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InterRidge News

InterRidge Update

InterRidge Phase 2

InterRidge has officially entered Phase 2 of its Program Plan which is designated to last from 1995 through 1997. Phase 2 involves in-depth studies in the form of major interdisciplinary field efforts conceived and co-ordinated by InterRidge, and development of a database information catalogue accessible to the international ridge sciences community via the Internet.

Thematic workshops held during Phase 1 (1992-1994) have enabled us to design a number of co-operative projects. With the foundations now laid for seven Phase 2 InterRidge Projects (see below), it is clear that 1995 will be a year of continued development and expansion for InterRidge. As these projects grow, international co-operation and participation will become increasingly important. The seven designated Phase 2 projects in the three overall themes are:

Global Studies:

- ***Global Digital Atlas***: the establishment of a global multibeam bathymetric database by linking distributed databases via the World Wide Web.
- ***SWIR*** (Southwest Indian Ridge): co-ordinated reconnaissance mapping and sampling of a complete super-segment, the Southwest Indian Ridge from the Bouvet Triple Junction to the Rodrigues Triple Junction including integrated Ocean Drilling experiments.
- ***Arctic Oceans:*** co-ordination of planning efforts for mapping and sampling of the Arctic Ridges.

Meso-Scale Studies:

- ***4-D Architecture of the Oceanic Lithosphere:*** an integrated study of a fast spreading segment (Hess Deep) in parallel with an integrated study of a slow spreading segment on the Mid-Atlantic Ridge both including important components of ODP.
- ***Quantitative Fluxes Experiment***: segment-scale experiment to measure integrated magmatic, thermal, chemical and biological fluxes at Mid-Atlantic Ridge.
- ***Back-Arc Basin Data Base***: petrological database of Back-arc Basins on the World Wide Web.

Active Processes:

- ***Event Detection and Response***: detection of transient ridge-crest seismic, volcanic and hydrothermal events, and logistical response to them through a strategy of international collaboration.

It is envisaged that these projects will move forward through concerted international actions at sea and elsewhere, co-ordinated by InterRidge over a period of several years. This action would bring the ships and technology of different nations together in major multi-disciplinary experiments focused on InterRidge thematic goals. Detailed science plans and calls to participate

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will be issued by the InterRidge Office in the near future.

It should be emphasised that the projects outlined above represent a focusing of InterRidge efforts in the near-term; however, broader long-term goals still remain. For example, it is the long-term aim of the Global Studies programme to complete reconnaissance mapping of all the world ridges, and the current emphasis on SWIR and the Arctic is simply a step on the way.

Membership

InterRidge Membership continues to expand. The InterRidge Chair and Steering Committee were very pleased to welcome Germany, India, Portugal, Spain and Switzerland as new or upgrading members of InterRidge. Germany and Portugal joined InterRidge as Associate Members for 1994 and Spain has agreed to join as a Principal Member for 1995. India and Switzerland have very recently joined as a Corresponding Member. In 1995, InterRidge expects to count 5 Principal Members (France, Japan, Spain, UK, USA), 2 Associate Members (Germany, Portugal) and 10 Corresponding Members (Australia, Canada, Iceland, India, Italy, Korea, Mexico, Norway, Russia, Sweden, Switzerland). The InterRidge Office is continuing in its efforts to increase membership by contacting nations with active ridge crest research communities such as Chile, China and New Zealand.

Workshops

The last half of 1994 and early 1995 saw the completion of the Phase 1 round of thematic workshops. In late September 1994, the Meso-Scale Workshop "4-D Architecture of the Oceanic Lithosphere" was held in Boston, USA. In November 1994, the Global Studies Workshop "Arctic Ridges: Results and Planning" was held in Kiel, Germany. Paris, France was the site of the January 1995 Active Processes Workshop "Event Detection and Response & A Ridge Crest Observatory". Each of these workshops was attended by enthusiastic participants whose efforts have forged the foundations for the above Phase 2 InterRidge Projects. Summaries of the results of these workshops may be found in this issue (pages 49-54) and the workshop reports are soon to be published.

