Geologisch-Paläontologisches Institut
und Museum
Christian-Albrechts-Universität
Kiel, Deutschland

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Nr. 56

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und Vulkanismus im Bereich der Tjörnes-Bruchzone nördlich Islands.
Fahrtbericht 185/3, F. S. „Poseidon"

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PREFACE

Cruise 185/3 of the F.S. "Poseidon" involved two distinct study areas, with two distinct scientific aims. For this reason the cruise report has been divided into two sections, the first covering the activitites of Leg 185/3a (Kiel-Reykjavik, 7.10.91 - 19.10.91, Dr. G. Hoffmann Chief Scientist) and the second covering Leg 185/3b (Reykjavik-Akureyri-Hamburg, 19.10.91 - 29.10.91, Dr. D.F. Mertz Chief Scientist). The ship tracks and locations of the study areas are shown in Figure 1.

The scientific objectives of the first leg of the "Poseidon"-cruise 185/3a were concentrated on the study of current controlled sedimentation patterns and the glaciation history of the Iceland-Faeroe Ridge, particularly on the southern slope near Iceland.

Leg 185/3b aimed to study the structure of the Mid-Atlantic Ridge (MAR) within the Tjörnes Fracture Zone, as well as the petrology of the recent volcanics found there. In association with the ship-board work, a land expedition to the onshore extension of the Tjörnes Fracture Zone in northeast Iceland (13.10 - 18.10.91) was also undertaken. Information about the samples collected on Iceland are presented in tabular form in this cruise report.

The cruise and field work were carried out in close cooperation between the Geologisch-Paläontologisches Institut der Universität Kiel, the Max-Planck-Institut Mainz and the Nordic Volcanological Institute, Reykjavik.

G. Hoffmann, D.F. Mertz

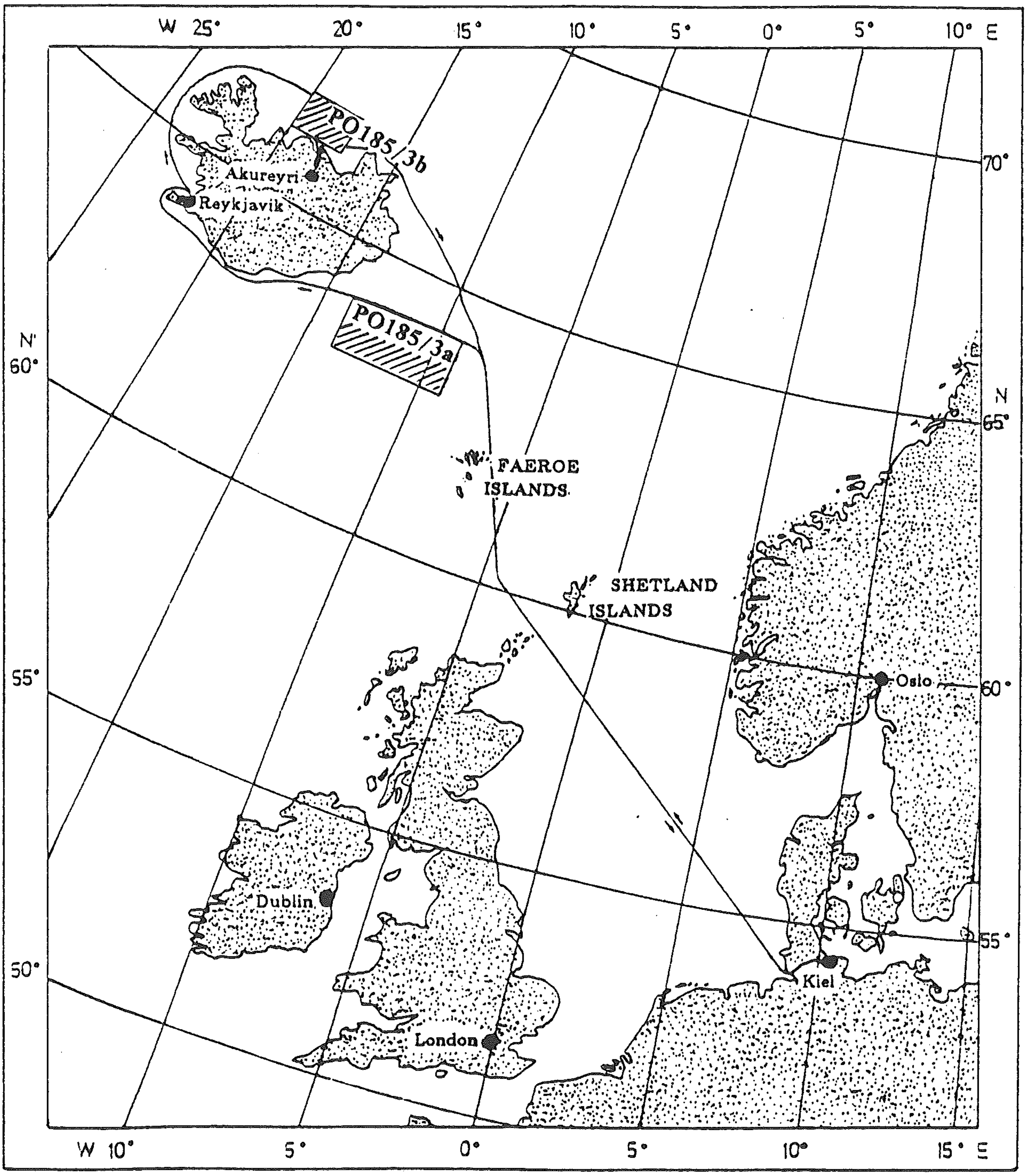

Figure 1: Tracks and study areas of cruise No. 185/3 of R.V. "Poseidon"

Cruise Report 185/3a, R.V. "Poseidon"

Current controlled sedimentation patterns and glaciation history of the Iceland-Faroe Ridge

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1. SCIENTIFIC CREW

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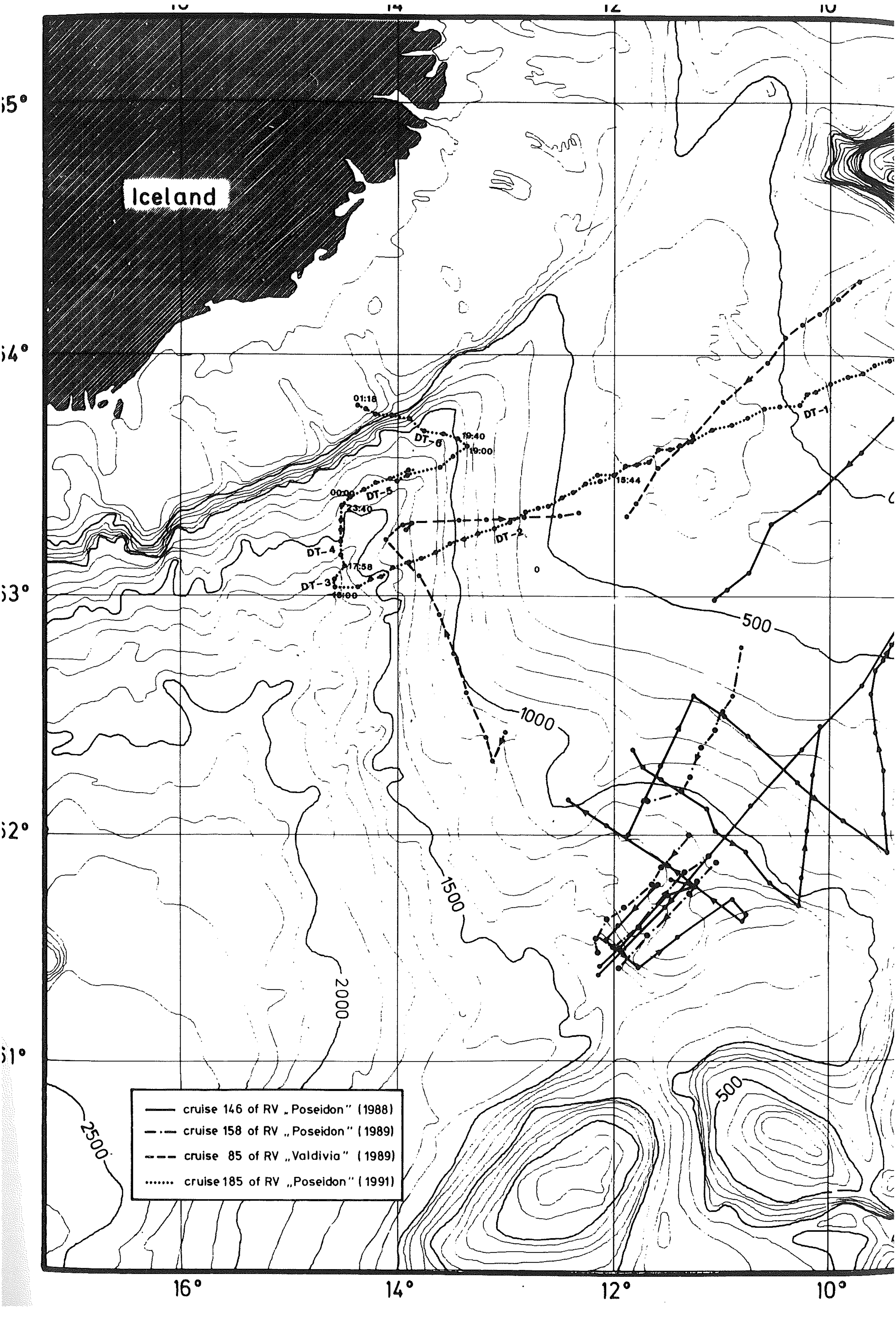
Orthmann, Thomas, cand. biol., IFM
Schott, Thorsten, techn., GECON
Wendt, Immo, Dipl.-Geol., MPI

GIK	=	Geologisch-Paläontologisches Institut der Universität Kiel
IFM	=	Institut für Meereskunde an der Universität Kiel
MIK	=	Mineralogisch-Petrographisches Institut der Universität Kiel
MPI	=	Max Plank Institut für Chemie an der Universität Mainz
GECON	=	Geophysik Consulting, Kiel

2. THE CRUISE

R.V. "Poseidon" left Kiel on October 7th 1991 at 09:15, heading for the first investigation area at the northern slope of the Island-Faeroe Ridge (IFR). The course to the IFR as well as the tracks in the study area on the IFR are shown in Fig. 1 and Fig. I.1. During the travel to the IFR the scientific equipment was installed.

On October 11th at 06:00 the investigation area was reached and the survey with the deep towed side-scan sonar and 3,5 kHz sediment profiler began. During the next days 6 Side-scan sonar tracks were run, due to technical problems only partly completed by 3,5 kHz profiling. Additionally 2 box corers were sampled. The scientific work was particularly done on the southern slope of the IFR (Fig. I.1).



Iceland
16°
14°
12°
10°
65°
64°
63°
62°
61°
01:18
DT-6
19:40
19:00
00:00
DT-5
23:40
15:44
DT-4
DT-2
17:58
DT-3
16:00
DT-1
500
1000
1500
2000
2500
cruise 146 of RV „Poseidon" (1988)
cruise 158 of RV „Poseidon" (1989)
cruise 85 of RV „Valdivia" (1989)
cruise 185 of RV „Poseidon" (1991)

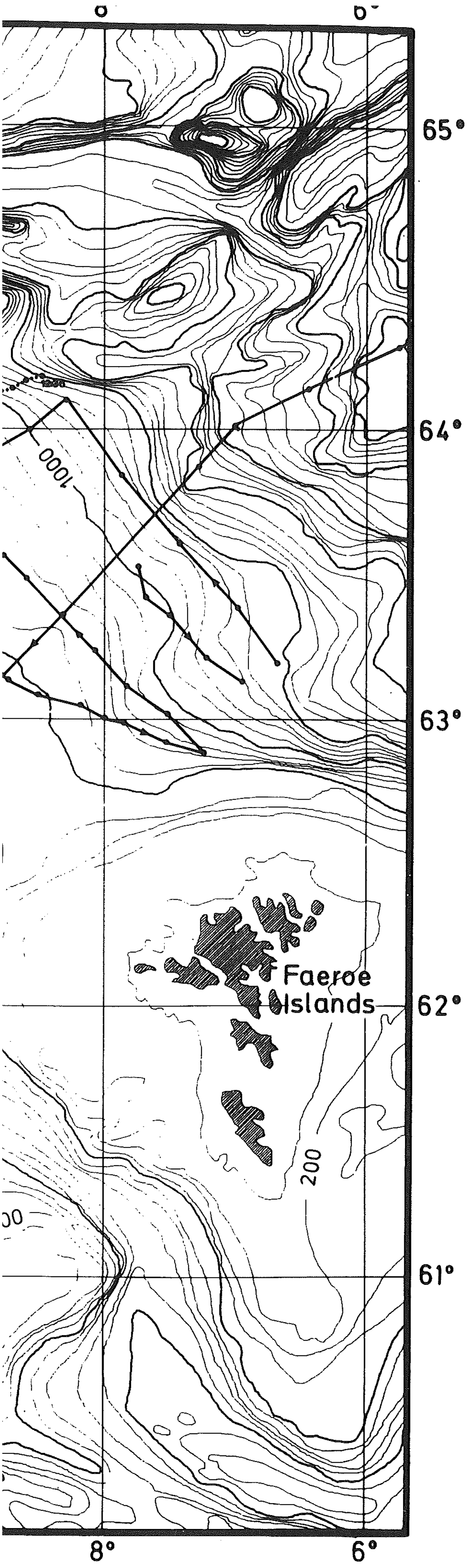


Fig. I.1: Bathymetric map of the Iceland-Faeroe Ridge including side-scan sonar/3.5 kHz- sediment profiler tracks of the cruises no. 146, 158 and 185 of R.V. "Poseidon" and cruise no. 85 of R.V. "Valdivia".

