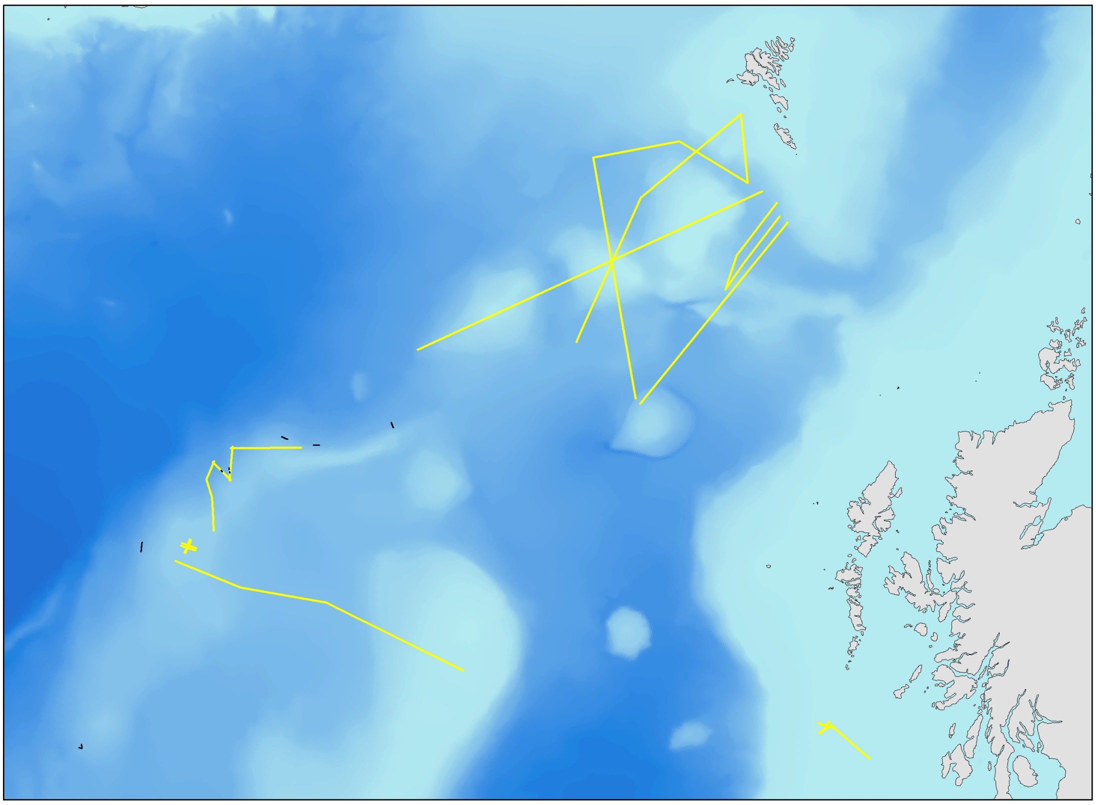
Hatton Bank–Faroe Bank Channel Geophysical Survey

RRS Charles Darwin Cruise CD180
BGS Cruise 06/02

Geological Summary Report

Marine, Coastal and Hydrocarbons Programme

Commissioned Report CR/06/190



BRITISH GEOLOGICAL SURVEY

MARINE, COASTAL AND HYDROCARBONS PROGRAMME

COMMISSIONED REPORT CR/06/190

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Geological Summary Report

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Keywords

Bill Bailey's Bank; Cenozoic; Compression; Faroe Bank; Faroe Bank Channel; Hatton Bank; Hatton–Rockall Basin; Lousy Bank; Rockall Bank.

Front cover

Survey lines run during the course of the BGS Cruise 06/02.

Bibliographical reference

STEWART, H A, HITCHEN, K, AND TUITT, A. 2006. Hatton Bank–Faroe Bank Channel Geophysical Survey RRS Charles Darwin Cruise CD180 BGS Cruise 06/02 Geological Summary Report. *British Geological Survey Commissioned Report*, CR/06/190. 325pp.

Edinburgh, Scotland British Geological Survey 2006

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Foreword

This cruise was funded by the British Geological Survey Science Budget allocation from the Natural Environment Research Council as part of its ongoing offshore mapping programme. Data collected in the Stanton Bank area was funded by MESH (Mapping European Sea-bed Habitats), a European Union Interreg IIIb project. This report was funded by the BGS Rockall Consortium which, in 2006, comprised BGS and Chevron, DTI, ENI, Shell and Statoil.

The report provides a preliminary overview and interpretation of data gathered during the *RRS Charles Darwin* cruise CD180, BGS Cruise 06/02. The cruise collected high resolution geophysical data on Hatton Bank, north-east across the Lousy, Bill Bailey's and Faroe Banks and finally in the Faroe Bank Channel. Seismic data were also collected to the south of St Kilda and Stanton Bank areas.

Acknowledgements

As with any field operation a large number of individuals contributed to the success of the cruise. A full list of BGS personnel and observers can be found in Appendix 1 of the Operations Report (Smith, 2006) and their contribution is acknowledged. Thanks are also due to Captain Peter Sarjeant, the officers and crew of the *RRS Charles Darwin* and the technical support provided by NOCS UKORS.

Contents

List of Figures

List of Tables

Summary

This report describes the initial geological observations made during BGS Cruise 06/02 carried out from the 18th May to the 9th June 2006 as part of the ongoing Marine, Coastal and Hydrocarbons Programme. Survey operations were undertaken in UK and Faroese national waters and were planned to integrate with existing BGS regional data and to fill in knowledge gaps.

The primary objectives of the cruise were:

1. To define the size and shape of a previously identified 'window' in the extensive Palaeogene basalt cover on Hatton Bank and to image structure within the underlying ?Mesozoic. Locate possible shallow borehole locations.
2. To investigate the relationship between cold water coral growth and geological structure on Hatton Bank.
3. To identify and characterise post-break up folds, faults and thrusts across major banks, the Wyville–Thomson and Ymir ridges and the 'Alpin Dome'.
4. To investigate the seismo-stratigraphy of the Faroe Bank Channel with a view to identifying potential borehole location(s).

In addition to the original survey objectives, two further aims were:

5. To acquire high-resolution seismic data to tie in an existing giant piston core site located south of St Kilda to an existing BGS deep tow boomer line.
6. To acquire high-resolution seismic data to integrate with existing BGS 05/05 MESH survey in the Stanton Bank area.

The seismic techniques employed during this cruise were high-resolution single channel seismic reflection (airgun and sparker systems). Gravitational field, magnetic field, precision echo sounder, pinger and multibeam bathymetry data were also collected. Only multibeam bathymetry data were collected along line 1 as seismic data had previously been acquired on BGS cruise 00/01 for the Rockall Consortium in 2000 (lines 00/01-16 and 44).

A total of 2243 line kilometres of survey data was collected.

1 Introduction

A complete account of operations can be found in the BGS Operations Report (Smith, 2006). To summarise, the vessel mobilised at Falmouth on the 18th and 19th of May and sailed on the 20th May taking a route north through the Irish Sea before heading west to the start of line 1 just south of Rockall Island. The original survey plan was completed on the 5th June and a number of lines in the St Kilda and Stanton Bank areas were collected between the 5th and 7th of June. The survey was completed on the 7th June and the vessel proceeded to Fairlie (Ayrshire) for demobilisation on the 9th June. During the course of this survey 2243 line kilometres of survey data were acquired.

Hatton Bank is an elongate, relatively shallow bathymetric high located on the western edge of the Rockall Plateau. The western margin of the bank descends into the Iceland Basin and the eastern edge into the Hatton Basin, sometimes referred to as the Hatton-Rockall Basin. The Lousy, Bill Bailey's and Faroe Banks form a chain of bathymetric highs between the north-eastern end of Hatton Bank and the Faroe Islands, which rise from approximately 1200m water depth to between 100 and 200m water depth. The Faroe Bank Channel, located to the northeast of the shallow water Wyville–Thomson Ridge and the southern-most end of the Faroe–Shetland Channel, forms a deep-water conduit, orientated roughly northwest-southeast.

It is suggested that Hatton Bank is, on the whole, underlain by Early Proterozoic Rockall Bank/Islay terrane metamorphic basement although the north-eastern end of Hatton Bank may be underlain by Lewisian strata at depth (Hitchen, 2004). Widespread Palaeogene lavas cover much of the Hatton Bank area, although several areas have been mapped which are devoid of lava. Seismic lines over these basalt-free areas image dipping seismic reflectors indicative of sedimentary strata, suggested in literature as Upper Palaeozoic–Mesozoic in age (Hitchen, 2004). Indeed, in one of these basalt 'windows', located slightly to the south of the survey area, boreholes 99/01 and 99/02A cored Albian mudstone and sandstone respectively (Hitchen, 2004).

Where Rockall High is suggested to comprise a basement block, Hatton High is interpreted to be underlain by Cenozoic and Mesozoic/Paleocene sedimentary rocks affected by Cenozoic tectonism (Johnson *et al*., 2005). The northern end of Hatton High comprises a large anticline. Speculatively, linear *en echelon* features identified on the sea bed of Hatton Bank may be the surface expression of underlying thrust faults initiated during the Cenozoic.

Tectonism during the Cenozoic in the Hatton Bank, Wyville–Thomson Ridge and Faroe–Shetland Channel areas resulted in a number of compressional features (Johnson *et al*., 2005). Tectonically driven changes in sedimentation and oceanographic pathways during the Neogene can be identified in the sediments deposited between the major banks located to the south-west of the Faroe Islands (Lousy, Bill Bailey's and Faroe Banks) and within the Faroe Bank Channel. Enhanced deep-water exchange through the Faroe Bank Channel may be associated with Miocene folding of the Wyville–Thomson Ridge Complex (Stoker *et al*., 2005).

