361.
Murton, B.J. et al., 2004. IODP Proposal.
Murton, B.J., Taylor, R.N. and Thirlwall, M.F., 2002. Geochemical interaction between the Iceland plume and the Reykjanes Ridge: a geochemical perspective. J. Petrol., 43, 1987-2012.
Neal, C.R. and 13 others, 2007. Investigating large igneous province formation and associated paleoenvironmental events: a white paper for scientific drilling. IODP Management International Workshop
Poore, H., Samworth, R., White, N., Jones, S., and McCave, I.N., 2006. Neogene overflow of Northern Component Water at the Greenland-Scotland Ridge. G-cubed, 7, doi:10.1029/2005GC001085.
Poore, H., 2008. Neogene history of the Icelandic plume. Unpublished PhD dissertation, University of Cambridge
Rudge, J.F., Shaw-Champion, M.E., White, N., McKenzie, D., and Lovell, B., 2008. A plume model of transient diachronous uplift at the Earth's surface. Earth Planet. Sci. Letts., 267, 146-160.
Talwani, M., Windisch, C., and Langseth, M., 1971. Reykjanes Ridge crest: a detailed geophysical study. J. Geophys. Res., 76, 473-517.
Vogt, P., 1971. Asthenospheric motion recorded by the ocean floor south of Iceland. Earth Planet. Sci Letts., 13, 153-160. White, R., Bown, J., and Smallwood, J., 1995. The temperature of the Iceland plume and origin of outward-propagating V-shaped ridges. J. Geol. Soc. Lond., 152, 1039-1045.
Wright, J.D. and Miller, K.G., 1996. Control of North Atlantic Deep Water circulation by the Greenland-Scotland Ridge. Paleoceanography, 11, 157-170.