On the morning of October 15th 1991 a gale called "Nora" with 9-10 beaufort from N to NE stopped our investigations. Due to the storm direction, it was not possible to reach the planned harbour of Akureyri in the North of Iceland. R.V. "Poseidon" set therefore course for Reykjavik and reached the harbour on October 17th at 16:30. The scientific crew of this leg left R.V. "Poseidon" on October, 19th at 05:00. with exception of V. Huehnerbach and I. Wendt, who participated also on PO 185/3b.

3. SCIENTIFIC OBJECTIVES

The cruise 185/3a of R.V. "Poseidon" was concentrated on the study of current controlled sedimentation patterns and the investigation of iceberg plow marks, that have shaped the sediment surface of the Iceland-Faeroe Ridge.

3.1. INTRODUCTION

The Iceland-Faeroe Ridge (IFR), major part of the Greenland-Scotland Ridge system, separates the Norwegian-Greenland Sea and the North Atlantic Ocean. The IFR is about 400 km long in NW-SE direction and 500 km wide, measuring NE-SW from the 2000m-isobathes. The broad ridge crest is about 400 m deep, the shallowest point shows a water depth of only 280 m.

The IFR acts as a natural barrier between different oceanic provinces. The inflow of the cold and heavy water masses (North Atlantic Deep Water = NADW) from the Norwegian Sea to the North Atlantic Basin passes either the Faroe Channels (Bowles & Jahn, 1983, Meincke 1983) or across the ridge crest of the IFR (Dietrich 1956, Steele 1959, Worthington, 1970, Fig. I.2)

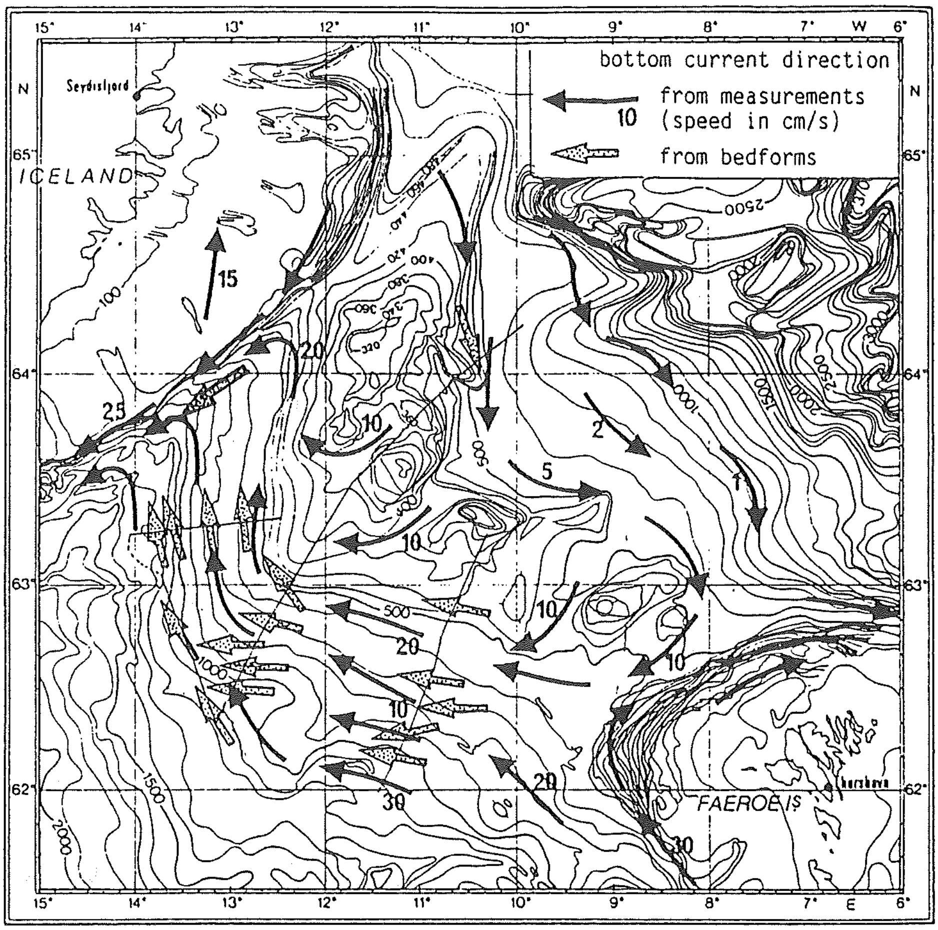


Fig. I.2: Direct current observations (Hansen & Meincke, 1979) and bedform induced flow directions (modified after Dorn & Werner, 1992)

3.2 PREVIOUS WORK

The investigations concerning sediment distribution and sediment dynamics on the IFR began 1988 as a sub-project of a major research project at Kiel University entitled "The Greenland-Scotland Ridge: Moderne Submarine Geodynamics of the most important Hot Spot System of the World", which was supported 1988-1991 by the Ministry of Research and Technology (BMFT-MFG 00664; Werner, Dorn, Bernhardt & Fu, 1991, Werner & Dorn, 1991). In this project, during 1988-1990, three cruises of R.V. "Poseidon" (Werner 1988 und 1990) and R.V. "Valdivia" (Dorn et al., 1989) have been carried out.

Before the beginning of this project, only a few sedimentological investigations concerning the influence of the "overflow" had been carried out at the IFR (Ludwig et al., 1976, Manze & Strauch, 1977, Wohlfeil, 1982, Bowles & Jahn, 1983), but no side-scan surveys.

Our investigations on R.V. "Poseidon" (Werner 1988 und 1990) and R.V. "Valdivia" (Dorn et al., 1989) revealed new results (Dorn & Werner, 1992):
- the ridge crest of the IFR is completely covered by iceberg plow-marks (IPMs) and the corresponding coarse sediments
- on the southern slope of the IFR occur well-developed current-induced bedforms, according to the known bottom currents
- all current bedforms occur in the absence of IPMs
- a channel system with unsymmetrical sediment fillings WSW of the Faroe Islands was detected and surveyed

As a consequence of the sub-project, another research project with the title "Bottom-effects of the overflow and conturite-sedimentation on the Iceland-Faroe Ridge" has been initiated, also supported by the Ministry of Research and Technology (BMFT).

3.3 AIMS

The influence of bottom-current flow on the sedimentation of the IFR's southern slope was the main interest of this leg. The major inflow of the arctic and subarctic water masses from the Norwegian Sea occurs through the Faeroe channels, southeast of the Faeroe Islands (Figs. I.1 and I.2). After passing these channels the major portion of the bottom-water flows along the southern slope of the IFR to the northwest. (Bowles & Jahn 1983, Meincke 1983).

Besides of water transport in the Faeroe channels, an at least temporal overflow of dense water across the ridge crest in the Atlantic basin takes place.

The maximum vertical and lateral extent of iceberg plow marks (IPM) is linked with the glaciation history of the IFR. The presumably surface current induced orientation of the IPMs as well as their preservation state will give more informations concerning erosional and depositional processes connected with bottom currents.

Hence the aims of this leg were focussed on the study of

- overflow induced sediment patterns on the IFR's southern slope near Iceland,

- current-induced bedforms on the deeper part (beneath 1300 m) of the IFR's southern slope,

- the distribution and preservation state of the iceberg plow marks also on the deeper parts of the ridge,

- the sediments underlaying the sand ribbons on the south flank by taking box core samples.

4. METHODS AND INSTRUMENTATION

Side-scan Sonar survey techniques complemented by the shipboard-installed 3.5 kHz ORE sediment-profiler were applied during the survey. The EG&G model 990 S side-scan sonar system of Kiel University was used, equipped with two 59 kHz transducers. Additionally, the side-scan sonar module is equipped with several sensors, allowing the record of bearing, depth and water temperature data.

In the deep-tow array of Kiel University, the side-scan sonar towfish is attached to a positive buoyancy body which is depressed by a separate 650 kg weight unit. (Fig. I.3)

The deep-tow array allows the towing of the "fish" close to the bottom, while the effects of surface waves are considerable damped. The mobile winch is operated by a remote-control panel next to the side-scan sonar recorder unit in the laboratory on R.V. "Poseidon", allowing quick response to sea-floor morphology changes, as indicated by the shipboard echosounder.

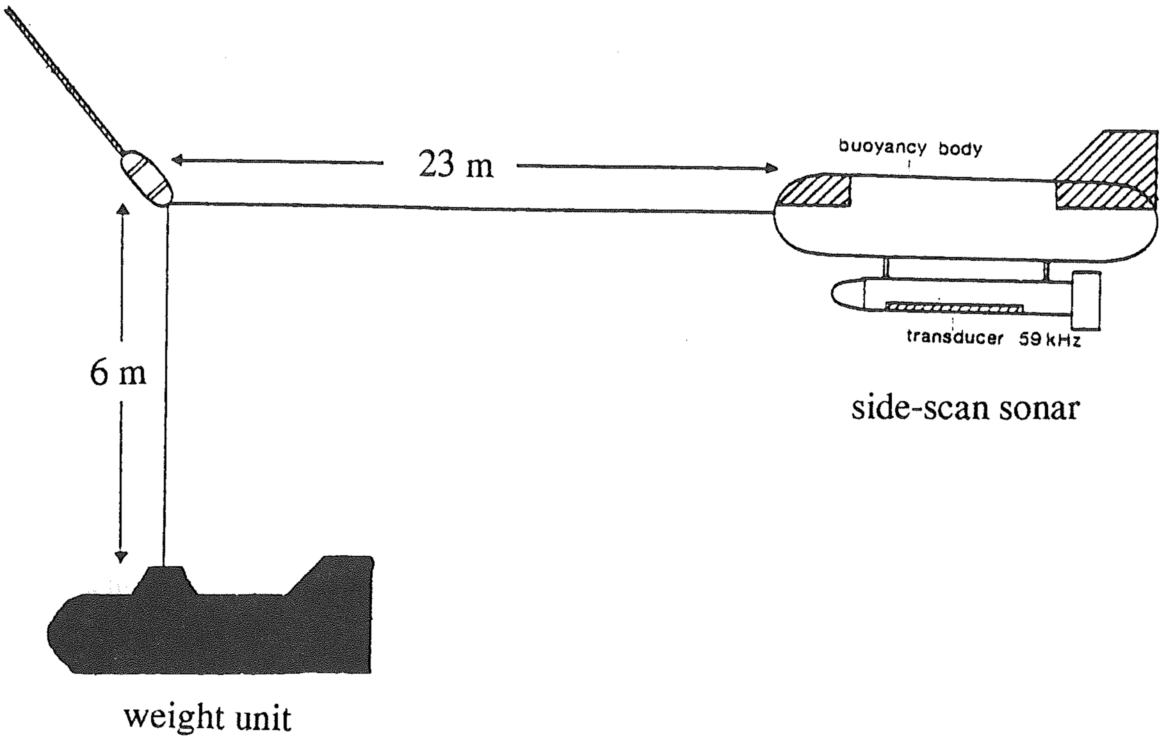


Fig. I.3: The configuration of the deep-towed side-scan sonar array of Kiel University

The towing device was towed with a HATLAPA electrical winch. The winch is eqippped with a steel armored 5,000 m single-conductor cable. In the IFR-survey tracks with water depths up to 1800 m a maximum of 4,850 m cable lengths was needed for a bottom distance of the side-scan unit of between 25 and 40 m, recording a total range of 400 m.

The tracks were run with a speed over ground of approximately 3,5 kn. In the deeper parts of the south flank the speed over ground was reduced to approximately 2 kn for getting the towfish closer to the ground.

The 3.5 kHz ORE sediment-profiler unit consisted of 9 transducers accomodated in the ship's instrument moon pool.

Before the beginning of the cruise, a bathymetrical map was created by digitalisation and magnification of the GEBCO-map (Fig. I.1), carried out by stud. geol. D. Butenhoff (GPI).

The shipboard GPS receiver and a hired LORAN-C receiver were used for the navigation. With both positioning systems an accuracy of about 50 m was reached on the IFR as proved by the repetition of a part of profile PO 185 DT 1.

Thanks to master and botswain the middle traverse of the A-frame of RV "Poseidon" was removed for an easier handling of the side-scan sonar equipment during launching and recovering (Fig. I.4).

Fig. I.4: Launching of the buoyancy body with towfish on R.V. Poseidon

5. PRELIMINARY RESULTS

Due to the good weather conditions during the first part of this leg, particularly the side-scan records are of high quality.

5.1 ICEBERG PLOW MARKS (IPMS)

Iceberg plow marks were recorded in the side-scan sonar tracks PO 185/DT 1 and Po 185/DT 2 (Fig. I.1). On the northern slope of the IFR isolated IPMs were detected down to a maximum water depth of about 950 m (Fig. I.5). Abundant IPMs were noted above nearly 700 m water depth. The highest concentration of IPMs was found in the crest area of the ridge, with a lot of IPM "stopping marks" in a water depth of about 350 m (Fig. I.6).