Sea-bed features on Hatton Bank also include a number of sea-bed mounds which may host biogenic reefs. The ridges and mounds of Hatton Bank stand approximately 30-40m in height above the surrounding sea bed and are 100-300m in diameter. They bear a strong resemblance to features reported in the Porcupine Seabight and the southern Rockall Trough which are proven to be bioclastic accumulations sustained by the growth of cold water corals (Masson *et al*., 2003). On this basis is it suggested that some of the Hatton Bank features are likely to be carbonate mounds whereas others are more likely to have a structural/tectonic origin comprising instead bedrock outcrop.

2 Survey Overview

2.1 SURVEY PLAN

The survey was planned to integrate with existing BGS data in the Rockall–Hatton–Faroes area (*Figure 1*). The rationale in choosing the lines for survey is summarised in *Table 1*. A summary of equipment run on each line is included in this report as Appendix 1 and information on the equipment used is included as Appendix 2.

Table 1 Summary of line objectives.

Line(s) **Prefix 06/02-**	**Rationale**
1	This line is coincident with existing BGS seismic lines 00/01-16 and 00/01-44. These existing lines show a variety of interesting features, such as incisions in the sea bed and faulting near sea bed possibly related to the presence of a polygonal fault system. Multibeam data collected along this line have allowed these features to be examined in 3 dimensions.
2 to 5	These lines image a known basalt window, better defining the size and shape of the window and orientation of fold axes in the underlying (?)Mesozoic sediments.
6 to 7	These lines build on data collected during the UK Department for Trade and Industry Strategic Environmental Assessment 7 (SEA7) collected in 2005. During the 2005 SEA7 cruise video footage of biogenic reef was gathered. These lines are coincident with the location of the video footage and have allowed the relationship between the geological structure and the presence of biogenic reef to be studied further.
8 to 11	These lines image a number of geological structures some of which may be compressional in origin. These lines transect a number of sea-bed ridges, identified using multibeam data collected in 2005 by the Instituto Español de Oceanografia. The seismic and additional multibeam data collected during the 06/02 survey allow the origin of these features to be better understood.
12, 16 (N end) and 21	These lines were acquired to investigate the structure of three major banks lying to the south-west of the Faroe Islands (especially Bill Bailey's Bank).
15 (SW end) and 16 (S end)	These lines were extended southwards towards Rosemary Bank to investigate the extent and trend of the Alpin Dome.
13, 14, 15 (NE end) and 17 to 20	These lines resolve the seismic stratigraphy and sediment patterns in the Faroe Bank Channel.
22 to 26	These lines tie the location of a giant piston core to an existing BGS high-resolution deep tow boomer line.
27 to30	These lines complement data gathered during the BGS 05/05 MESH survey in the Stanton Bank area.

2.2 SUMMARY OF DAILY OPERATIONS

A comprehensive account of the operations during the BGS 06/02 cruise can be found in the BGS Operations Report (Smith, 2006). In order to put the information contained in this report into context a summary has been provided here for reference.

18-19th May 2006

Mobilisation of the *RRS Charles Darwin* in Falmouth.

20th May 2006

The vessel sailed at 10:00. The poor weather experienced at the time of sailing, coupled with the forecast received, resulted in a route taken through the Irish Sea to the start of survey rather than the planned route west of Ireland.

21-22nd May 2006

Transit to the multibeam system calibration site located south-east of Rockall Bank.

23rd May 2006

Arrived south-east of Rockall Bank at 07:00. Calibration of the multibeam bathymetry systems was carried out before the planned traverse to the start of line 1. Due to poor weather the traverse to the start of survey was delayed.

24th May 2006

Arrived at start of line 1, approximately 15 miles south of Rockall Island. Multibeam bathymetry systems only online, as per the survey specifications.

25th May 2006

Line 1 completed. Airgun, sparker and magnetometer systems deployed, multibeam system remained online. Lines 2 to 5 completed covering the basalt window on Hatton Bank.

26th May 2006

Transit to start of line 6 which is the first of a series of lines examining areas of cold water coral reefs. Lines 6 to 10 completed, on line 11 by end of day.

27th May 2006

Finished line 11. This completed all survey lines on Hatton Bank. Recovered airgun, sparker and magnetometer systems before transiting to the start of line 12 that runs across Lousy, Bill Bailey's and Faroe Banks. The multibeam system remained on during the transit. The start of line 12 was reached in the evening and the airgun, sparker and magnetometer systems were re-deployed.

28th May 2006

Continued on line 12. The weather deteriorated resulting in the sparker being recovered in the early hours of the morning. The airgun data quality was also affected by the poor weather, however at this time the vessel was passing over Lousy Bank and there was no penetration through the basalt which was observed to be present at the sea bed. The weather improved enough for the sparker to be re-deployed at 12:30 although it was noted that the data quality was poor. The sparker was recovered for a second time at 16:30 due to the confused sea state caused by variable wind direction and a significant swell.

29th May 2006

Sparker was redeployed in the early hours of the morning. Line 12 was completed at 20:03 and all equipment was recovered.

30th May 2006

By midnight all the equipment was re-deployed and line 13 was completed during the course of the day. Line 14 was two-thirds completed by the end of the day.

31st May 2006

Line 14 completed and line 15 started. Line 15 was approximately two-thirds completed by the end of the day.

1st June 2006

Line 15 completed and line 16 begun.

2nd June 2006

Line 16 completed and line 17 begun.

3rd June 2006

Line 17 completed at 06:03. During the course of the night the online airgun printer was malfunctioning. The problem could not be pinpointed. Line 18 was completed and line 19 was started at 16:21.

4th June 2006

Line 19 and 20 completed and line 21 begun.

5th June 2006

Line 21 completed at 16:18 finishing the original survey plan. All equipment was recovered and the vessel began transit to a position just south of St Kilda.

6th June 2006

The additional time allowed a short excursion around the World Heritage Site of St Kilda. This allowed time for survey in two areas:

- An area to the south of St Kilda to collect high-resolution sparker data across an existing piston core location in order to tie this into an existing BGS deep tow boomer line.
- Stanton Bank to collect high resolution sparker data to fill in data gaps from the BGS 05/05 MESH survey in this area.

Work began at the St Kilda survey area at 18:00. The five lines, 22 to 26 were completed by 22:00 with sparker, pinger, multibeam and precision echo sounder data collected for each of the lines. At the end of line 26 all the equipment was recovered and the vessel transited to the Stanton Bank area.

7th June 2006

Arrived on station at 07:30 in Stanton Bank survey area, deployed sparker, pinger, multibeam and PES systems. Began line 27 at 07:54 and the four lines (27 to 30) were completed by 22:00. All equipment was recovered and the vessel began transit to Fairlie, Ayrshire. This concluded data acquisition.

8th June 2006

On transit to Fairlie.

9th June 2006

Arrived in Fairlie at 11:30. Gravity meter was left to settle and final readings recorded before being switched off. Equipment demobilised, departed vessel at 14:00.

3 Preliminary Interpretation of Geological Data

3.1 LINE 06/02-1

This line runs from approximately 15 miles south of Rockall Island west to Hatton Bank, following the same track as existing BGS high-resolution seismic lines 00/01-16 and 00/01-44. The line is approximately 308km in length and the primary equipment type utilised on this line was multibeam.

A variety of sea-bed features has previously been identified on seismic lines 00/01-16 and 44 including incised channels and sea-bed depressions. These features have now been imaged on the multibeam data allowing a limited 3D perspective. It should be noted that many features will be better resolved with further processing of the data. This is also likely to bring out features as yet unidentified. The incised channels, and the moat at the foot of Rockall Bank, are probably the result of strong contour currents, some of which may be active at the present time.

In the centre of Hatton Basin water depths range between 1000m and 1200m. The existing seismic data shows numerous shallow faults in the centre of the basin, many of which affect the sea bed. The new multibeam data confirms an irregular polygonal pattern for the sea-bed expression of these faults.

Where the western margin of Hatton Basin merges with the lower slopes of Hatton Bank the sea bed is incised by a series of elongate *en echelon* depressions which cut down into pre-Pliocene sediments. These features are thought to be caused by eddying, strongly-erosional, along-slope currents.

3.2 LINES 06/02-2 TO 06/02-5 – THE BASALT WINDOW

Widespread basalt flows extruded during the Palaeogene in the Hatton-Rockall area are sourced from the large igneous complexes (Rockall, Swithin, Sandastre, Mammal, Lyonesse and Sandarro), local volcanoes and fissures and also from the incipient rift axis located west of Hatton Bank at the time of continental break-up (Hitchen, 2004). However there are several places on Hatton Bank where the basalt was either not extruded or was removed by subsequent erosion during the Cenozoic. It is one of these known 'windows' within the extensive basalt cover that lines 06/02-2 to 06/02-5 image, better constraining the size and shape of the window and the underlying Mesozoic section.

Lines 06/02-2 and 3, orientated WNW-ESE, were acquired first and used as a guide to locate the two NNE-SSW lines. Line 06/02-2 shows the presence of one 'window' in the basalt, whereas line 06/02-3 images two windows separated by a small section of basalt.

Only one of the two NNE-SSW lines (06/02-5) successfully imaged the basalt window. This showed the window apparently divided into two sections by a small section of basalt (*Figure 2*). Within the window the dipping reflectors are considered to be Upper Palaeozoic–Mesozoic tilted sedimentary rocks (Hitchen, 2004, and references therein). It should be noted that mid-Cretaceous mudstone, dated as Albian, has been drilled in borehole 99/01 and terrestrially derived Albian sandstones were drilled by borehole 99/02. These two boreholes are located to the southwest of lines 06/02-2 to 5 (*Figure 1*). Unfortunately line 06/02-4, located approximately 3.5km east from line 06/02-5, to test the extent of the window in this direction, imaged basalt at, or close to, the sea bed along its entire length.