Upcoming Events & News

The InterRidge Biological Studies *Ad Hoc* Committee will convene a workshop on 24 & 25 April 1995, at Rutgers University, New Brunswick, NJ, USA (see announcement page 67). The convenors for the workshop, Daniel Desbruyères and Richard Lutz, have outlined the following three objectives as the focus for discussion:

- Development of an Implementation Plan for the integration of biological studies into the three principal InterRidge themes.
- Draft a formal international agreement endorsed by InterRidge to provide for exchanges of samples and data in order to avoid duplication of effort and to broaden effective distribution of data and samples.
- Maximisation of the effectiveness of biological sampling and observations during "geological" cruises.

Planning is also underway for a workshop which will draw up a science plan and implementation outline for the Meso-Scale Working Group Project "Quantification of Fluxes", as well as for the 1995 InterRidge Steering Committee Meeting which will be held in parallel with a meeting of DeRidge in Kiel, Germany.

WWW

The InterRidge World Wide Web home page is now on line. The home page address is:

http://www.dur.ac.uk/~dgl0zz1/

The InterRidge home page provides links to the InterRidge Researcher Electronic Directory, information concerning InterRidge program structure and events calendar, workshop announcements and various national and international program home pages.

- Prof. Roger Searle,
InterRidge Chair.

- Dr. Heather Sloan,
InterRidge Co-Ordinator.

Provisional InterRidge Calendar

1995

Active Processes Workshop: "Event Detection and Response & A Ridge Crest Observatory"
Paris, France; 16-18 January, 1995.

Biological Studies Workshop
New Brunswick, NJ, USA; 24 & 25 April, 1995.

Meso-Scale Workshop:
"Quantification of Fluxes at Mid-Ocean Ridges: Design/Planning for the Segment-Scale Box Experiment."
September, 1995 (provisional).

InterRidge Steering Committee Meeting
to be held in parallel with a Meeting of DeRidge
Kiel, Germany; September, 1995.

International Co-Operative Research

Indian Ocean Column

Crustal Sturcture at the Very Slow-Spreading Southwest Indian Ridge

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Introduction

Wide-angle seismic measurements show that oceanic igneous crustal thickness is remarkably uniform across almost an order of magnitude change in full spreading rate from 20-160 mm/a (Fig. 1). No significant deviation from an average thickness of 7 ± 1 km is observed for crust generated at ridges away from the influence of mantle plumes, fracture zones or extension immediately adjacent to nonvolcanic rifted margins (White et al., 1992). As Figure 1 shows, very few measurements of crustal thickness have been made at very slow spreading ridges, but those few that are available suggest a marked decrease in thickness at full spreading rates below 20 mm/a. The thickness of the crust is important because it reflects the degree of melting that has occurred in the mantle beneath mid-ocean ridges. Thermal models suggest that conductive cooling of upwelling mantle might reduce the amount of melt formed at very slow spreading rates (Bown and White, 1994), but there is a shortage of data to constrain these models.

RRS Discovery Cruise 208, to the Southwest Indian Ridge (SWIR) during April-May 1994, aimed to establish detailed seismic velocity models of the crust and upper mantle at two locations on a very slow spreading ridge. The full spreading rate at the SWIR in the area of our experiment is 16 mm/a and has remained unchanged for the last 20 Ma (Patriat and Segoufin, 1988).

The experiment

Two sites were investigated. The first site was around Ocean Drilling Program borehole 735B, near the Atlantis II Fracture Zone. Borehole 735B drilled through a 500 m section of lower crustal gabbros,