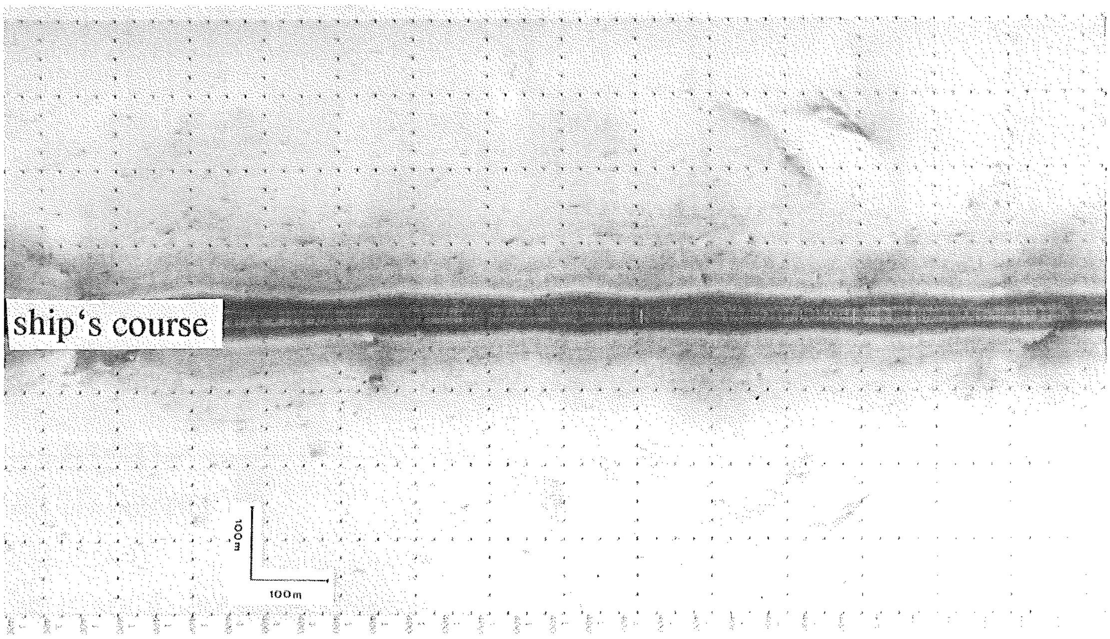


Fig. I.5: Isolated Iceberg Plow marks on the northern slope of IFR in a water depth of 950 m (PO 185/DT 1)

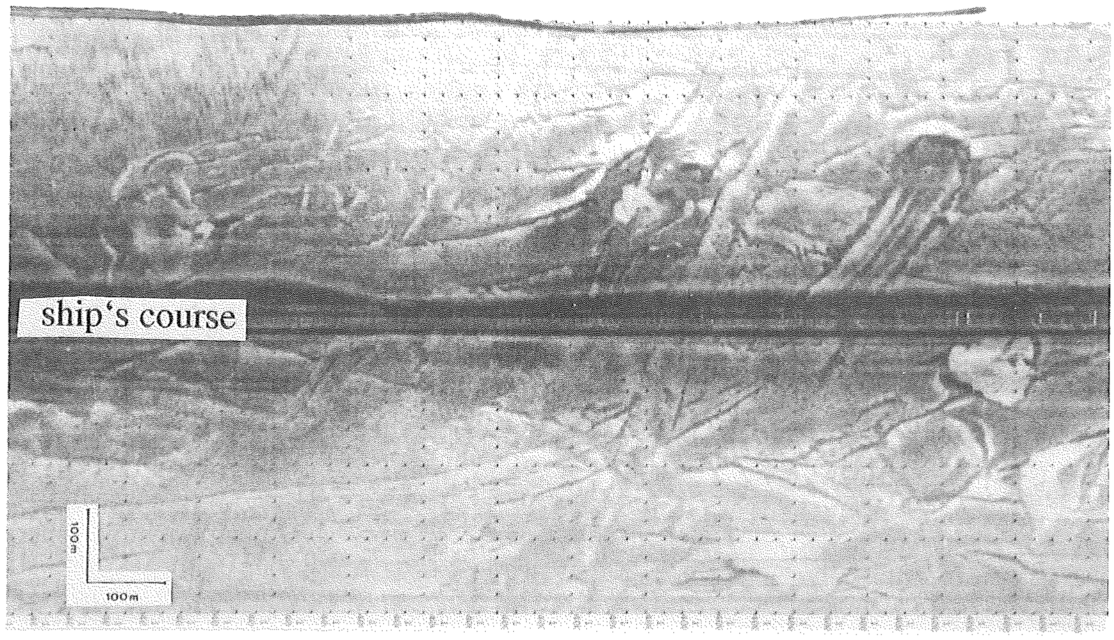


Fig. I.6: "Stopping marks" of Iceberg plow marks in the crest area of IFR in a water depth of 350 m (PO 185/DT 1)

On the southern slope IPMs were detected down to a water depth of about 540 m. In the deeper part of the southern slope the IPMs are presumably covered by sediments. The width of the IPMs recorded on this cruise range between 20 and 130 m. First analyses of the IPM's orientation shows peferred alignments in NNE/SSW directions, coinciding with the recent direction of the North Atlantic Current. In the crest area of the ridge the IPMs show a weaker relief compared with the slopes of the IFR.

5.2 CURRENT INDUCED BEDFORMS

Bottom current induced bedforms are noted on the side-scan sonar records PO 185/DT 2 to PO 185/DT 6, only on the south flank in a water depth of 540 m downwards and only in the absence of Iceberg Plow Marks. In contrast to former cruises the side-scan sonar tracks of this cruise were extended down to nearly 1800 m water depth on the IFR's southern slope.

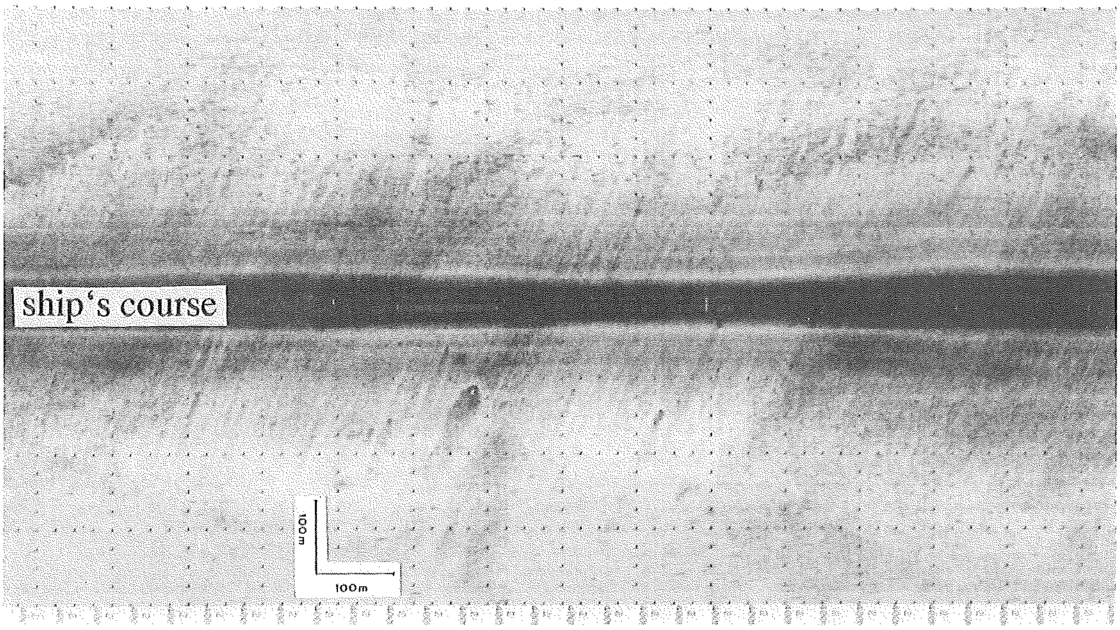


Fig. I.7: Sand tails and comet marks behind isolated obstacles in a water depth of 550 m (PO 185/DT 2)

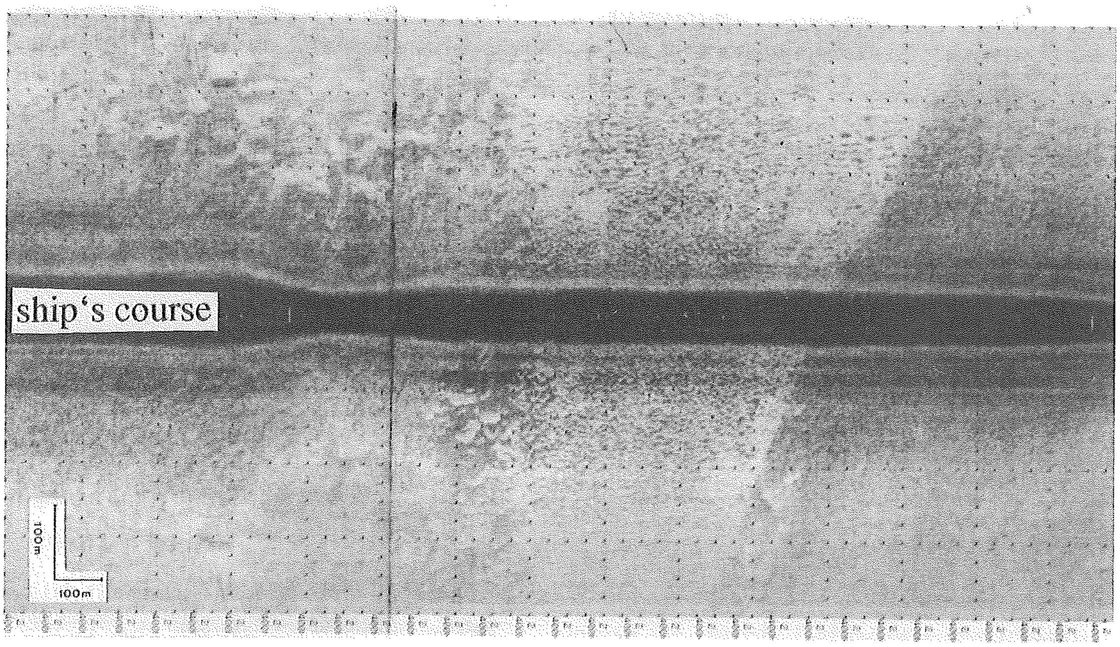


Fig. I.8: sand ribbons with fields of sand dunes in a water depth of 710 m (PO 185/DT 2)

Similar to the results of the previous cruises of RV "Poseidon" (Werner, 1988 and 1990) and RV "Valdivia" (Dorn et al. 1990) obstacle marks, sand ribbons and sand waves were found in a water depth of between 540 and 750 m (Figs. I.7, I.8, I.9).

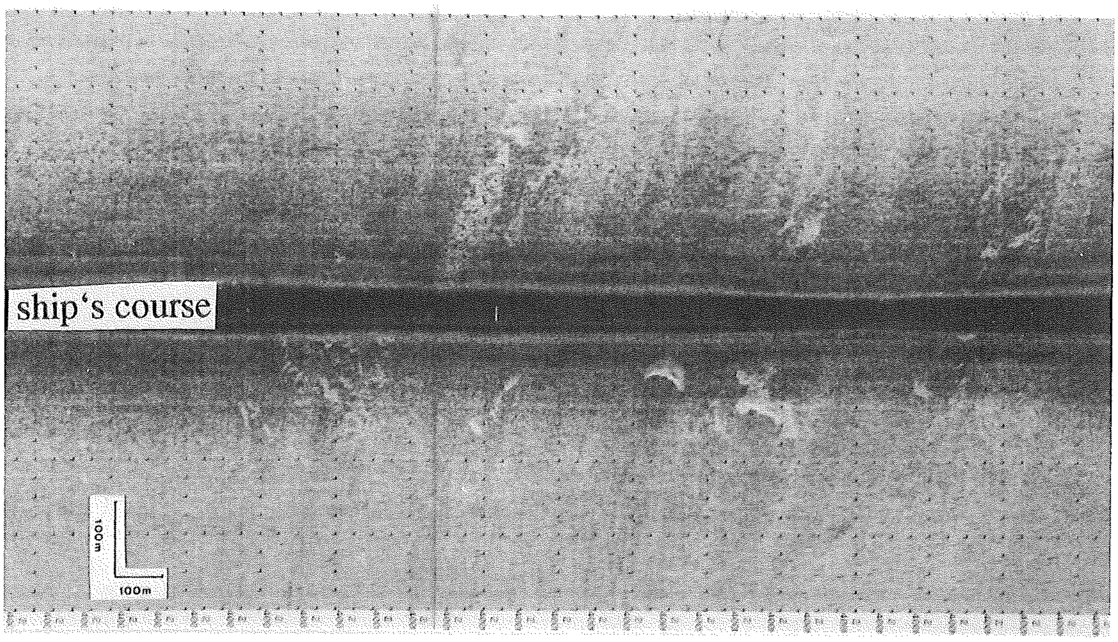


Fig. I.9: Isolated, well developed barchan-shaped sand dunes in a water depth of 740 m (PO 185/DT 2)

Additional bottom-current features clearly indicating NW transport direction were recorded also in a water depth of nearly 1300 m up to 1600 m and 1680-1730 m (Fig. I.10). The sand wave fields show crest-distances up to 100 m. It seems that the sand wave field between 1300 and 1600 m is connected with a similar field, detected on cruise no. 85 of R.V. "Valdivia" (Dorn et al., 1989) in a water depth of about 1300 m. The depth-extension of this field was not detected on the R.V. "Valdivia" - cruise. The connection with the sand wave field between 1680 and 1730 and with bottom current structures, detected on the cruises of R.V. "Poseidon" (Werner 1988 and 1990) is still uncertain.