3.3 LINES 06/02-6 TO 06/02-11 – HATTON BANK

Data were collected on these lines to (i) coincide with video footage gathered as part of the SEA7 survey investigating the relationship between cold water coral growth and geological structure and (ii) to image the possible subsurface geological structure associated with regular linear sea-bed ridges first identified by multibeam data collected in 2005 by the Spanish Instituto Español de Oceanografia.

The most prominent feature on line 06/02-6 is a southward-facing escarpment approximately 75m in height which is well imaged on all datasets. This may be related to faulting in the subsurface. Further north along this line (downslope), a single mound is present on the profile data which appears as a discreet topographic high on the multibeam data. Erosion is visible at the base of this mound forming a moat on the southern side.

On lines 06/02-7 to 10 a number of sharp depressions are visible on the sparker and airgun records. These have a sharper upslope side with the eroded sediments deposited downslope of the incision. The multibeam data show these features as corresponding to linear depressions visible on the sea bed. Previous work in the area has identified these features as elongate ridges and furrows thought to be caused by erosion from along-slope currents. Line 06/02-8 demonstrates folding at Top Basalt level associated with a possible thrust. The sea-bed morphology partially mirrors the underlying structure. Similar features have previously been identified on airgun records in the vicinity (for example on MH90-20C).

Line 06/02-9, on the north side of Hatton Bank, shows three distinct mounds, at least two of which directly overlie faults (*Figure 3*) recognised in the subsurface. Sediments are ponded up dip (south) of the mounds and debris piles are present downdip. These are possible carbonate mounds on the oceanward slope of Hatton Bank. Further downdip on the same line, the headwall of a slide can be identified (*Figure 3*). This does not have significant expression on the multibeam data. However reprocessing the bathymetry data may resolve this feature better. Taking lines 06/02-9 and 10 together, a number of discreet topographic highs can be identified on the multibeam data. The seismic data across the same features suggests that a variety of mechanisms may be responsible for their formation including bedrock outcrop, simple faulting (possibly associated with sediment / fluid mobilisation) and carbonate growth. Another feature visible on line 10 is what appears to be an in-filled palaeo-furrow, coinciding with a slight topographic depression on the multibeam.

3.4 LINES 06/02-12, 16 AND 21 – LOUSY, BILL BAILEY'S AND FAROE BANKS

These lines were acquired to investigate the structure of these major banks located to the south-west of the Faroe Islands. For the purposes of this report the channel located between Lousy and Bill Bailey's banks will be called Channel 'A' and the channel between Bill Bailey's and Faroe banks will be called Channel 'B' (*Figure 4*).

Unconformities identified during preliminary interpretation of the 06/02 data include ones tentatively correlated at this time with C10 and C30 (Early Pliocene and Late Eocene respectively, as documented in the Rockall Basin) (Stoker *et al.*, 2005, Vanneste *et al.*, 1998), and the Top Palaeogene Unconformity (TPU) in the Faroe–Shetland Basin (Smallwood, 2004).

3.4.1 Line 06/02-12

Line 06/02-12 is approximately 377 km in length (*Figure 1*). Approximately 120m of post-basalt sediment is present at the start of line to the south-west of Lousy Bank. This thickness reduces over the bank where basalt occurs at, or near, sea bed. Occasional sediment filled depressions are visible on the western flank of the bank. A large fan progrades eastwards off the Lousy Bank into Channel 'A' onto the C30 unconformity (unconformity identified from

Vanneste *et al*, 1998). Other unconformities, post-date the C30 unconformity and may have formed as a result of tectonic uplift (compression or underplating) of Bill Bailey's Bank.

Basalt occurs at, or just below, the sea bed on Bill Bailey's Bank. The post-basalt sediment thickness in Channel 'B' is in excess of 400m and at least four unconformities can be identified. A discrete package of sediments (?contourite) onlap onto the Faroe Bank from the deepest central section of this channel. The rippled appearance of the upper surface of the sediment package may be representative of large-scale sediment waves or may have been formed as a result of compression. This sediment package is onlapped by two packages of younger sediments, possibly sourced from the Bill Bailey's Bank, and separated by an unconformity. Small fans, possibly contemporaneous with the contourite, prograde into Channel 'B' from the Faroe Bank.

Basalt occurs at, or just below, the sea bed over Faroe Bank. Within the Faroe Bank Channel at least three unconformities can be identified. The C30, TPU and C10 unconformities have been correlated with unconformities identified north of the Wyville–Thomson Ridge.

3.4.2 Lines 06/02-16 (N end) and 21

The post-basalt sediment thickness to the south of Bill Bailey's Bank is in excess of 400m and at least four unconformities can be identified. On the south-western margin of Bill Bailey's Bank, onlapping sediment packages appear to be disturbed by channels possibly formed by turbidity currents. The sedimentary sequence is better imaged on the north-eastern margin of the bank where the onlapping sequences are separated by at least four unconformities. The ages of these unconformities will be investigated during subsequent interpretation of the data. The thickness of the post-basalt sediment reduces over the Bank where basalt is present near the sea bed.

3.5 LINE 06/02-15 (SW END) AND LINE 06/02-16 (S END) – THE ALPIN DOME

The southern ends of lines 15 and 16 were extended to investigate the size, orientation and extent of the Alpin Dome which is located to the north of Rosemary Bank (*Figure 4*). The new data complement the existing lines acquired in this area by BGS in 2002.

The dome is a very broad elongated east-west anticline within UK waters. It is defined at C30 level suggesting formation at the end of the Eocene. On line 06/02-16 it appears to have a wavelength of 50km and an amplitude of 750 ms and it forms a low dome at the sea bed. Its flanks are draped by younger sediments (*Figure 5*). On line 06/02-15 the Alpin Dome is less pronounced, does not affect the sea bed and is completely overlain by younger sediments. This suggests the dome plunges eastwards. The Mordor Dome is a much smaller secondary feature between the Alpin Dome and the Ymir Ridge.

3.6 LINES 06/02-13, 14, 15 (NE END), 17 TO 20 – THE FAROE BANK CHANNEL

Basalt underlies the whole of the Faroe Bank Channel and is present near the sea bed on the Faroe Shelf. To the northwest of the Faroe Bank, the western section of line 17 images basalt near the sea bed. Bottom current activity may have stripped the superficial sediment from the sea bed exposing the underlying basalt surface. Basalt is also present near the sea bed over the Wyville–Thomson Ridge and the Ymir Ridge.

The post-basalt sediment thickness is in excess of 400m within the Faroe Bank Channel and at least three unconformities can be identified (*Figure 6*). The main unconformities, C30, TPU and C10, have been correlated with unconformities identified north of the Wyville–Thomson Ridge.

Lines 13, 14 and the NE end of line 15 image a sediment package ?Mid-Late Miocene in age bounded by a composite TPU and C30 unconformity and the C10 unconformity. Unconformities identified within the sediment package appear to document the episodic growth of the Wyville–Thomson Ridge. Below the composite TPU and C30 unconformity the sediments are faulted (*Figure 6*). It is suggested here that the faulting may not be caused by compression in this case, but rather by hydrostatic release forming a possible polygonal fault system.

3.7 LINES 06/02-22 TO 26 – SOUTH OF ST KILDA

These data were collected in order to tie in an existing giant piston core (MD95-2007), located within the St Kilda Basin, to a high-resolution BGS deep tow boomer line (*Figure 7*). Samples from the core are being examined for evidence of post-glacial climate change and changes in the sedimentary depositional environment. Results from the study will be used to determine the extent of post-glacial changes in the middle and inner continental shelf to the west of the Outer Hebrides. Due to local variability in stratigraphy and depositional environment, these addition lines were required in order that the sample data could be placed in a regional context. The data collected clearly shows the uneven palaeo-topography of Lewisian basement infilled by well-layered Quaternary sediments (*Figure 8*).

3.8 LINES 27 TO 30 – STANTON BANK

Stanton Bank is a bathymetric term applied to the area between 7°30’ and 8°30’W and between 55°50’N and 56°20’N, approximately 60km south of Barra Head. The four high-resolution seismic lines (*Figure 9*) acquired during this survey infill data gaps in the 05/05 MESH Stanton Bank survey carried out in 2005 (Wallis, 2005). The new seismic lines traverse features previously identified using multibeam data and its associated backscatter data.

The new data reveal a spectacular subsurface buried landscape of irregular bedrock highs, which crop out at the sea bed, partially covered by overlying well-layered Quaternary sediments (*Figure 10*). These show several units and unconformities which appear to illustrate the complex history of the area that includes glaciation and episodes of transgression and regression.

Samples of the bedrock, previously recovered by shallow drilling and divers, comprise granite, gneiss, amphibolite and monzo-diorite (Binns *et al.*, 1974; Hitchen *et al.*, 2002). Although superficially similar to rocks of the Outer Hebrides, the Stanton Bank samples are Early Proterozoic in age at c. 1790 to 1800 Ma (Chambers *et al.*, 2005) rather than Lewisian (Archaean) and hence probably belong to a different basement terrane.