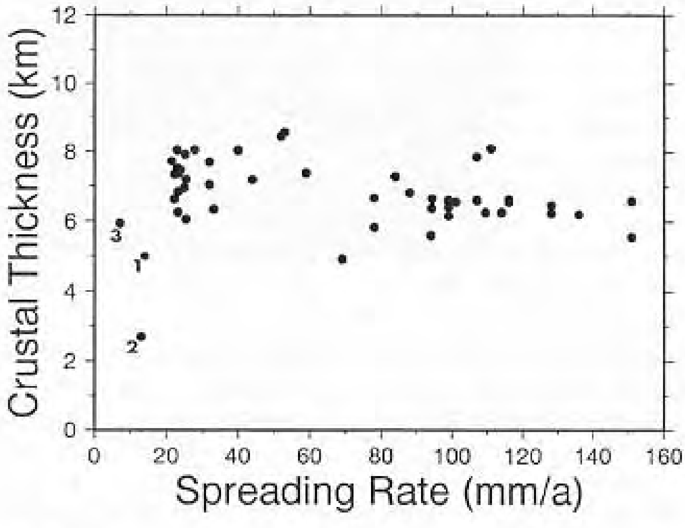

Figure 1. Igneous crustal thickness plotted against spreading rate for oceanic crust located away from fracture zones, mantle plumes and rifted continental margins. All data points were derived from wide-angle seismic studies in which results were constrained by synthetic seismograms. Numbered data points correspond to the following studies: (1) Southwest Indian Ridge, Francis and Raitt, 1967, and Minshull and White, unpbl. data; (2) Arctic Ridge, Jackson et al., 1982; (3) Labrador Sea, Osler and Louden, 1992.

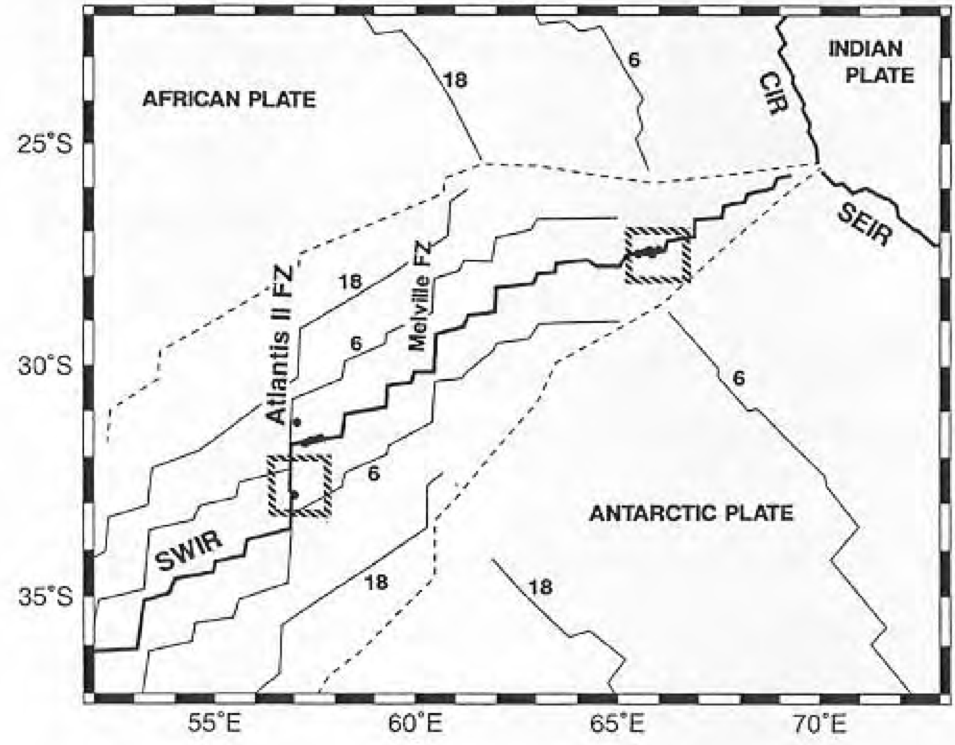

Figure 2. Location of survey areas on the Southwest Indian Ridge during *RRS Discovery* Cruise 208. The hashed boxes show areas where seismic data was acquired and the solid dots show dredge localities. Ridge axes, triple junction traces, and magnetic anomalies 6 and 18 were taken from Patriat and Segoufin, 1988.

encountering no upper crustal basalts at all.