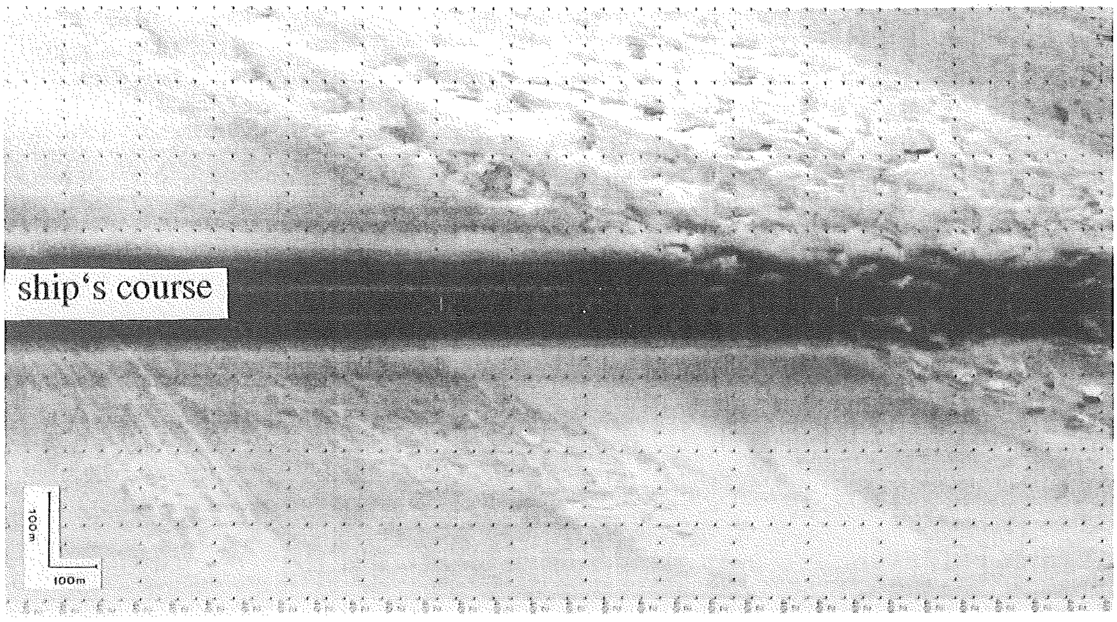


Fig. 1.10: Sand wave field at about 1650 m water depth (PO 185/DT 3)

Further west, recorded on PO 185/DT 3, this large sand wave field follows a very complex sea floor morphology to the west and meets the overflow bottom current crossing the IFR ridge axis, detected on PO185.DT6 (Fig. I.11).

Close to Iceland (PO 185.DT 6) NE-SW striking rift systems of presumably volcanic material are detected.

Parallel to this rift system detected megaripples (Fig. I.11) prove - beside of the comet marks, detected by Dorn et al. (1989) - a strong NE-SW directed overflow bottom current, crossing the IFR-ridge axis (Fig. I.2).

Box corer samples, taken at the border of the main large sand wave field show, that well sorted terrigenous material is overlaying glacial sediments, derivating mainly from iceberg transported material.

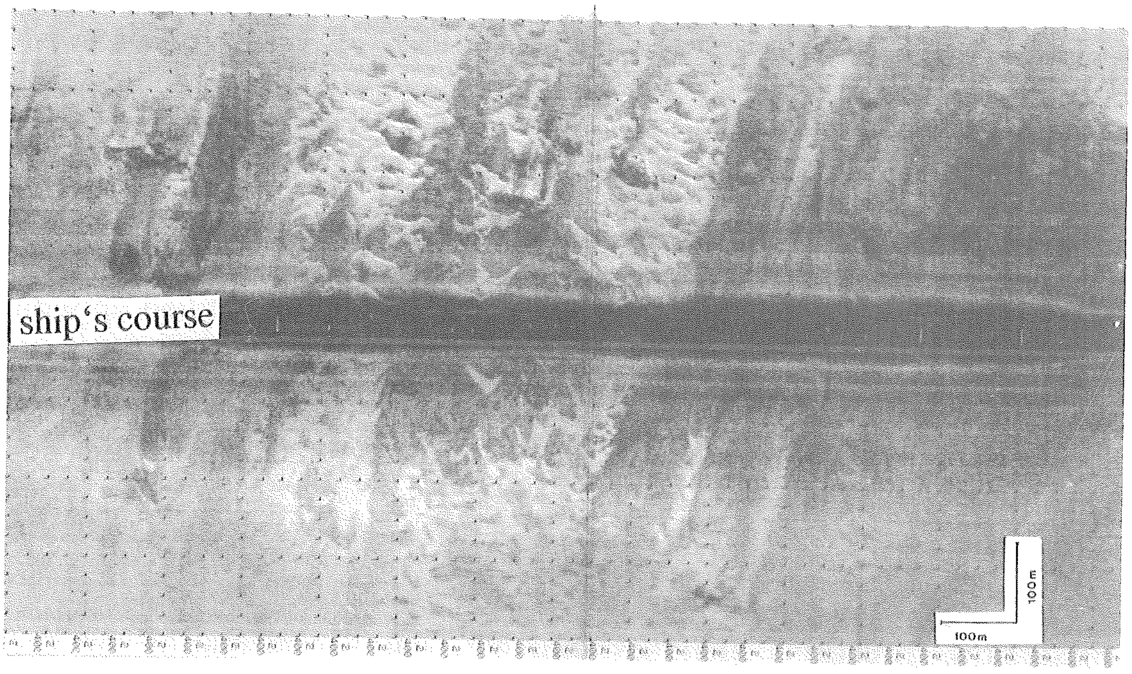


Fig. 1.11: Megaripples indicating bottom currents crossing the IFR ridge axis(water depth: 1110 m, PO 185/DT 6)

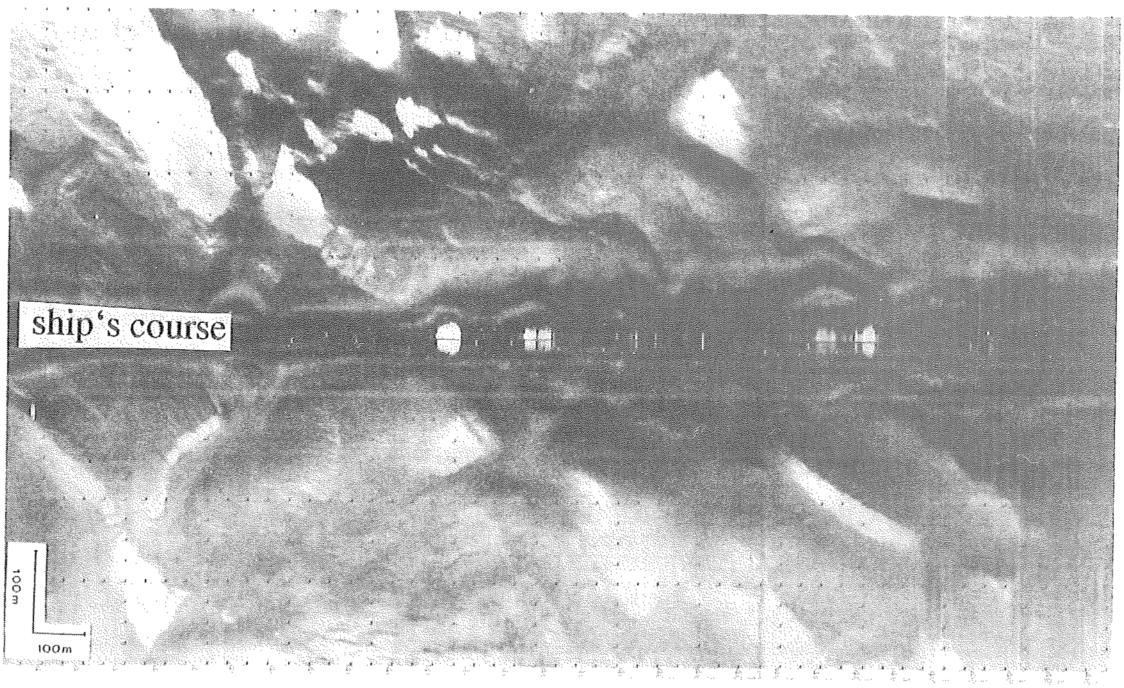


Fig. I.12: Presumably vulcanical material close to Iceland (water depth: 1050 m, PO 185/DT 6)

6. CONCLUSIONS

Iceberg plow-marks have been found on the northern flank down to 950 m, on the southern flank down to 550 m. First analyses of the IPM's orientation shows preferred alignments in NNE/SSW directions, according to the analyses of former cruises. Better preservation of the IPMs below a water depth of 400 m seems to indicate lower erosional energy, but some of the IPM's depressions are completely filled up with sediments. Therefore they could be detected in the side-scan records only by their marginal walls just reaching the bottom surface. Hence the erosional respectively depositional processes in this area are not completely understood.

First flow directions analyses indicate that sedimentation on the predominant part of the southern slope of the IFR between 550 to 1730 m water depth is influenced by bottom current activity from the contour-current flow from the Faroe channel (Bowles and Jahn, 1983; PO 185/DT 2 and DT 3). The sediment patterns on the southern slope, particularly the connections between all bottom-current structures detected on the four cruises, should be investigated on further cruises in tracks parallel to the IFR.

Beside of obstacle marks in the immediate ridge crest area in a water depth of 520 m, detected by Dorn et al. (1989) on RV "Valdivia", sediment patterns detected near Iceland indicate the relationship between current bedforms and IFR "overflow" water crossing N-S the ridge axis.

The area of intersection of the NE-SW directed overflow bottom-current with SE-NW orientated bottom current from the Faeroe channel on the southern flank of IFR is recorded partly by the tracks PO 185/DT3-6. Morphology and sediment patterns indicate an abrupt transition of both directions which indicates a shearing flow of both current systems.

7. CRUISE DATA OF PO 185/3A

7.1 TRACKS OF THE DEEP TOWED SIDE-SCAN SONAR

Date 1991	Track-no. PO 185 /		Time UTC	Latitude	Longitude
11.10.	DT 1	Beg.	12:36	64°09,262'N	08°30,340'W
12.10.		End.	15:44	63°29,997'N	12°00,050'W
12.10.	DT 2	Beg.	15:44	63°29,997'N	12°00,050'W
13.10.		End.	16:00	62°59,528'N	14°34,999'W
13.10.	DT 3	Beg.	16:00	63°59,528'N	14°34,999'W
13.10.		End.	17:58	63°05,908'N	14°30,083'W
13.10	DT 4	Beg.	17:58	63°05,908'N	14°30,083'W
13.10.		End.	23:40	63°23,565'N	14°29,271'W
14.10.	DT 5	Beg.	00:00	63°23,936'N	14°26,579'W
14.10.		End.	19:00	63°36,028'N	13°20,013'W
14.10.	DT 6	Beg.	19:21	63°37,466'N	13°20,699'W
15.10		End.	01:18	63°45,013'N	14°15,093'W

7.2 TRACKS OF 3,5 KHZ SEDIMENT PROFILER

Date 1991	Track-no PO 185 /		Time UTC	Latitude	Longitude
12.10.	DT 2	Beg.	15:44	63°29,997'N	12°00,050'W
12.10.		End.	21:45	63°26,181'N	12°21,508'W
13.10.	DT 3	Beg.	17:58	63°05,908'N	14°30,083'W
14.10.		End.	02:30	63°27,802'N	14°05,772'W
14.10.	DT 4	Beg.	14:00	63°28,426'N	14°02,606'W
14.10.		End.	21:45	63°40,358'N	13°41,755'W

7.3 POSITIONS OF BOX CORE SAMPLING

Date 1991	No. GIK	Thickness cm	depth m	Latitude	Longitude
14.10	13986-1	25	1296	63°29,11'N	13°56,41'W
14.10	13987-1	12	1268	63°30,68'N	13°53,29'W

8. LITERATURE

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9. ACKNOWLEDGEMENTS

We would like to thank the master of R.V. "Poseidon", Mr. M. Gross and his crew for their considerable contributions towards the success of the cruise.

Furthermore, we are grateful to the Foreign offices of Iceland and Denmark for permission to carry out the research in the areas of investigation.

The successful scientific work of this cruise is due to the engaged support of the whole scientific team, specially to Doris Milkert, who competently led the "second shift", and to Thorsten Schott, who solved a lot of technical problems.

This work was supported by grants from the Ministry of Research and Technology (BMFT) to the University of Kiel (Dr. F. Werner, GPI).

Cruise Report 185/3b, R.V. "Poseidon"

Structure and volcanism of the Mid-Atlantic Ridge within the Tjörnes Fracture Zone north of Iceland

CONTENTS

1. RESEARCHERS AND INSTITUTES INVOLVED IN THE CRUISE

The research group aboard Leg 185/3b consisted of two Icelandic and six German scientists from Reykjavik, Kiel and Mainz:

Dr Devey, Colin William	GPI Kiel
Endres, Christoph Peter	GPI Kiel
Hühnerbach, Veit	GPI Kiel
Dr Mertz, Dieter Friedrich	GPI Kiel
Palsson, Karl	NVI Reykjavik
Schillerup, Henrik	NVI Reykjavik
Dr Todt, Wolfgang	MPI Mainz
Wendt, Immo	MPI Mainz

GPI Kiel:	Geologisch-Paläontologisches Institut der Universität Olshausenstr. 40 2300 Kiel Germany
NVI Reykjavik:	Nordic Volcanological Institute University of Iceland Geosciences Building 101 Reykjavik Iceland
MPI Mainz:	Max-Planck-Institut für Chemie Postfach 3060 6500 Mainz Germany

2. STUDY PROJECT

2.1 INTRODUCTION

The study area covers the Tjörnes Fracture Zone (TFZ) north of Iceland (Fig. II.1). The TFZ is an ESE-striking, tectonically complex, active dextral transform zone (McMaster et al., 1977), which comes ashore in NE Iceland. Seamundsson (1974) has shown on the basis of field and geophysical studies that the region of deformation associated with the TFZ is some 80km wide, bounded to the south by the Husavik Fault (Fig. II.1, enlarged inset). The TFZ is the region where the Mid-Atlantic Ridge (MAR) passes from the Icelandic axial rift zone in the south to the Kolbeinsey Ridge in the north. The location and structural setting of volcanic activity in the TFZ is only sketchily known.