4 Conclusions

- During 15 days of BGS 06/02 survey operations in May to June 2006, 2243 line kilometres of seismic, multibeam bathymetry, gravity and magnetic data were acquired.
- Palaeogene basalts are widespread and imaged on most lines. Where surveyed, basalts are at, or close to, the sea bed over the crests of Hatton, Lousy, Bill Bailey’s and Faroe Banks and the Faroe Shelf. Between the banks the basalt is more deeply buried beneath several hundred metres of younger Cenozoic sediments.
- Lines 06/02-2 to 5 improved the delineation of a previously-identified basalt ’window’ on Hatton Bank and imaged dipping ?Mesozoic sedimentary sequence which may have been uplifted during the Cenozoic.
- Where the Cenozoic sequence is thicker (in-between the bathymetric banks) a number of major unconformities can be identified some of which can be stratigraphically correlated to the C10 and C30 unconformities identified in the Rockall Basin and the TPU in the Faroe–Shetland Basin. These, and other unconformities identified, point to the complex history of this region which has been dominated throughout the Cenozoic by geological processes which include compression, uplift, differential subsidence and massive changes in bottom water currents and sediment supply.
- Compressive tectonism initiated during the Cenozoic (Oligocene–Miocene) resulted in the formation of a number of inversion structures (Stoker *et al*., 2005). Within the survey area these include the Wyville–Thomson Ridge, Hatton Bank, Faroe Bank, Bill Bailey’s Bank, Lousy Bank, Ymir Ridge and the Alpin Dome. Examining the erosional truncation and onlapping unconformities is valuable in linking compression to regional events. For example, the large fan identified prograding eastwards off the Lousy Bank into Channel A is thought to be related to compressional uplift during Miocene times.
- Lines 06/02-22 to 26 (to the south of St Kilda) and 06/02-27 to 30 (across Stanton Bank) did not image basalt but clearly illustrate a highly-irregular basement palaeo-topography which is now partially buried by younger Quaternary sediments.

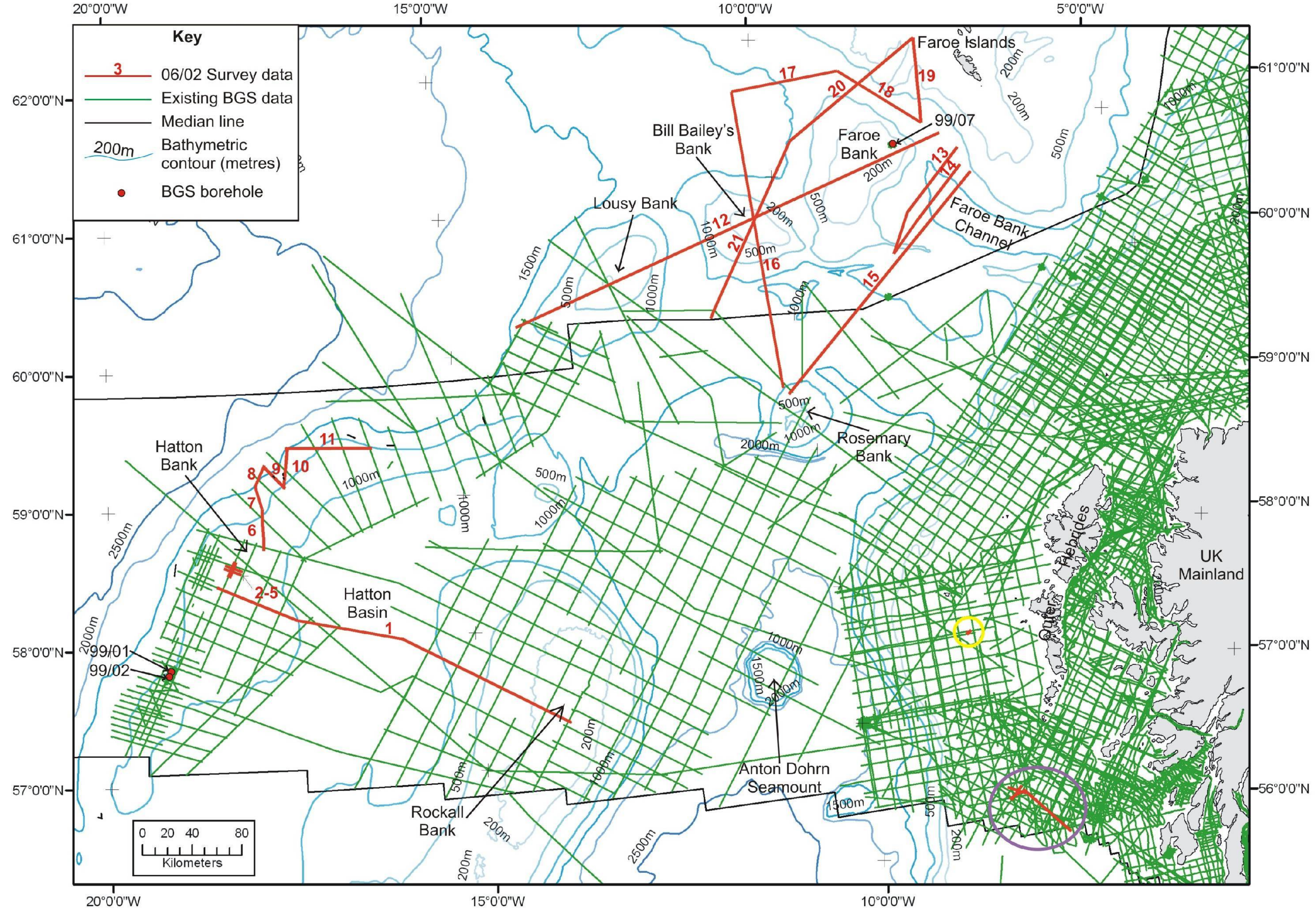

Figure 1. Location of the 06/02 survey lines and existing BGS seismic lines. Lines 22-26 located south of St Kilda are indicated by the yellow circle, 27-30 located in the Stanton Bank area are indicated by the purple circle

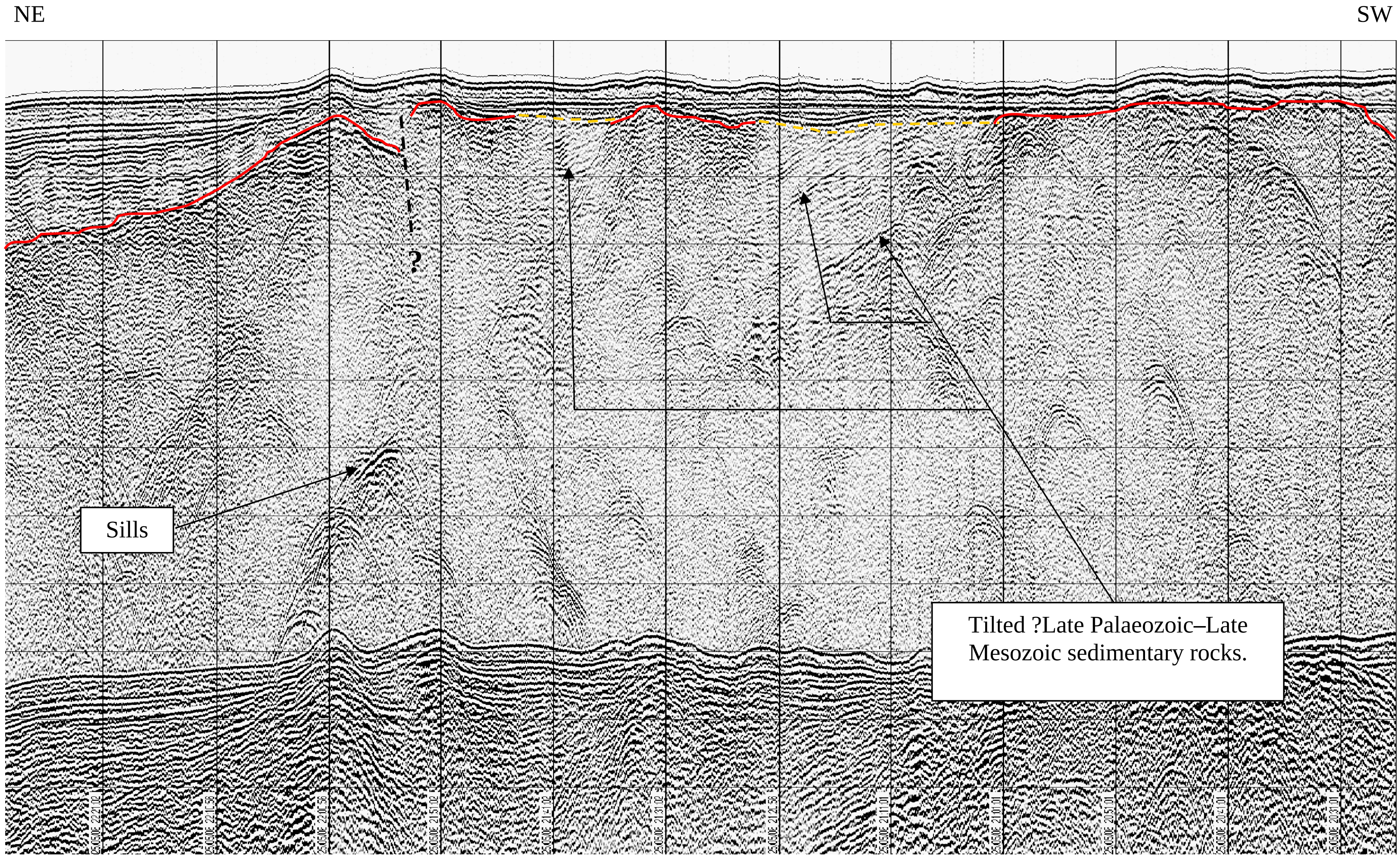

Figure 2. Line 06/02-5 imaging a 'window' in the basalt on Hatton Bank. A preliminary interpretation is shown on the section with the top of the basalt indicated by the red horizon. Tilted ?Mesozoic sedimentary rocks are seen beneath the irregular ?Mesozoic/Cenozoic unconformity (orange horizon) which in turn is overlain by near horizontal Cenozoic sediments.