The second site was on the ridge axis at 66°E, in an area away from major fracture zones. Both sites have good existing swath bathymetry, gravity and magnetics data.

Wide-angle seismic data were recorded at each site by nine ocean bottom hydrophones (OBHs) deployed in a grid pattern with a spacing of approximately 20 km. Airgun shots were fired every 40 s from a 10-gun, 71 l tuned array along ship tracks over the OBH positions. We acquired simultaneously approximately 800 km of seismic reflection data by recording the airgun shots on an 8 channel, 800 m streamer. Underway gravity, magnetics and bathymetry were recorded continuously.

As a complementary experiment, we also dredged for basalts along the ridge axis east of the Atlantis II Fracture Zone and along the spreading axis at 66°E (Fig. 2). Geochemical analysis of the samples should establish the degree of melting at the SWIR. C. Robinson at the Bullard Laboratories is working on these rocks.

In addition to constraining the crustal thickness, the seismic experiment should also allow us to address other issues that are currently under debate in the scientific community relating to mid-ocean ridge processes: (1) the thermal cooling effect of thick, cold lithosphere on the degree of mantle melting at the ridge-transform intersection, (2) episodicity of melt generation and variation in structure along flow lines, both in the vicinity of, and away from a major fracture zone, (3) ridge segmentation and variation in structure parallel to the ridge axis, (4) the nature of the uplifted transverse ridge adjacent to a fracture zone.

Seismic data at the Atlantis II Fracture Zone

Our initial work has concentrated on data collected in the vicinity of ODP borehole 735B at the Atlantis II Fracture Zone, largely because of the considerable interest in returning to this borehole to attempt to drill into upper mantle peridotites (Swift et al., 1991, for example, "tentatively" interpreted reflections observed in a borehole seismic profile at 735B as originating from near the Moho at a depth of about 800 m). Data quality from the OBHs is variable. Seismic arrivals are visible to offsets of 40-45 km in "good" seismic sections. In poorer sections, generally recorded at deeper OBH stations (4000-6000 m) arrivals fade out at about 15-20 km. The disappearance of coherent seismic energy may be caused by lateral heterogeneity in crustal structure as well as by ambient noise levels.

Typical features observed in the wide-angle data are illustrated in the "good" record section of OBH06 (Fig. 4) recorded on line CAM101, shot north-south along the transverse ridge east of the transform valley (see Fig. 3 for locality). The shape of the arrivals is controlled strongly by sea floor topography, the depth varies from 870 m at the northern end of the section to 3000 m at the southern end. The following seismic arrivals are interpreted in the data:

(1) Pg, turning rays travelling through the crust, with amplitudes decreasing with increasing offset.

(2) PmP, reflections off the Moho Discontinuity at the base of the crust. The critical distance is estimated to be at about 20 km. No coherent pre-critical reflections are apparent.

(3) Moho triplication at 30-35 km where the simultaneous arrival of Pg, PmP, and Pn (head waves travelling along the Moho) produces a very high amplitude signal.

(4) Sg, mode-converted shear waves turning in the crust.

Interpretation and discussion

OBH06 is located 5 km north of ODP borehole 735B. Both a sonic log (Iturrino and Christensen, 1991) and a vertical seismic profile (Swift