The study of the volcanism within the TFZ region is a continuation of previous collaborative work between GPI Kiel and MPI Mainz on the Kolbeinsey Ridge. This previous work concerned the interaction between the various mantle sources around north Iceland (Mertz et al., 1991a, 1991b) as well as the petrogenesis of the Mid-Ocean Ridge Basalts (MORB) in the transition region between the Iceland hotspot and the Kolbeinsey Ridge (Devey et al., 1992).

2.2 PREVIOUS WORK

2.2.1 Mantle dynamics

Interactions between hotspot basalts (plume basalts or Ocean Island Basalts: OIB) and "normal" ridge basalts (MORB) can provide information about the dynamics of magma generation within the mantle. The particular tectonic position of the Iceland plume, directly beneath the

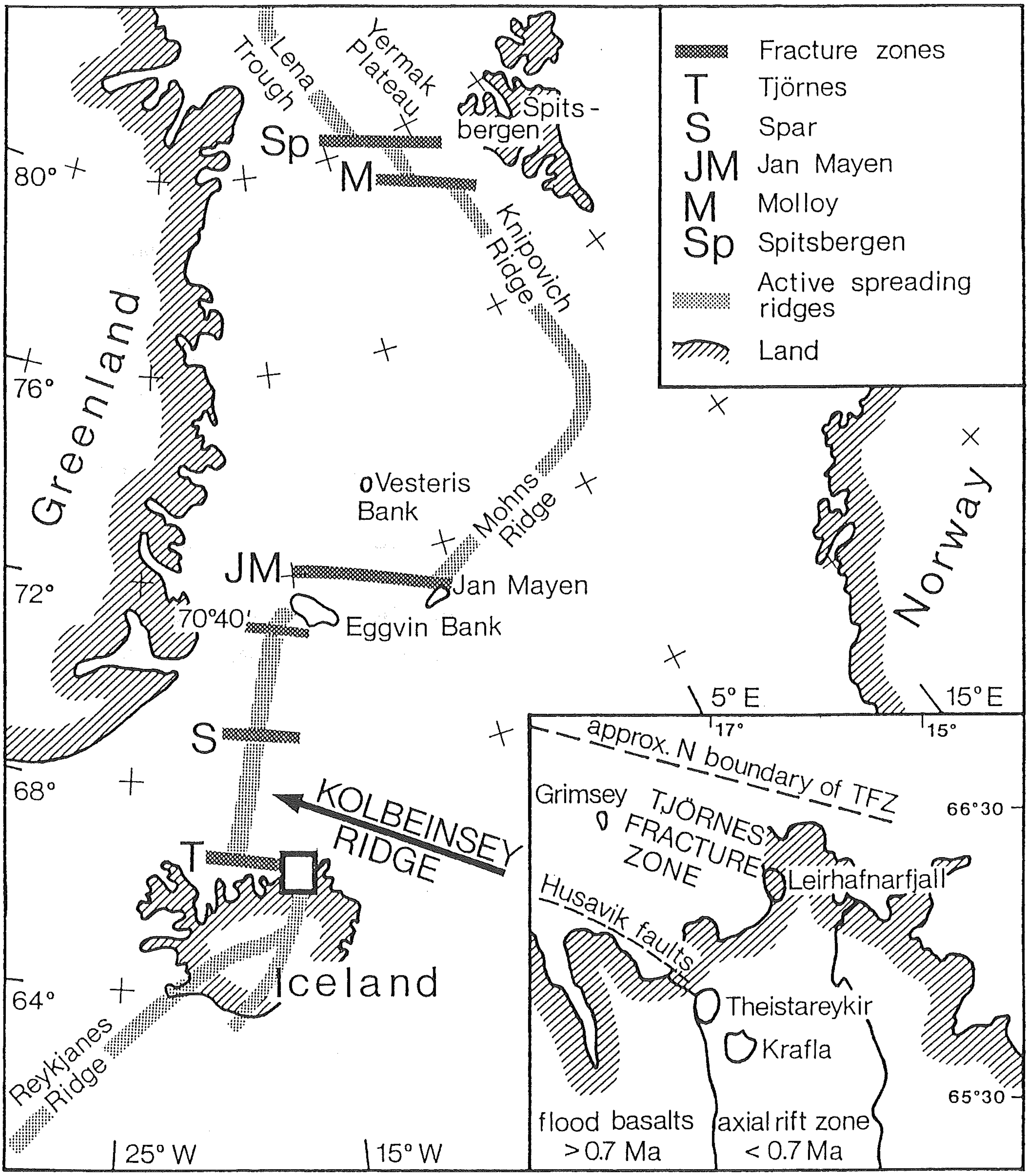

Fig. II.1: Geotectonic map of the north Atlantic. The study area covers the Tjörnes Fracture Zone directly north of Iceland and is marked with a "T".

Mid-Atlantic Ridge, allows us to examine its influence on the adjacent ridges both in the north (Kolbeinsey Ridge) and the south (Reykjanes Ridge, Fig. II.1).

On the basis of Pb and Sr isotope as well as Rare-Earth Element (REE) studies (Schilling, 1973; Hart et al., 1973; Sun et al., 1975), a model for the generation of the Reykjanes Ridge basalts involving binary mixing between the Iceland plume and a MORB source was proposed. This basic model has been taken, with various minor modifications, as being globally applicable.

The Sr, Nd and Pb isotope systematics of the Kolbeinsey Ridge basalts between 67° and 69°N show that the Reykjanes Ridge binary mixing model is not applicable here. Thus although the increase in Sr and decrease in Nd isotope ratios found along the Kolbeinsey Ridge as Iceland is approached would seem to support the binary mixing model, the constant Pb isotope ratios found are not consistent with such a model. On the basis of variations in the $^{208}Pb/^{204}Pb$ vs. $^{207}Pb/^{204}Pb$ and $^{206}Pb/^{204}Pb$ vs $^{87}Sr/^{86}Sr$ diagrams, the Iceland plume can be completely excluded as having influenced the Kolbeinsey Ridge source. Thus Mertz et al. (1991b) proposed a model for an asymmetrical Icelandic plume, whereby the normal outward radial flow of plume material beneath the lithosphere is hindered to the north of Iceland by a southward component of flow in the asthenosphere (Fig. II.2). The stagnation boundary between these two opposing flows was suggested to lie beneath the TFZ, which was then interpreted as a crustal response to the instabilities along this flow boundary. In this model, the isotopic variations seen in the Kolbeinsey basalts result purely from variations in the MORB source.

2.2.2 Petrogenesis

The Kolbeinsey basalts are tholeiitic with MgO between 6-10% and large variations in incompatible element ratios (K_2O/TiO_2 varies by a factor 15 for example). Devey et al. (1992) show that the ridge basalts nearer Iceland show a tendency to the depleted in incompatible elements even though in terms of Sr and Nd isotopes these basalts should be derived from a somewhat more enriched source. This discrepancy between the elemental and isotopic variations is probably related to recent

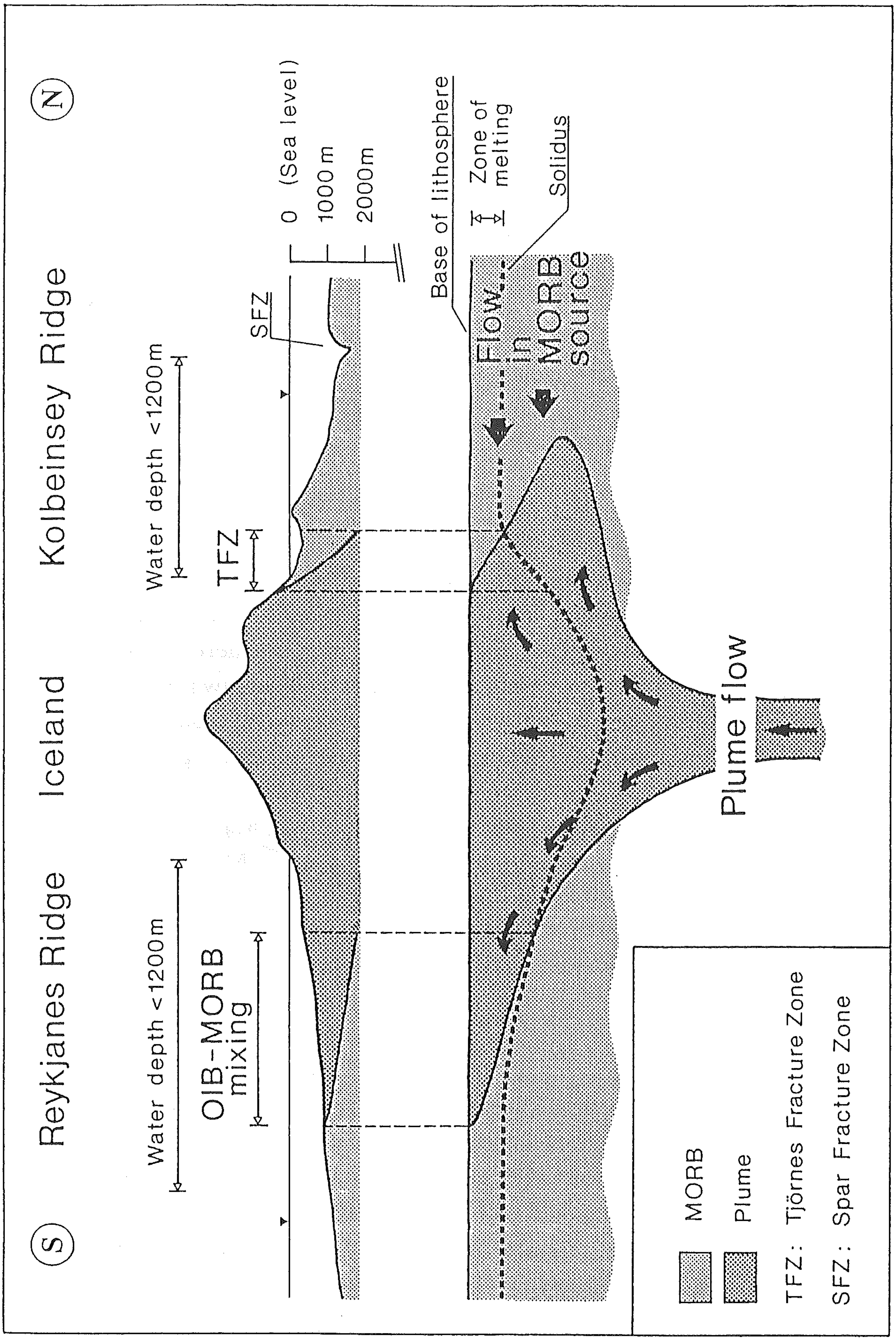
S
N
Reykjanes Ridge
Iceland
Kolbeinsey Ridge
Water depth <1200m
Water depth <1200m
OIB-MORB
mixing
TFZ
SFZ
0 (Sea level)
1000 m
2000m
Base of lithosphere
Zone of
melting
Solidus
Flow
in
MORB
source
Plume flow
MORB
Plume
TFZ: Tjörnes Fracture Zone
SFZ: Spar Fracture Zone

Fig. II.2: (after Mertz et al., 1991b): Schematic interpretation of the disposition of mantle sources beneath Iceland and the surrounding ridges. The upper part shows the geochemistry observed at the surface, and assumes only that magmas rise vertically from their source regions. Beneath is a possible mantle configuration which could account for the topographic and geochemical variations observed at the surface.

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fractionation of the incompatible element ratios by partial melting. Modelling of the amount of melting required to produce the effects observed shows that at most 9%, and more likely only 2-3%, partial melting is needed to produce the highest enrichment in incompatible elements. Over the whole range of partial melting, fractionation-corrected Na contents are constant. This implies that Na does not behave as an incompatible element during MORB melting. This means that the global correlations observed between average Na content and ridge depth are most likely related to chemical variations in the source mantle rather than variations in the degree of partial melting.

2.3 Aims

Based on the previous work described in sections 2.2.1 and 2.2.2, the following were the major aims of the Poseidon cruise:

a) Mapping of the location and structural setting of recent volcanism within the TFZ.

b) Sampling of zero-age basalts within the TFZ.

c) Sampling of hydrothermal minerals associated with the active volcanism.

The mapping was to provide a basis for a tectonic model of the MAR structure within the TFZ. The hydrothermal minerals were to be collected in order to investigate their genesis using petrography, major and trace element, and Sr, O isotope geochemistry. It was planned to carry out petrographic, chemical (major and trace element) as well as isotopic studies (Sr, Nd, Pb, Noble gases) of the basaltic samples in order to investigate their mantle source and their petrogenesis. The major questions which we aimed to answer were:

How are the picrites within the TFZ produced?

Elliott et al. (1991) have suggested that picrites found within the landbased section of the TFZ, which are characterised by extreme chemical and isotopic depletion, were generated by melting in a source composed of a volumetrically dominant plume component mixed with a subordinate asthenospheric member. Mertz et al. (1991b) on the other hand, because of the isotopic similarities between the Tjörnes picrites and Kolbeinsey basalts, suggested that the former were derived from a dominantly Kolbeinsey-like MORB source. This implies that, due to a southward flow component in the MORB asthenosphere, MORB mantle is introduced into the plume beneath the ridge axis in large quantities.

Does the TFZ overlie a zone of mantle convergence?