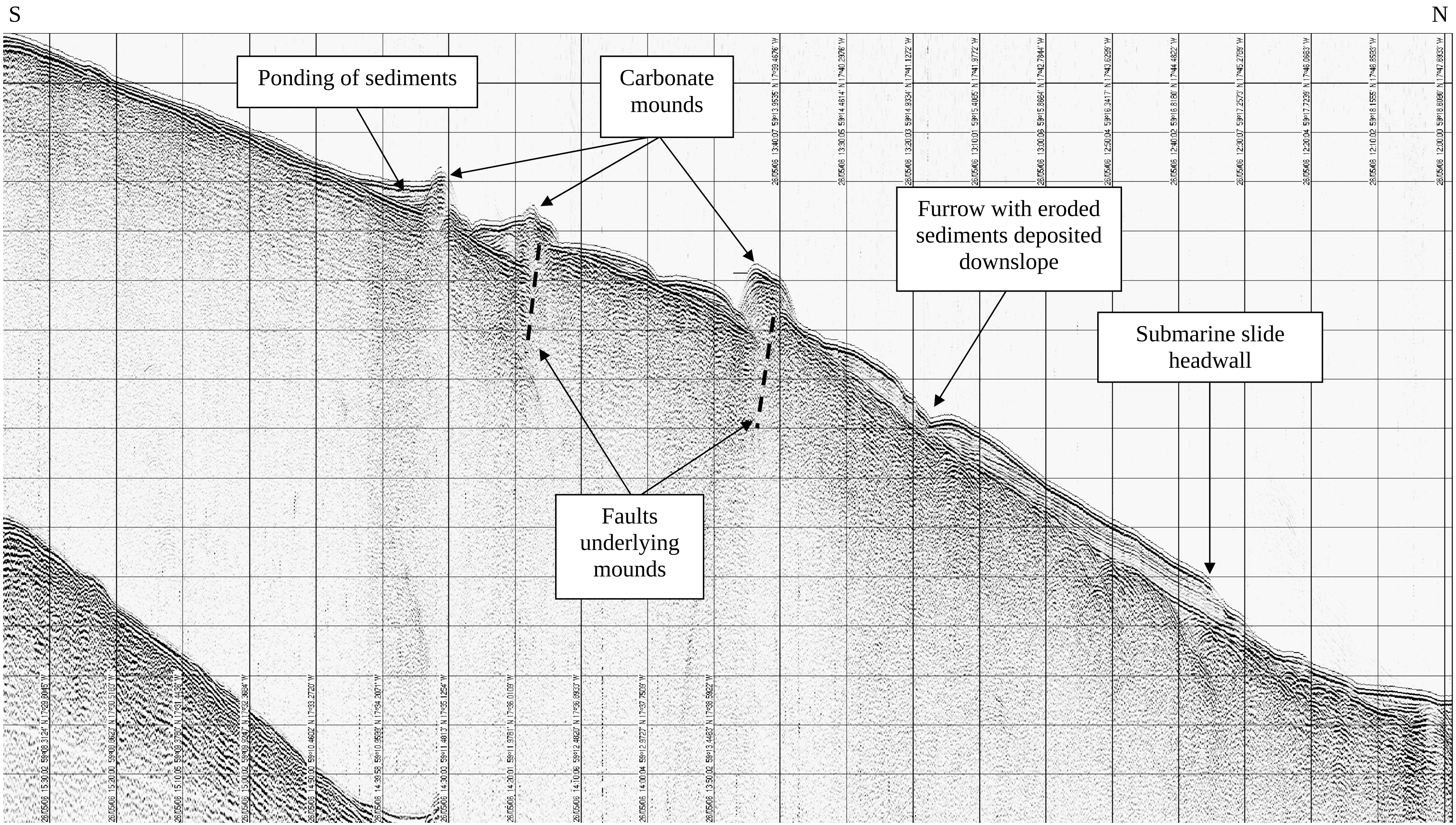

Figure 3. Airgun line 06/02-9 showing the presence of a number of features on Hatton Bank such as sea bed mounds with underlying faults, furrows caused by alongslope currents and the headwall of a submarine slide.

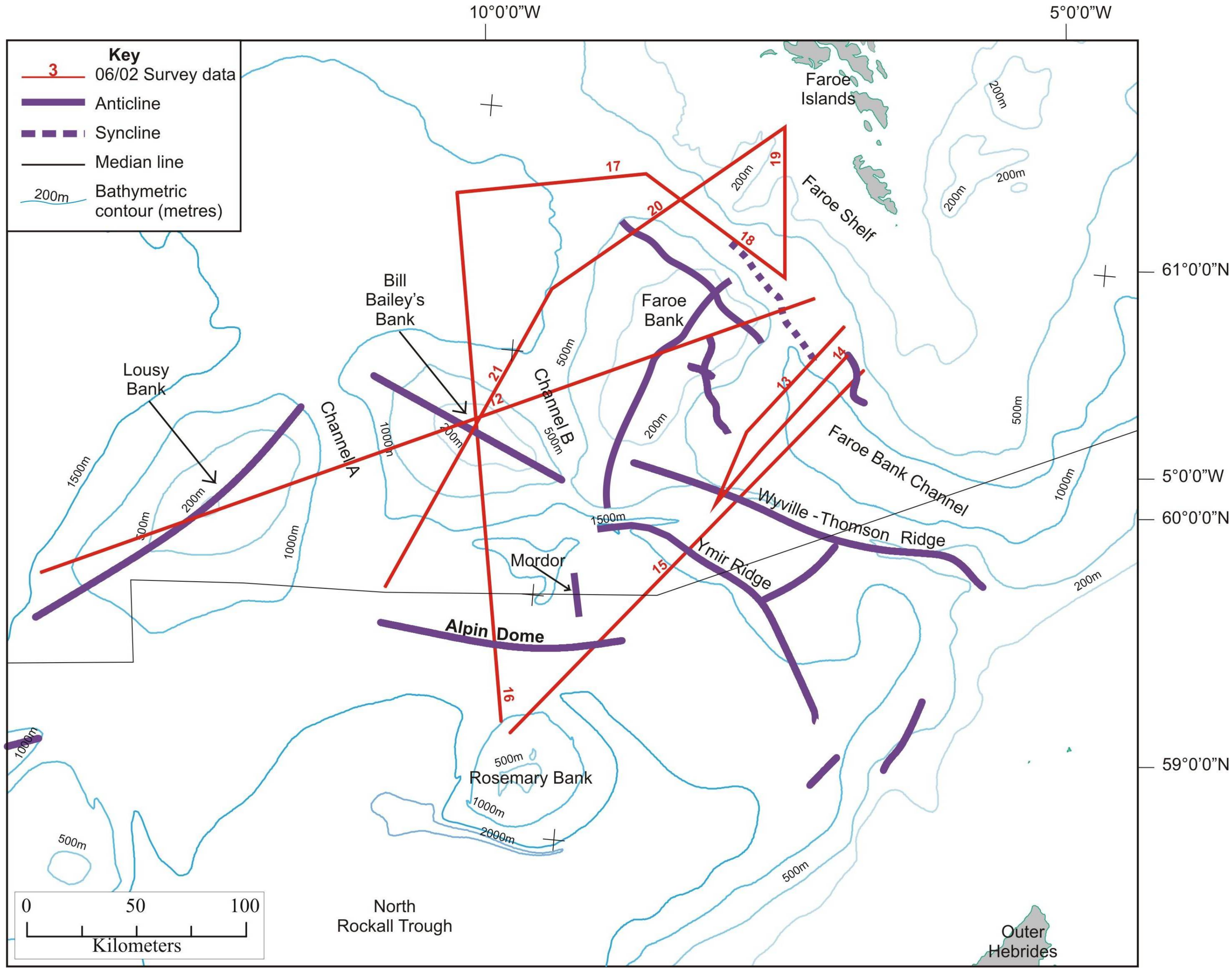

Figure 4. Location of lines 06/02-12 to 21 with the location of some interpreted folds in the area. The Alpin Dome is highlighted in bold. Interpreted by Mr A Tuitt as part of his PhD research project.