NATURAL ENVIRONMENT RESEARCH COUNCIL

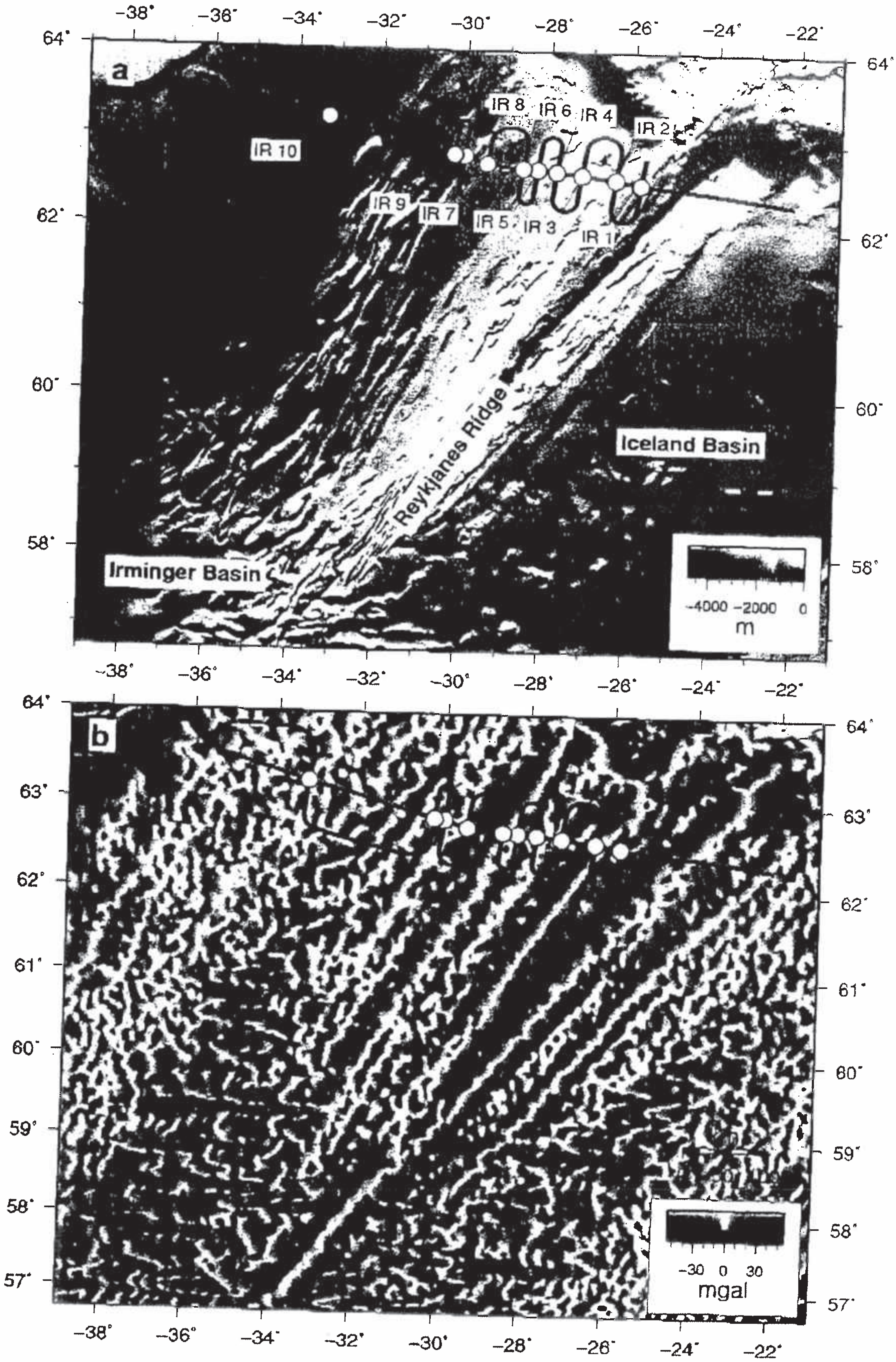

Figure 2: (a) Bathymetric map of site survey area south of Iceland. Circles = planned IODP site locations; thick black lines = seismic reflection lines. The priority lines are those which cross the drilling sites. (b) Free-air gravity anomaly map which clearly shows V-shaped ridges.

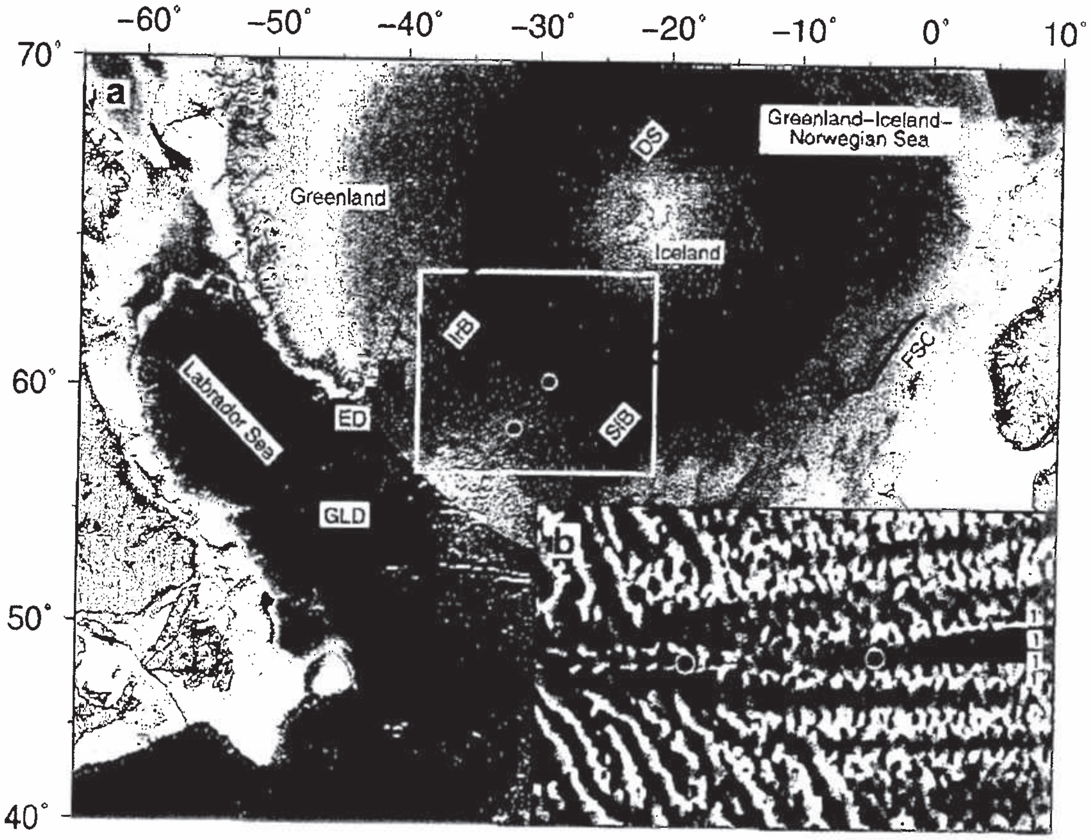

Figure 1: (a) Bathymetric map of North Atlantic Ocean which shows idealized planform of Icelandic plume. Note spatial relationship between plume, present-day overflow of deep-water masses and sedimentary drift deposits. Large pink disk = idealized extent of plume; inner red disc = intersection of youngest V-shaped ridge with Reykjanes Ridge; red and blue circles = positions where chemistry of dredged basaltic rocks are consistent with asthenospheric temperature difference of 30 degrees C; ED and GLD = Eirik and Gloria contourite drifts; black arrows = trajectories of deep-water overflow; white box = location of Figure 3; black box = inset. (b) Detail of free-air gravity map showing V-shaped ridges.