The model of Mertz et al. (1991) suggests that the TFZ overlies a zone of convergence in the upper mantle, where restricted amounts of mixing between the Iceland plume and the MORB source may take place. In this case, the basalts from the TFZ should show geochemical characteristic transitional between MORB and OIB. In particular, the idea of limited mixing in the TFZ can be tested using samples from the TFZ. For these reasons a relatively close-spaced dredge sampling of the TFZ region was planned.

3. CRUISE PROGRAM

Leg 185/3b began on the 19th October 1991 in Reykjavik, where the ship left harbour at ca. 1 pm. After sailing around the west coast of Iceland, the study area was reached on the evening of the 20th. The research work continued until the early morning of the 24th. At approximately 10 am the ship arrived in Akureyri to refuel. The ship left Akureyri again on the same day and returned to Hamburg passing close to the Faroe and Shetland islands. The ship docked in Hamburg on the 29th October at ca. 6 pm.

The Poseidon was in the study area for 85 hours, during which time favourable weather conditions meant that the research program could be carried out without problem. The daily schedules were so organised that during the night 3.5 KHz sonar profiles were measured, and then during the day dredges were taken at points located during the previous night´s mapping. In total 45 hours was spent run profiles, and 40 hours dredging, yielding a total of 21 profiles and 20 dredge attempts.

4. INSTRUMENTS USED

Because of the short cruise duration, and the specific nature of the research objectives, the instruments used were restricted to chain-bag dredge for rock sampling and 3.5 KHz echosounder for studying the bathymetrie and construction of the seafloor. Technical information on the 3.5 KHz sonar are contained in the section "Instruments used" in part I of this report.

5. STATIONS OCCUPIED

The 3.5 KHz profile lines and dredge positions are shown graphically in Figure II.3 (Chart 1 and 2). The exact start and end-point coordinates for the profiles, as well as the dredge locations, are given in Tables II.1 and II.2. The profiles run generally E-W over the N-S running ridge axis, whilst the dredges were taken in regions where, based on the 3.5 KHz records, young magmatic rocks were exposed on the seafloor.

Table II.1: Start- and end-point coordinates for the 3.5 KHz profiles (see also Figure II.3).

Track no.	**Start Lat.[°N]/Long [°W]**	**End Lat.[°N]/Long.[°W]**
1	67°00.022/18°59.912	66°59.970/18°27.000
2	66°55.152/18°25.634	66°55.000/19°00.000
3	66°50.099/18°59.648	66°50.086/17°55.056
4	66°45.000/18°59.844	66°44.984/17°40.271
5	66°40.024/17°30.239	66°39.974/19°10.018
6	66°38.074/19°09.503	66°38.015/18°55.484
7	66°30.033/17°34.788	66°30.009/16°45.445
8	66°29.767/16°45.390	66°27.895/16°15.640
9	66°27.900/16°46.500	66°27.700/17°35.180
10	66°27.475/17°35.226	66°24.125/17°34.989
11	66°24.015/17°34.045	66°24.008/16°46.972
12	66°23.771/16°46.737	66°15.192/16°46.991
13	66°15.078/16°47.769	66°15.204/16°53.440
14	66°15.335/16°53.885	66° 30.103/16°53.514
15	66°30.214/16°54.268	66°24.108/17°04.411
16	66°30.405/17°18.909	66°40.012/17°54.030
17	66°36.102/17°39.052	66°35.971/17°15.710
18	66°35.971/17°15.223	66°33.308/17°14.911
19	66°33.181/17°15.343	66°32.929/17°51.706
20	66°32.929/17°51.706	66°33.503/18°14.930
21	66°33.503/18°14.930	66°52.083/18°14.891

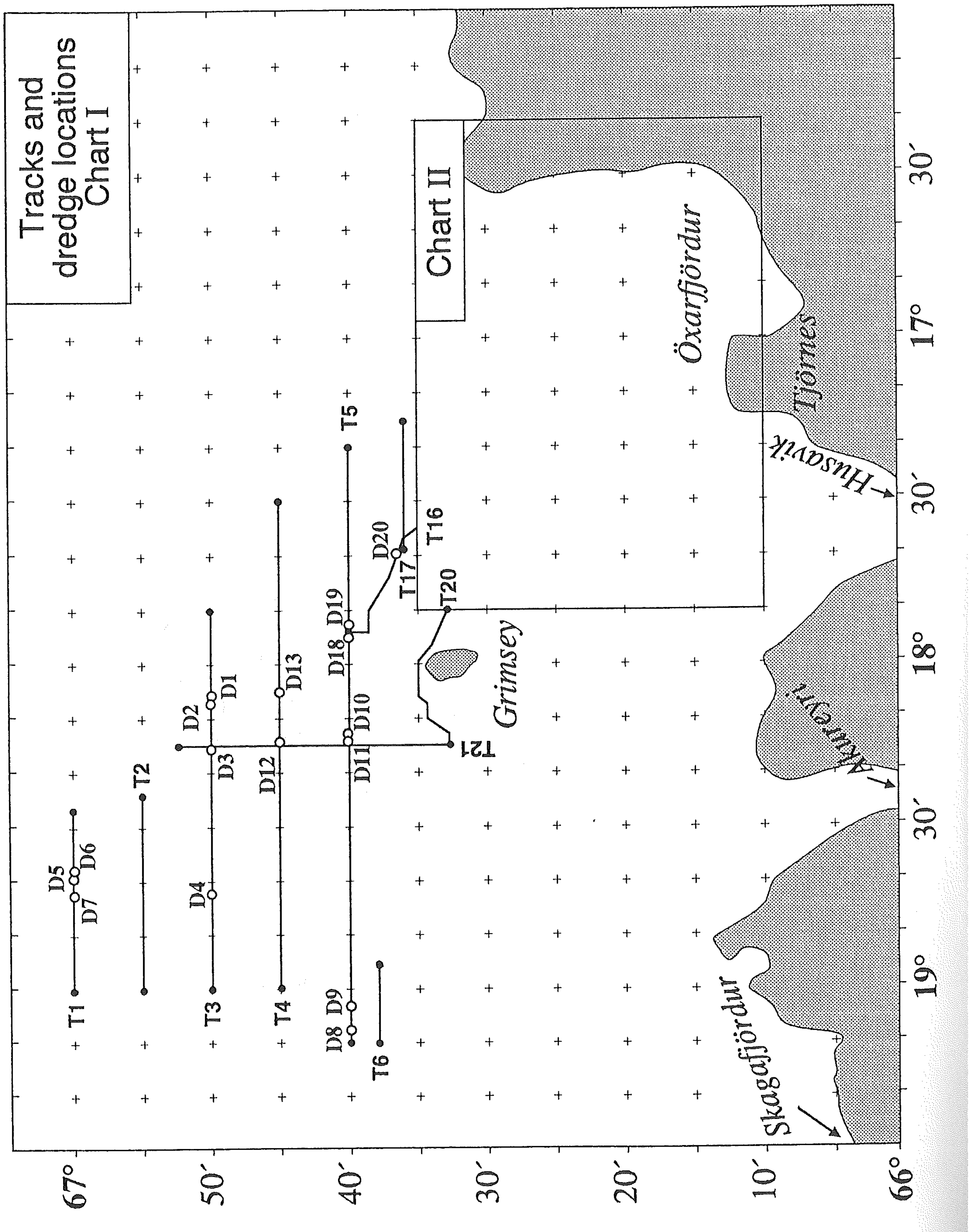
Tracks and
dredge locations
Chart I
Chart II
Öxarfjördur
Tjörnes
Húsavík
Grimsey
Akureyri
Skagafjördur
T1
T2
T3
T4
T5
T6
T16
T17
T20
T21
D1
D2
D3
D4
D5
D6
D7
D8
D9
D10
D11
D12
D13
D18
D19
D20
67°
50´
40´
30´
20´
10´
66°
17°
30´
18°
30´
19°

Figure II.3: Tracks and dredge locations (Chart 1 and 2).

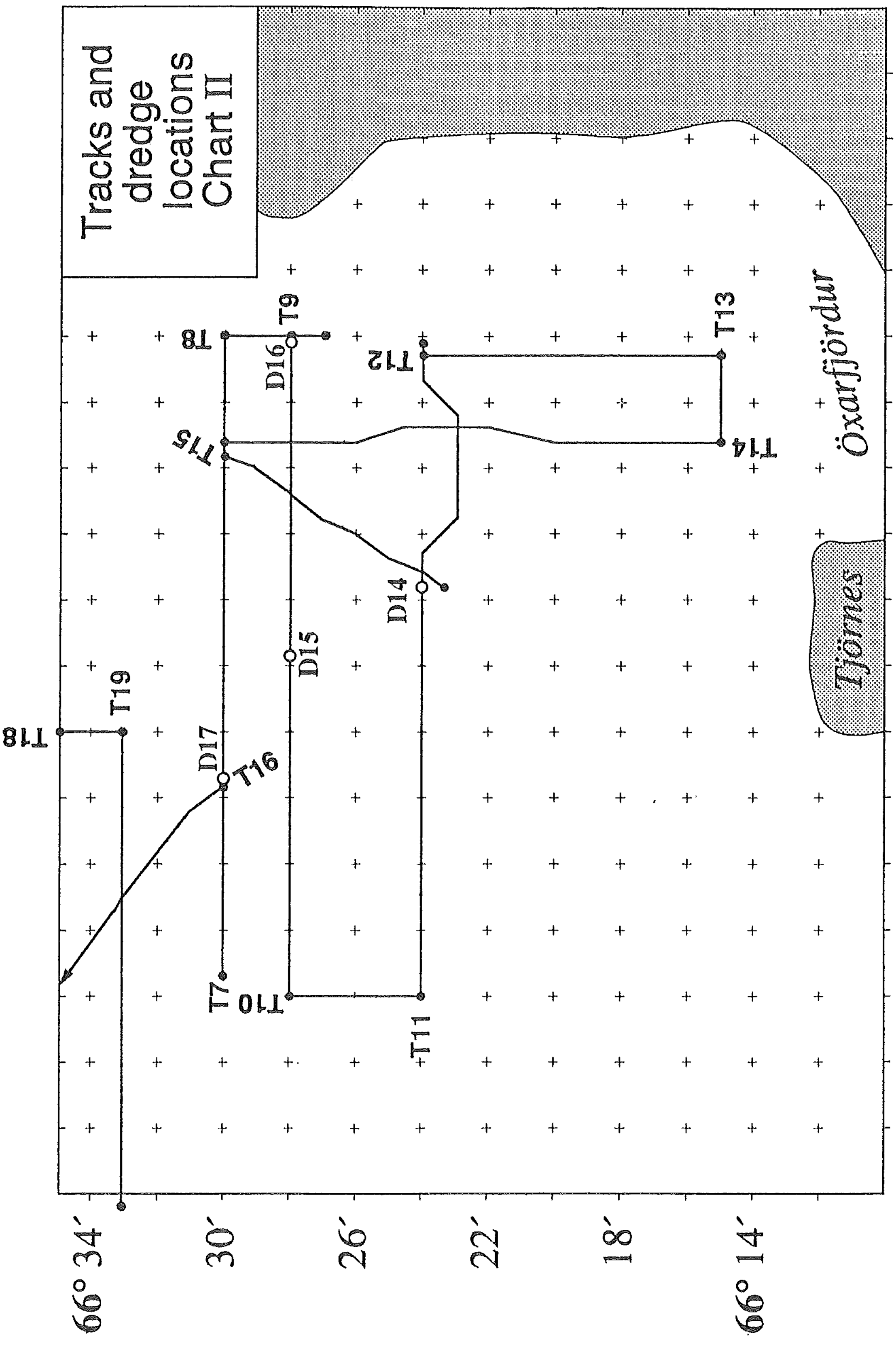

Table. II.2: Dredge Stations (see also Figure II.3).

Station and dredge no.	GPI Kiel no.	Lat.[°N]/Long.[°W] (1st bottom)	Depth range [m]
1090/D1	17061	66°50.12′/18°06.05′	340-270
1091/D2	17062	66°50.65′/18°06.94′	290-260
1092/D3	17063	66°50.10′/18°15.22′	320-300
1093/D4	17064	66°50.32′/18°42.46′	610-580
1094/D5	17065	67°00.03′/18°39.87′	285-270
1095/D6	17066	66°59.96′/18°38.94′	307-271
1096/D7	17067	66°00.04′/18°42.24′	346-298
1100/D8	17068	66°40.05′/18°08.18′	350-310
1101/D9	17069	66°40.03′/19°03.25′	363-330
1102/D10	17070	66°40.10′/18°14.34′	180-170
1103/D11	17071	66°40.09′/18°14.49′	180-187
1104/D12	17072	66°45.07′/18°14.56′	310-273
1105/D13	17073	66°45.16′/18°05.46′	397-467
1114/D14	17074	66°24.05′/17°04.69′	123-85
1115/D15	17075	66°27.84′/17°09.27′	94-86
1116/D16	17076	66°27.92′/16°45.48′	156-128
1117/D17	17077	66°30.00′/17°18.05′	201-64
1118/D18	17078	66°39.99′/17°54.10′	120-107
1119/D19	17079	66°39.84′/17°53.77′	138-116
1120/D20	17080	66°36.39′/17°39.34′	390-370

Table II.3 contains sampling locations for the land expedition which took place in NE Iceland before the cruise. The onshore part of the TFZ was so sampled that all the magmatic units differentiated on the 1:500,000 (Jòhannesson and Seamundsson, 1989) and 1:250,000 (Seamundsson, 1977) maps, and their various sub-types, were collected. The units sampled belonged mainly to the types described as "Basic and intermediate lavas. Postglacial, prehistoric, older than 1100 years", "Basic and intermediate hyaloclastite, pillow lava and associated sediments. Upper Pleistocene, younger than 0.7 Ma" (Jòhannesson und Saemundsson 1989) and "Hyaloclastite and tuffaceous sediment, Pleistocene, younger than 0.7 Ma", "Interglacial and supraglacial lavas, Pleistocene, younger than 0.7 Ma", "Postglacial basalt and andesite lavas" (Saemundsson 1977). Through extensive sampling, a relatively complete age sequence of magmatic rocks was collected. Together with the dredged samples, this collection gives a good coverage of the whole TFZ region, with which the geological, geochemical and isotopic evolution of the region can be studied.