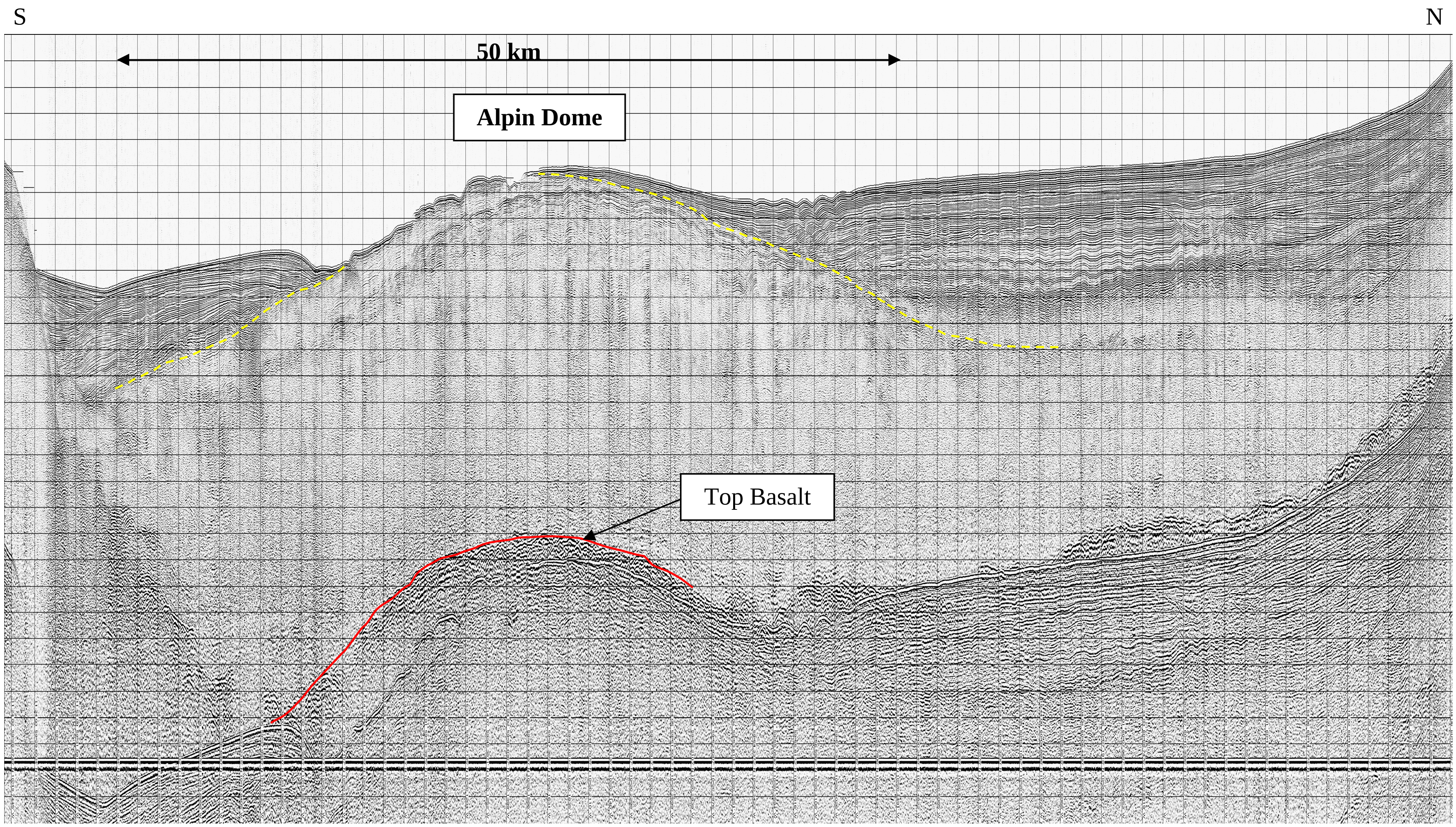

Figure 5. Southern end of line 06/02-16 imaging the Alpin Dome. The top of the basalt is indicated by the solid red line and the TPU by the dashed yellow line.

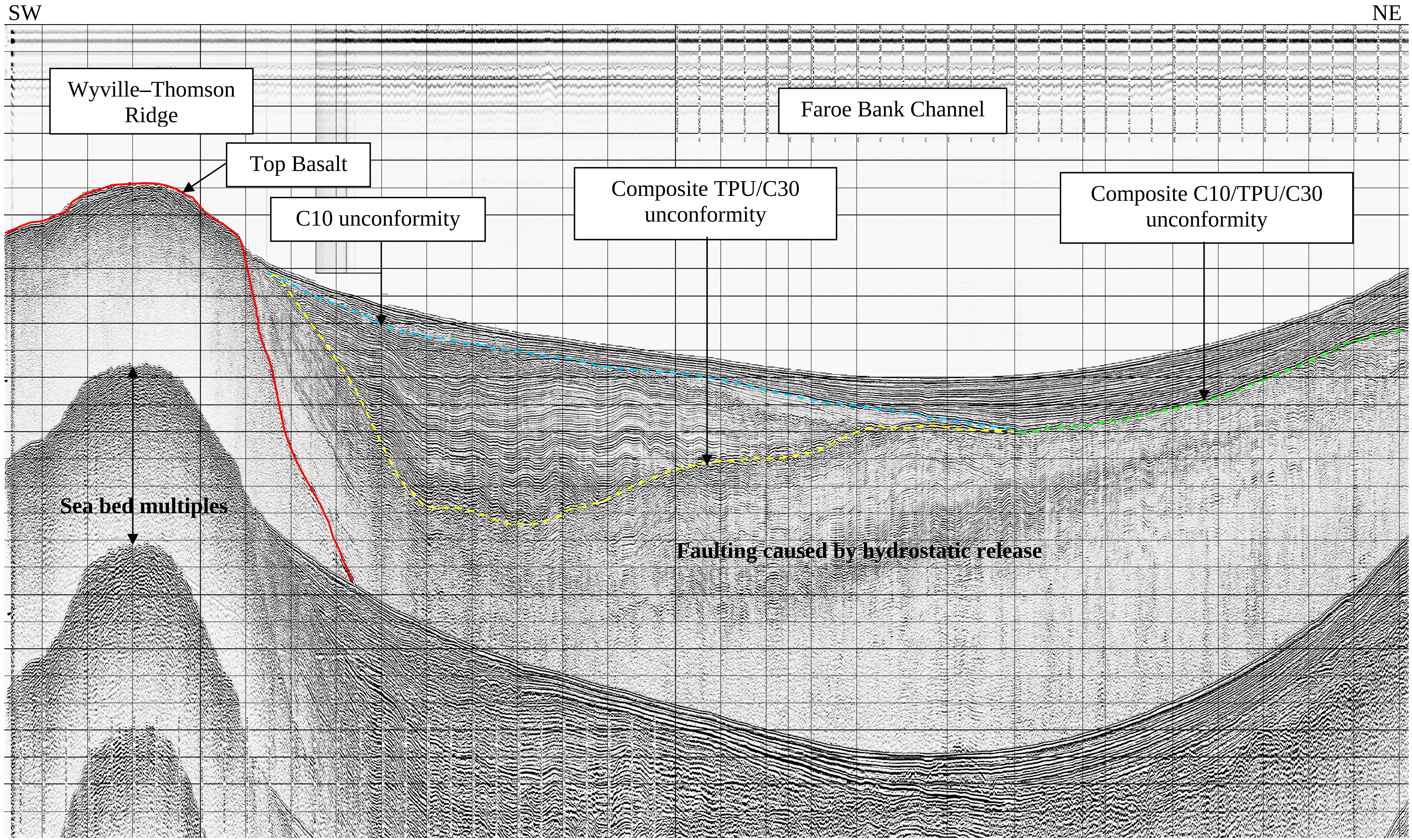

Figure 6. Line 06/02-14 showing the main unconformities in the Faroe Bank Channel (C10, TPU and C30) and the underlying faulted sediments. The sediment package documents growth of the Wyville–Thomson Ridge.

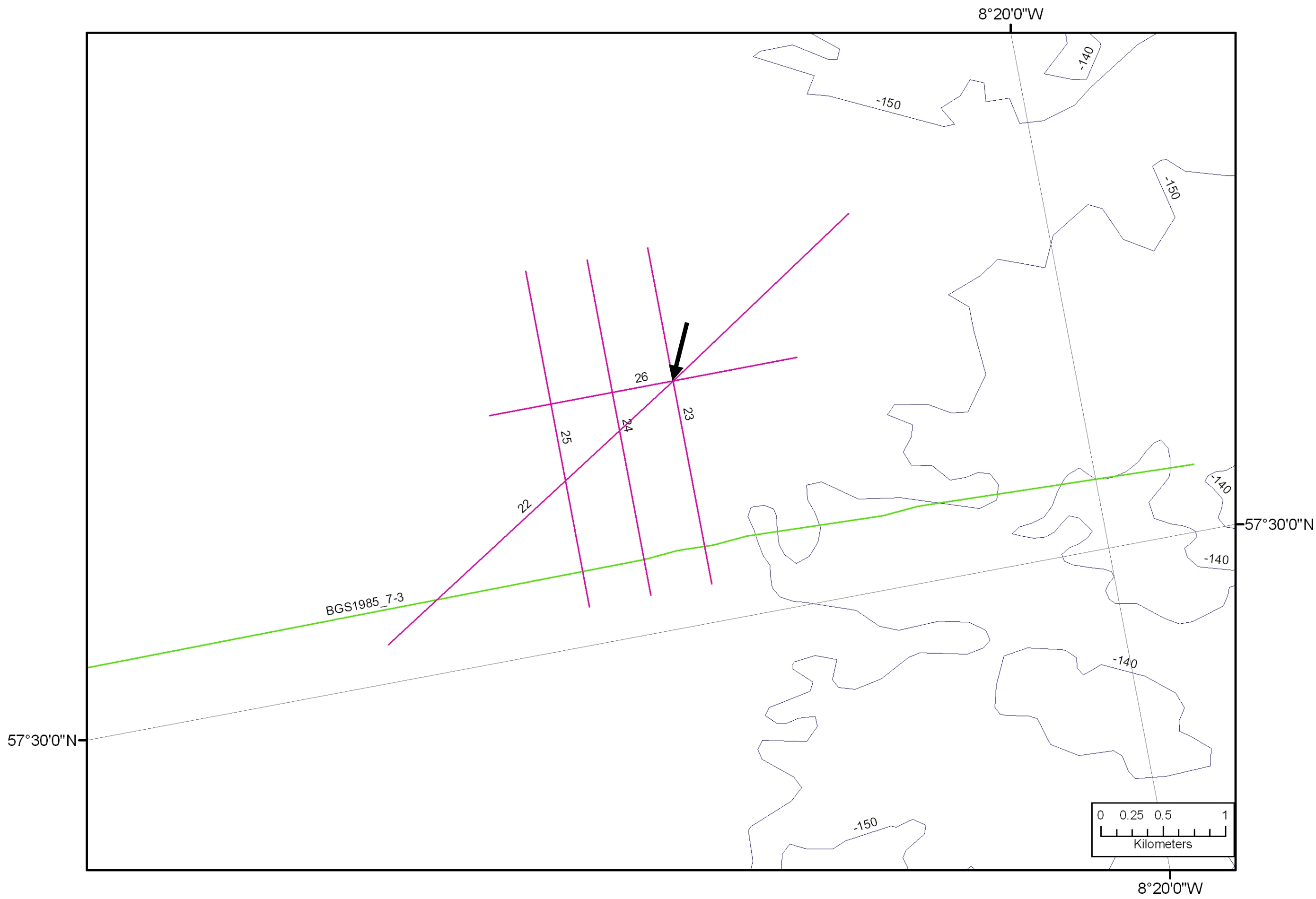

Figure 7. Location of lines 06/02-22 to 26 south of St Kilda. The existing BGS deep tow boomer line 85/7-3 is also shown. Location of the giant piston core (MD95-2007) is indicated by the arrow.