Table II.3: Sample localities for volcanic samples collected in the onshore region of the Tjörnes Fracture Zone in NE Iceland.

Expedition sample no.	**GPI Kiel sample no.**	**Lat.[°N]/Long.[°W]**	**Location name**
I-91/1	17081	66°08′/17°12′	Skeifa
I-91/2	17082	66°09′/17°15′	Isolfsstadir
I-91/3	17083	66°10′/17°16′	Furuvik
I-91/4	17084	66°11′/17°14′	Sandholar
I-91/5	17085	66°12′/17°06′	Lighthouse, Manar basalt
I-91/6	17086	66°04′/16°25′	Skularlardur, Lindabrekka
I-91/7	17087	65°39′/16°25′	North of Hrossaborg
I-91/8	17088	65°52′/16°25′	Randarholar
I-91/9	17089	66°04′/16°21′	Gilbakki
I-91/10	17090 A-D	66°03′/16°20′	Hafrafell
I-91/11	17091	66°02′/16°19′	Hafrafelltunga
I-91/12	17092 A, B	66°08′/16°20′	Vulcano Nupar
I-91/13	17093	66°10′/16°08′	Raudholar
I-91/14	17094	66°16′/15°47′	Raudanes
I-91/15	17095 A, B	66°12′/15°21′	Poershöfn
I-91/16	17096 A, B	66°25′/15°50′	Súlur
I-91/17	17097	66°25′/15°52′	Raufarhöfn
I-91/18	17098	66°28′/16°15′	Blekalondsdalus
I-91/19	17099	66°30′/16°32′	Raudinupu
I-91/20	17100 A-C	66°24′/16°28′	Lerhöfn (Leirhafnarfjall)
I-91/21	17101 A-C	66°22′/16°29′	Snartarstadrupu (-"-)
I-91/22	17102	66°16′/16°26′	Prestholar
I-91/23	17103	66°12′/16°23′	Vulcano Nupar

6. PRELIMINARY SCIENTIFIC RESULTS

6.1 DREDGED SAMPLES

Table II.4 contains a brief description of the rock types recovered at each dredge station. The samples consist mainly of basaltic material, either recovered in-situ on within-ridge highs or present as transported fluvial cobbles. Occasionally sediment was recovered, as well as in one case hydrothermal minerals. The main types of seafloor which it proved possible to distinguish on the 3.5 KHz sonar (in-situ volcanics, fluvial material, sediment) are illustrated in Figure II.4 (A, B, C).

Table II.4: Description of dregded samples (abbreviations used: ol = olivine, plag = plagioclase, phenos = phenocrysts).

Station and dredge no.	Samples
1090/D1	A. Vesicular, small ol + plag phenos, glass old, Mn-coating B. More vesicular than A, abundant glass, ol phenos, vesicles with sediment filling C. Vesicular, ol phenos, no glass
1091/D2	A. Vesicles with sediment filling, rare ol phenos, glass B. Sheet flow, glassy margins, plag phenos, fresh C. Grey dolerite, ol phenos, irregularly distributed vesicles D. Glassy knob from sheet flow, many ol + plag phenos (plag>ol) E. Vesicular, ol + plag phenos, no glass F. Pillow fragment, plag megacrysts, ol phenos, no glass G. As F, smaller ol
1092/D3	A. Almost pure glass B. Vesicular, ol + plag phenos (plag<ol) C. Less vesicular than B
1093/D4	Glass
1094/D5	A. Consolidated sediment crusts B. Glass C. Vesicular basalt, no glass, plag phenos D. More vesicular, less porphyritic than C E. Compact, slightly vesicular, aphyric
1095/D6	A. Cemented sediment B. Altered, no glass, few vesicles, some plag phenos C. Fewer vesicles and phenos than B, fresher D. Plag-phyric, sediment coated

continuation of table II.4

1096/D7	A. Sheet flow fragment, 1cm glass rim, few vesicles and plag phenos B. Glassy basalt, small vesicles C. Pillow fragment, vesicular, aphyric D. Pillow fragment with several glassy zones
1100/D8	Mud, some glacial erratics and consolidated clay
1101/D9	Mud, some glacial erratics and consolidated clay
1102/D10	Rounded boulders (river gravel?)
1103/D11	Rounded cobbles and consolidated clay
1104/D12	A. Vesicular, frothy basalt (unlikely to have withstood transport far) B. Hyaloclastite
1105/D13	A. Vesicular, glass-rich basalt B. Vesicular, numerous small plag phenos, glass C. Looks older than B, little glass, plag phenos
1114/D14	River cobbles, no sediment
1115/D15	River cobbles, no sediment
1116/D16	River cobbles, no sediment
1117/D17	A. Vesicular, many pl phenos, glass crust B. Strongly rounded cobble, some glass, numerous plag (?) phenos
1118/D18	No material
1119/D19	Massive, grey basalt, some vesicles, aphyric, no glass
1120/D20	Hydrothermal material, some Fe-staining

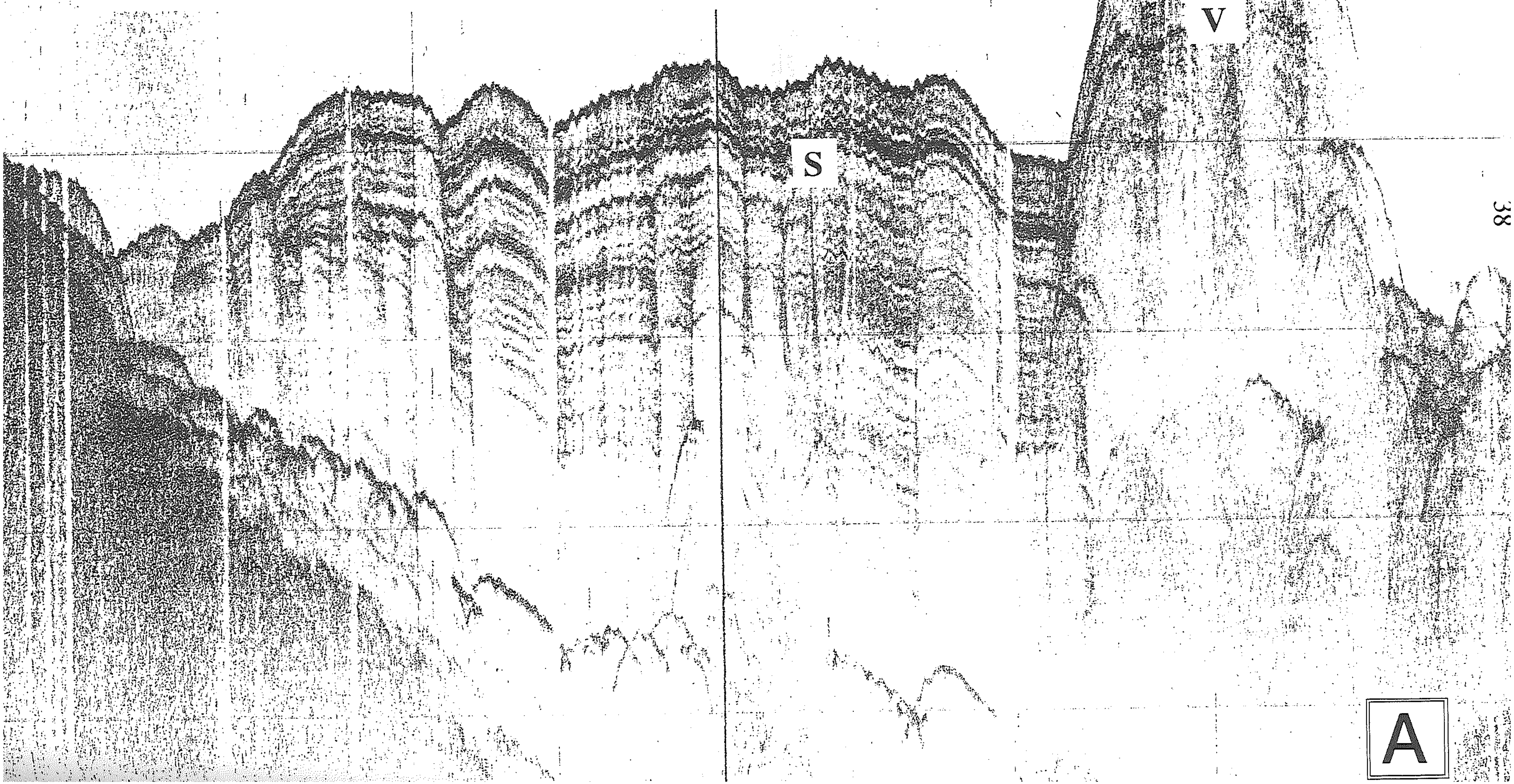

Figure II.4: 3.5 KHz sonar record of typical seafloor types in the study area. The individual records (A, B and C) are about 5.4 km wide, and about 130 m high.

A: Recent volcanic activity (V) on the western volcanic zone (see Figure II.5, profile T5) produces within-ridge highs which penetrate the sediment cover.

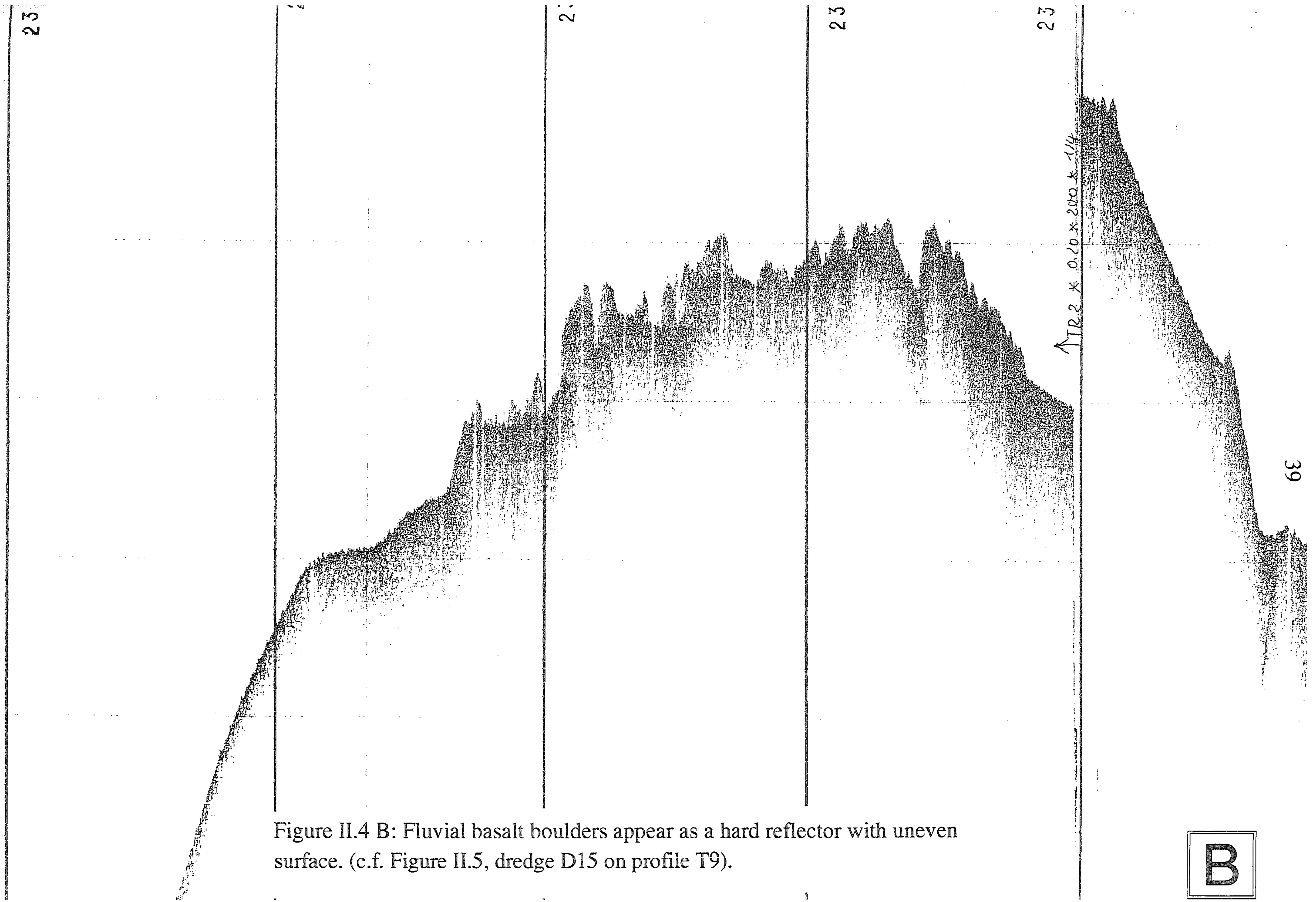

Figure II.4 B: Fluvial basalt boulders appear as a hard reflector with uneven surface. (c.f. Figure II.5, dredge D15 on profile T9).

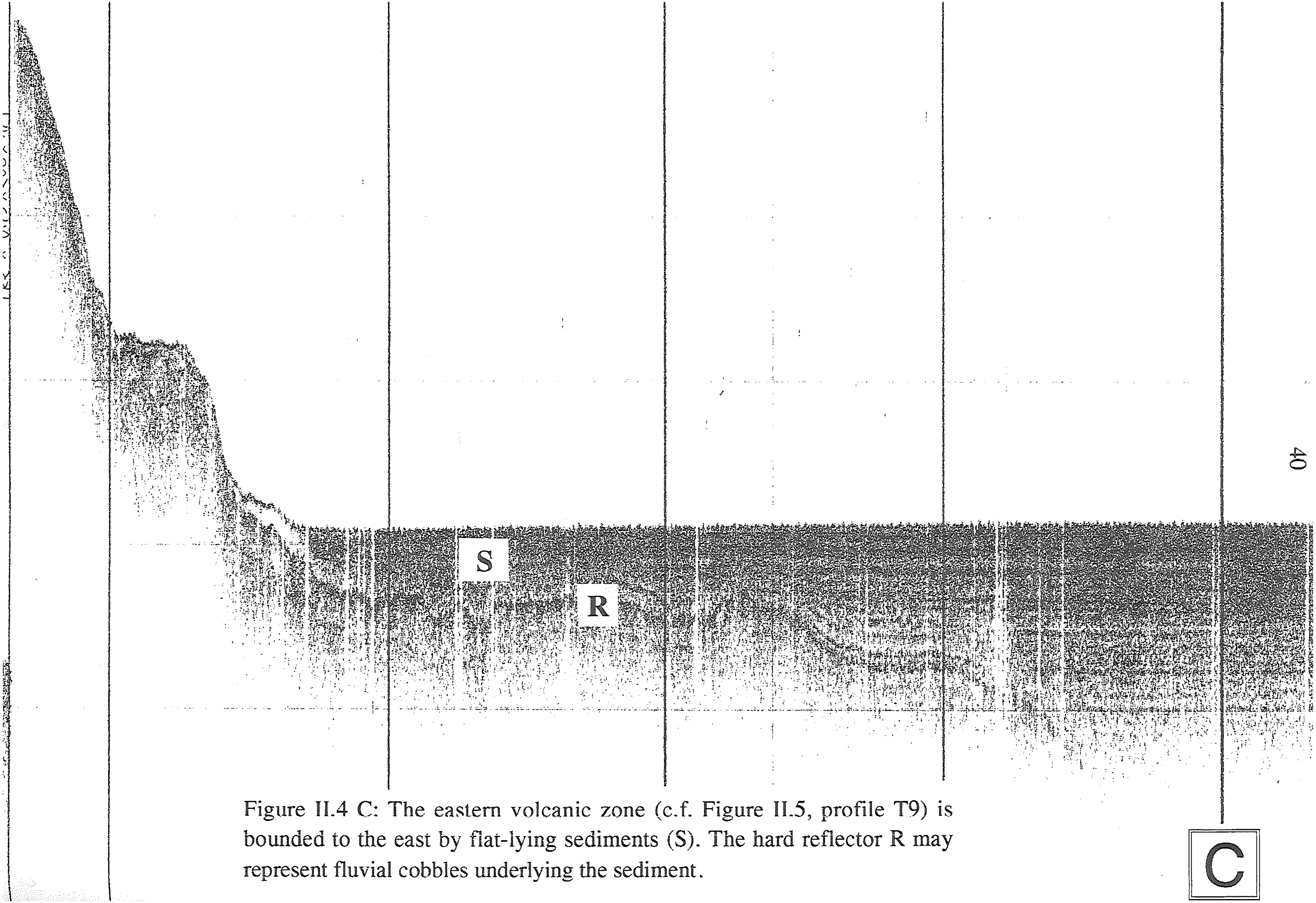

Figure II.4 C: The eastern volcanic zone (c.f. Figure II.5, profile T9) is bounded to the east by flat-lying sediments (S). The hard reflector R may represent fluvial cobbles underlying the sediment.

6.2 THE LOCATION OF THE ACTIVE VOLCANIC ZONE

6.2.1 Cruise data of PO 185/3b

The location of the active Kolbeinsey Ridge volcanic zone north of 67°N has been presented by Schilling et al. (1983), Mertz et al. (1991b) and Thiede and Hempel (1990). Between 67°N and the north coast of Iceland, the situation is complex, with three parallel rift zones running north-south each one of which is only partially active at present (see section 6.2.2).

The results of the 185/3b cruise are presented diagrammatically in Figure II.5, where the location of the active volcanic zone is shown. When constructing this figure, the active volcanic zone was placed at locations where either fresh, in-situ volcanic glass was recovered, or where the 3.5 KHz record showed conspicuous within-ridge highs.

At 67° 0'N, the ridge is relatively symmetrical, with well developed shoulders. These ridge shoulders become progressively less distinct southward. Between 67° and 66°50'N (profile T3) the ridge splits into two active zones.

The westerly of these two zones lies along the N-S prolongation of the Kolbeinsey Ridge. At 66°45'N (profile T4) this zone is marked by a sediment-filled graben. Volcanic activity occurs on within-ridge highs which penetrate the sediment cover (Figure II.4, A). By 66°40'N (profile T5) the within-ridge highs are no longer present, although the graben structure is still clearly visible. A similar profile was seen at 66° 38'N (profile T6), although here the graben is much narrower than in the profile to the north, and is somewhat displaced to the west. We assume from the comparison of profiles T5 and T6 that the graben has taken on an approximately NE strike, and that it dies out fairly rapidly south of 66° 38'N. There appear to be two explanations for the absence of surface expression of volcanism in the graben south of 66°40'N. Either the zone is no longer volcanically active, or the sedimentation rates in the graben so close to Iceland are so high that volcanic products are buried almost immediately after eruption.

The easterly volcanic zone strikes SE to 66°50'N, then south to 66°45'N, once more SE to 66°28'N (profile T9) and finally southwards to join the Icelandic mainland. Between 66°50 and 66°45'N the volcanic axis appears to be relatively sediment-free, then south of 66°45′N the within-ridge highs are separated by noticable sediment pockets whose thickness and frequency increases markedly southwards. At the same time the relatively angular and rugged morphology of the within-ridge highs in the north becomes transformed into more rounded topographic forms in the south. Between 66°55′N (profile T2) and 66°30′N (profile T7) active volcanism has been shown by fresh volcanic glass and hydrothermal minerals in dredge hauls. Attempts to dredge fresh volcanics south of 66°30′N were unsuccessful, and we assume in this region that the rate of sediment supply from Iceland is so high that any volcanic products are very quickly covered with sediment. Morphological studies of the seafloor suggest however that south of 66°30′N the active volcanic zone crosses the Manareyjar "ridge" and then joins up with the active Icelandic rift zone in Axarfjördur.

6.2.2 Previous studies

Based on dredge results, bathymetric, magnetic and seismic measurements, McMaster et al. (1977) distinguished three N-S oriented troughs within the TFZ which they interpreted as spreading axes (from W to E: Kolbeinsey Ridge - Eyjafjardaráll, Kolbeinsey Ridge - Skjálfandadjúp and Öxarfjardardjúp Troughs; see McMaster et al. 1977, p. 664: Fig. 1). Evidence for recent volcanic activity was found in the Eyjafjardaráll and Skjálfandadjúp troughs, although not over the entire N-S extent. The volcanic zones are apparently arranged en echelon between the Kolbeinsey Ridge and the NE Iceland neovolcanic zone, and Mc Master et al. (1977) interpreted these en echelon volcanic zones to mark

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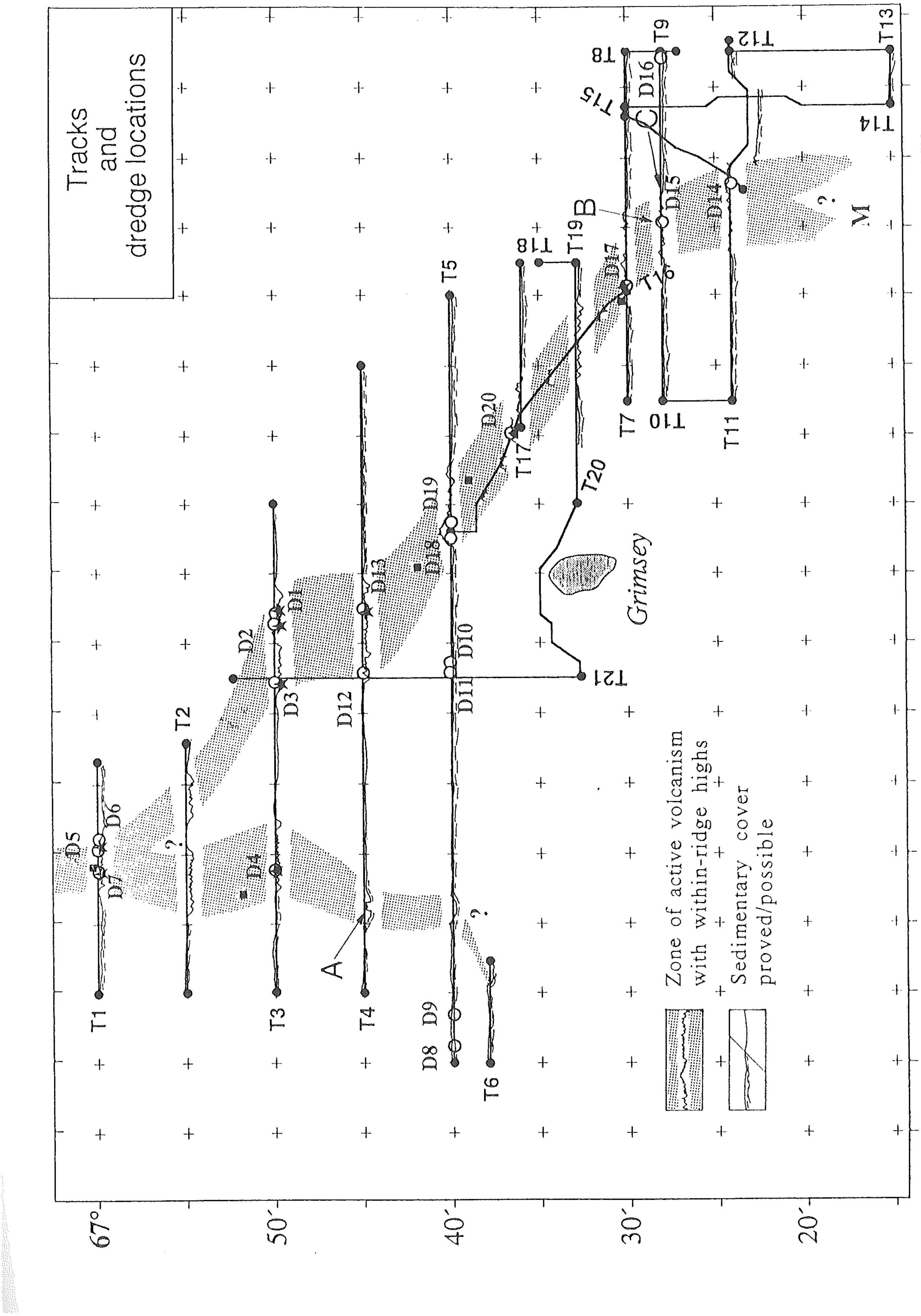
Figure II.5: Location of the active volcanic axis within the TFZ based on 3.5 KHz profiles and dredge results. Profile lines and dredge locations are shown. Positions marked A, B and C correspond to the typical seafloor types shown in Figure II.4. Regions where fresh volcanic glass has been recovered are shown with a star (Poseidon 185/3b cruise) or square (McMaster et al., 1977). Hydrothermal precipitates have been recovered where a triangle is shown (Poseidon 185/3b cruise). M marks the Manareyjar "ridge". >>>


Tracks
and
dredge locations
Zone of active volcanism
with within-ridge highs
Sedimentary cover
proved/possible
Grimsey
67°
50´
40´
30´
20´
19°
30´
18°
30´
17°
T1
T2
T3
T4
T5
T6
T7
T8
T9
T10
T11
T12
T13
T14
T15
T16
T17
T18
T19
T20
T21
D1
D2
D3
D4
D5
D6
D7
D8
D9
D10
D11
D12
D13
D14
D15
D16
D17
D18
D19
D20
A
B
C
M

the present boundary between the Eurasia and Greenland plates. These authors found no evidence (with the exception of the now-inactive Husavik fault) for any typical transform fault structures in the TFZ.

The new Poseidon data support the basic model of the TFZ proposed by McMaster et al. With the present smaller grid survey and dredge localities, it is however now possible to determine the location of volcanism much more precisely.

7. CONCLUSIONS

Despite the fact that relatively little time (3 days, 4 nights) was available for the extensive research program planned, all research goals were achieved. Regions such as the Tjörnes Fracture Zone, which apparently mark the boundaries between different mantle sources have recently become the subject of extensive international research (e.g. Klein et al., 1988; Mertz et al., 1991b; Elliott et al., 1991). For this reason we plan to publish the results of our studies of the course followed by the MAR through the Tjörnes Fracture Zone shortly (Devey and Mertz). The analytical data on the samples collected will require longer to gather (Mertz, Devey, Todt, Ingolfsson and Stoffers) and so a later publication of this data is envisaged.

Future joint projects between the GPI Kiel and MPI Mainz in the north Atlantic will concentrate further on the interface regions between OIB and MORB. In particular the boundaries Eggvin Bank - N. Kolbeinsey Ridge, Jan Mayen Plateau - S. Mohns Ridge and Yermak Plateau - Nansen Gakkel Ridge are of great interest (see Figure II.1).

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