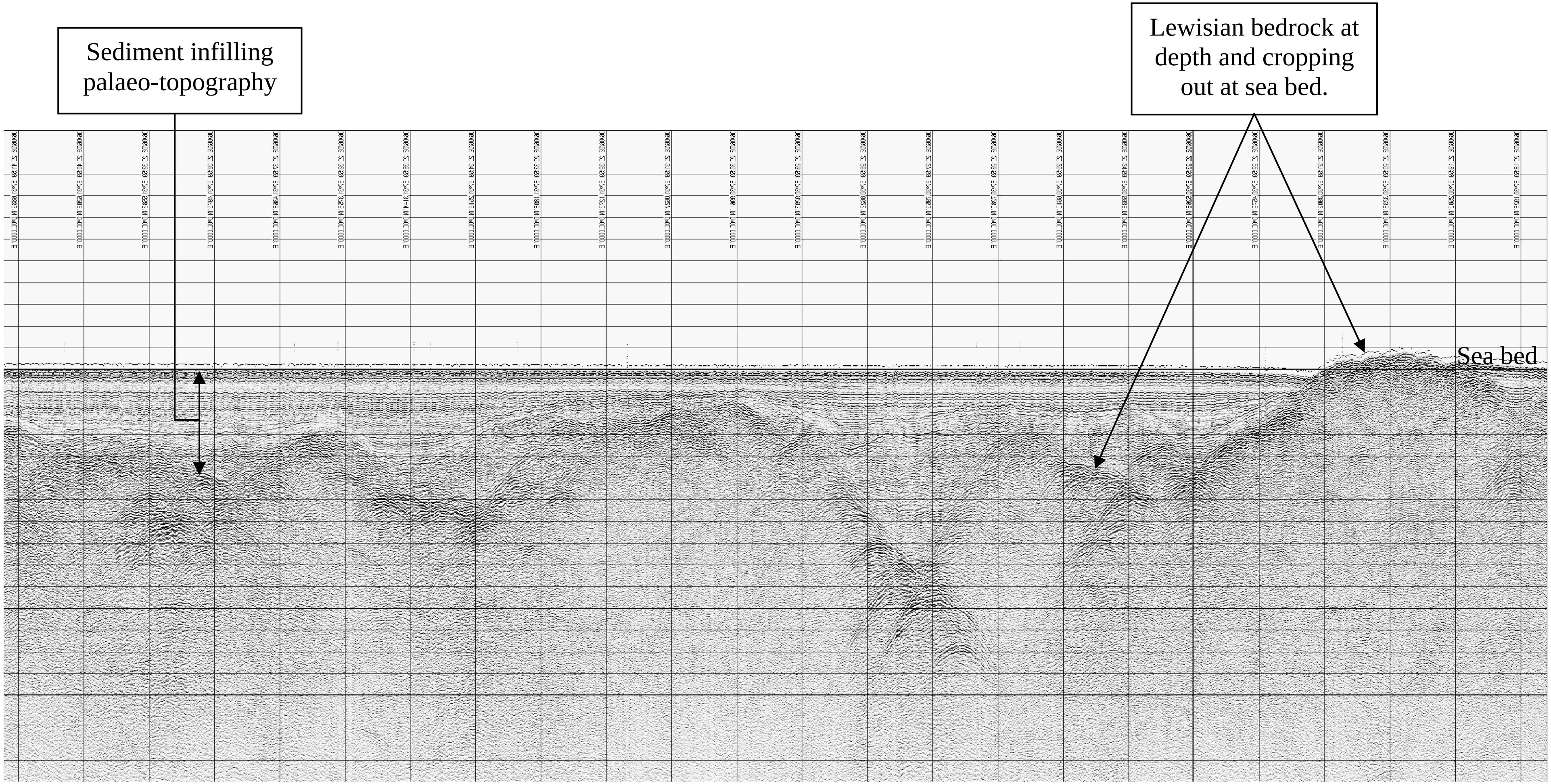

Figure 8. Line 06/02-24 illustrating the infilled palaeo-topography composed of Lewisian gneiss which, in places, crops out at sea bed.

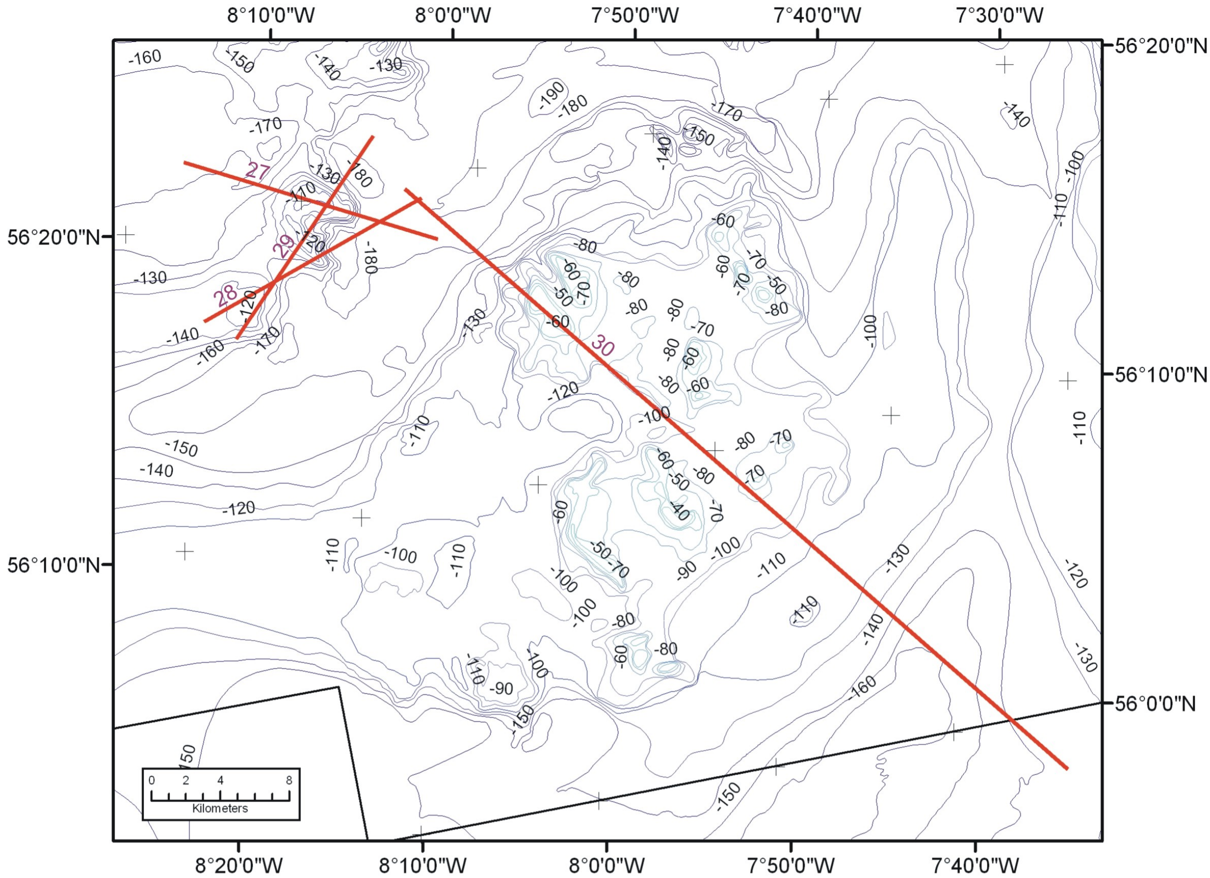

Figure 9. Location of lines collected in the Stanton Bank area to complement the data collected during the BGS 05/05 survey.

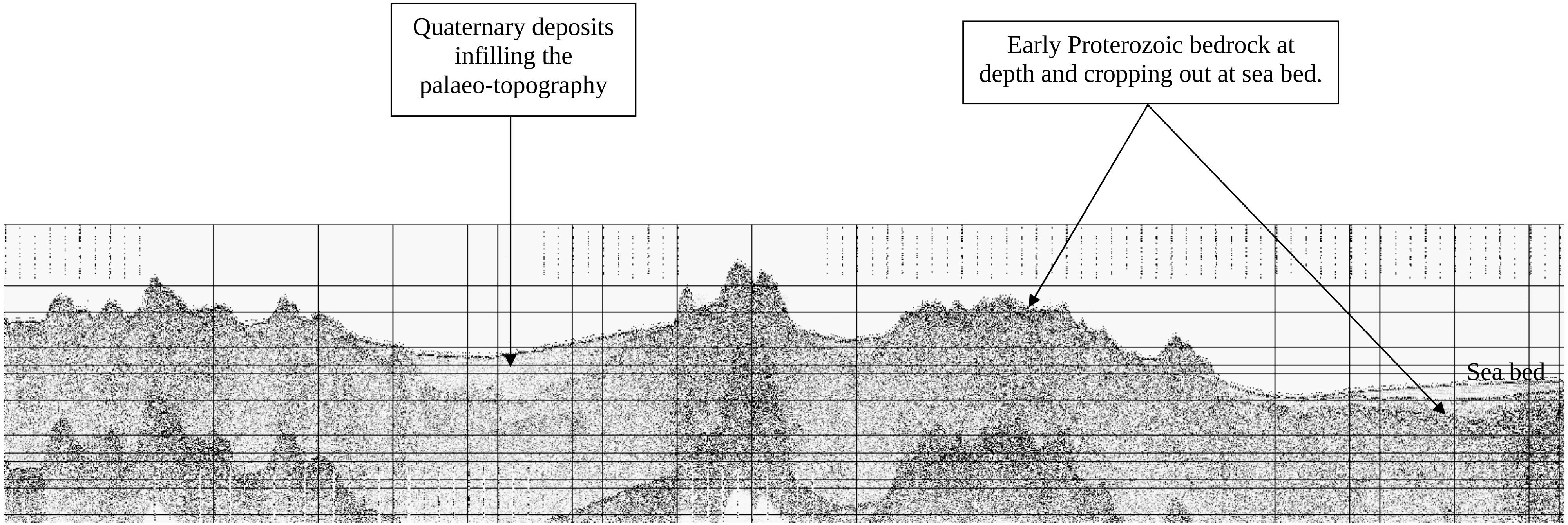

Figure 10. Line 06/02-29 in the Stanton Bank area illustrating the variable outcrop of Early Proterozoic rocks. Palaeo-topography partially infilled with Quaternary sediments.

Appendix 1 Summary of Equipment Run on Each Line

Adapted from the BGS Marine Operations Line Summary Log for BGS project 06/02 (Smith, 2006).

Line	Equipment run						
	Airgun	Sparker	Magneto-meter	Gravity	Pinger	Precision Echo Sounder	Multibeam
1				X	X	X	X
2	X	X	X	X	X	X	X
3	X	X	X	X	X	X	X
4	X	X	X	X	X	X	X
5	X	X	X	X	X	X	X
6	X	X	X	X	X	X	X
7	X	X	X	X	X	X	X
8	X	X	X	X	X	X	X
9	X	X	X	X	X	X	X
10	X	X	X	X	X	X	X
11	X	X	X	X	X	X	X
12	X	X	X	X	X	X	X
13	X	X	X	X	X	X	X
14	X	X	X	X	X	X	X
15	X	X	X	X	X	X	X
16	X	X	X	X	X	X	X
17	X	X	X	X	X	X	X
18	X	X	X	X	X	X	X
19	X	X	X	X	X	X	X
20	X	X	X	X	X	X	X
21	X	X	X	X	X	X	X
22		X		X	X	X	X
23		X		X	X	X	X
24		X		X	X	X	X
25		X		X	X	X	X
26		X		X	X	X	X
27		X		X	X	X	X
28		X		X	X	X	X
29		X		X	X	X	X
30		X		X	X	X	X

Appendix 2 Equipment

Airgun System

Source: An array of 5 x 40 cu inch Bolt 600B airguns with waveshape kits and time break solenoids was utilised as the airgun source. Routinely, up to four guns were fired simultaneously, keeping the fifth gun as a ready spare. The number of guns used varied with water depth, with only one being used in shallower areas. The firing rate varied from 6-7 seconds depending on water depth. The airgun array firing synchronisation was achieved by monitoring the time break solenoids and manually adjusting each airgun's trigger as required. This introduces a short time delay into the system of between 25 and 38 milliseconds and thus the sea bed return time is not an absolute measurement of depth. Two Reavell type VHP36 compressors supplied the high-pressure air for the airguns. Air was fed from the compressors through the vessel's internal pipe-work to the aft deck and connected into the BGS airgun control panel.

Hydrophone: A four channel 32m SIG Hydrophone was utilised as the receiver for the airgun source. The four channels were summed to give a single output.

Recording: The BGS CODA DA200, software version 3.9.11.5L(3360) 2005 four-channel digital recording and processing system was utilised to record the raw data. The data were recorded to Flipdisks in CODA format with a sampling frequency of 3kHz, record length of four seconds and bandpass filter of 25-800 Hz, The start of recording was delayed in deep water to permit a minimum of two seconds of data below the sea bed. The CODA system also received a navigation data string from the vessel's Trimble DGPS system, and logged position, time and date for each shot.

On line processing: In addition to the recording described above, the CODA system was also used to process the data online and produce a real time hard copy output on an Ultra 120 thermal printer. Processes applied were time varied gain (TVG), time varied filtering (TVF) and trace mixing. In extremely large amplitude sea swell situations a swell filter was also utilised. Both TVG and TVF were applied from the sea bed, which was tracked automatically. A 1.5 second record length was used for the online hard copy, with a delay adjusted to give an optimum record length for the water depth.

Sparker System

Source: An EG&G, nine candle, multi-tip sparkarray with 135 tips was utilised as the sparker source.

High voltage power supply: An Applied Acoustic Engineering CSP2200 capacitor charging unit provided the power for the sparker system. This is a single unit, powered from the ship's 240VAC supply incorporating switchable output energy up to a maximum of 2200 J. Apart from lines 2-5 (1800 J) the whole survey was conducted at an output of 2200 J.

Hydrophone: A seven channel Teledyne 10m hydrophone, summing on the most part, all channels to give a single output, was utilised as the receiver for the sparker data.

Recording: This utilised the same CODA DA200 four-channel digital recording and processing system as the airgun, with the data recorded on the same file to Flipdisk in CODA format. The data were recorded with a sampling frequency of 5kHz, record length of 1.9 seconds and a bandpass filter of 100-1730 Hz. The start of recording was delayed in deep water to permit a minimum of one second of data below the sea bed. As with the airgun, position, time and date were recorded with every shot.

On line processing: The sparker data were processed on line. Processes applied were time varied gain (TVG), time varied filtering (TVF) and trace mixing. In extremely large amplitude sea swell situations a swell filter was also utilised. Both TVG and TVF were applied from the sea bed, which was tracked automatically. A hard copy output could not be obtained on line as the BGS only has one thermal printer that will operate with the CODA. During long transits and weather downtime hard copies were generated. A 700 milliseconds record length was used for the hard copy, with a delay adjusted to give an optimum record in the prevailing water depth. Ideally a second printer would be beneficial on these projects to obtain the on line hard copies required and as a backup for the only printer.

Gravity Meter

The gravity meter used was a ZLS Corporation UltraSys controlled LaCoste and Romberg sensor serial No. S75 system. This consists of a highly damped, zero-length spring type gravity sensor mounted on a gyro-stabilised platform, together with associated control and recording electronics. The sensor and control electronics were located in the 'Controlled Temperature Laboratory' adjacent to the 'Main Laboratory', this allowed easy access for observation. It was impractical to mobilise the meter in the vessel's 'Gravity Room' due to access restrictions for both equipment and cables to the main laboratory. Gravity was measured continuously and the gravity spring tension and cross coupling correction values were logged at one second intervals in L&R Long Format onto the ship's logging and processing system and internally in the gravity control computer. Additional backup data storage was achieved through utilising the zip drive incorporated with the gravity control computer. Data were also output to a colour printer for quality control purposes. No data processing was carried out during the cruise.

The vessel suffered two complete blackouts during the transit to the work area. This resulted in the meter losing power and having to be clamped and kept on heat using a battery power supply. At the time of writing it is unknown whether these two events have had an adverse effect on the data, although this is unlikely.

Magnetometer

The system used was a Barringer proton precession magnetometer with a one gamma sensitivity. The sensor was towed 200m astern to minimise the effects of the vessel's steel hull on the local magnetic field. The system was triggered by the seismic control system such that the sensor was polarising when the sparker fired. This eliminated electrical interference from the sparker discharge. The data were converted from parallel Binary Coded Decimal (BCD) data to serial data within a BCD to serial converter before being logged onto the ship's logging and processing system.

Multibeam

The vessel has an elderly deep water Simrad EM12 multibeam system, which was used throughout the survey. Checks of the multibeam calibration were made when the vessel arrived at Rockall Bank. Lines were run up the bank and down on a reciprocal course. A further line was run back up the slope. However the data were lost when the vessel suffered a complete blackout. After half a day attempting to check the calibration of the multibeam system without success, coupled with the poor weather conditions, it was decided, with advice from the multibeam operator on board, that no further attempts would be made. The vessel was weathered off for the next twelve hours.

The calibration of the multibeam historically has proven to be stable and as such no recalibration was deemed necessary or was planned for this project. The attempted checks of the multibeam calibration were just that, checks.

Several sound velocity profiles were made during the survey, on Rockall Bank, prior to the start of line 12 and in the Faroe Bank Channel. It was noted that a profile in the Faroe Bank Channel indicated the presence of fresh water located close to the sea bed.

Pinger

The 3.5kHz pinger is a transducer mounted in a tow fish towed over the starboard side. This was controlled by an IOS transceiver with the data recorded on a CODAOctopus360 acquisition system and was part of the standard shipboard equipment. The pinger gave poor sub-bottom records compared with the sparker system and was affected by the sparker especially in the St Kilda and Stanton Bank areas where the sparker was fired at the faster rate of 0.6 seconds.

Precision Echosounder

The Precision Echosounder (PES) is a 10kHz IOS transducer mounted in a tow fish deployed off the port side close to amidships. This is controlled by a Simrad EA500 transceiver and display and was compensated for fish height with the depth recorded.

Abbreviations

MESH Mapping European Sea-bed Habitats, a European Union Interreg IIIb project.

NOCS National Oceanography Centre, Southampton.

PES Precision Echosounder.

UKORS United Kingdom Ocean Research Services.

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