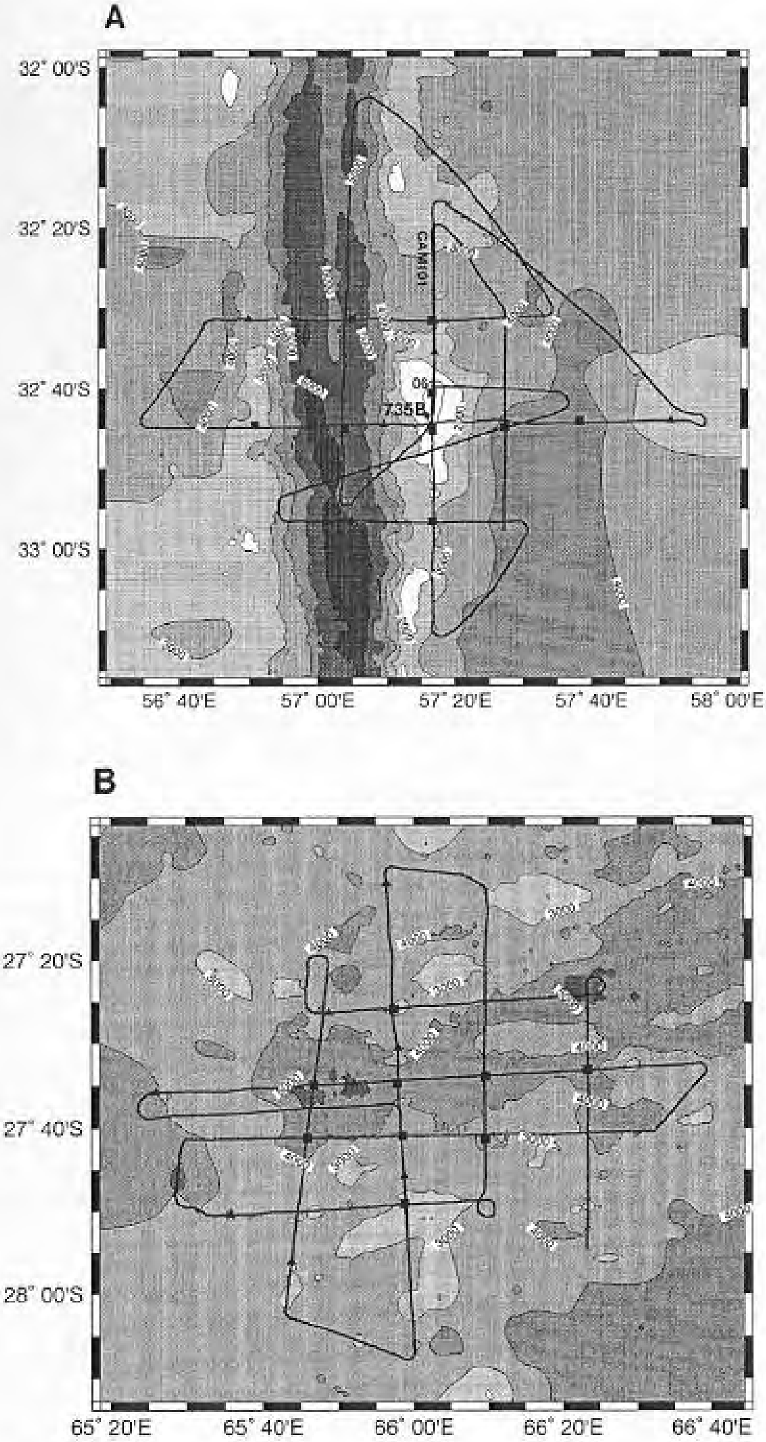

Figure 3. Layout of the seismic experiments at (a) the Atlantis II Fracture Zone, and (b) on the SWIR at 66°E. The contours and black and white shaded grid show bathymetry. White squares show OBH locations on the sea floor, triangles show deployment positions of disposable sonobuoys and lines show the ship's track while shooting over the OBH positions. Spacing between the OBHs is approximately 20 km.

et al., 1991) down this borehole indicate seismic velocities of about 6.7 km/s, which is typical of unfractured gabbroic rock. Simple modelling of the seismic arrivals referred to above shows that a 5 km thick crust is required to match a PmP critical distance of 20 km and a Moho triplication at 30-35 km offset, given crustal velocities consistent with those observed in borehole 735B.

Recently we have completed a more detailed 2-D travel-time raytrace model of the crustal structure along line CAM101, constrained by seismic arrivals at all four OBH stations on the line. Our model confirms that the crust is 4-5 km thick. This result must be regarded as preliminary until the interpretation of the seismic phases (Pg, PmP, critical distance and triplication) has been confirmed by amplitude modelling, but it is unlikely to change much. Provided that our phase interpretation is correct, we can draw several conclusions from the work: (1) The

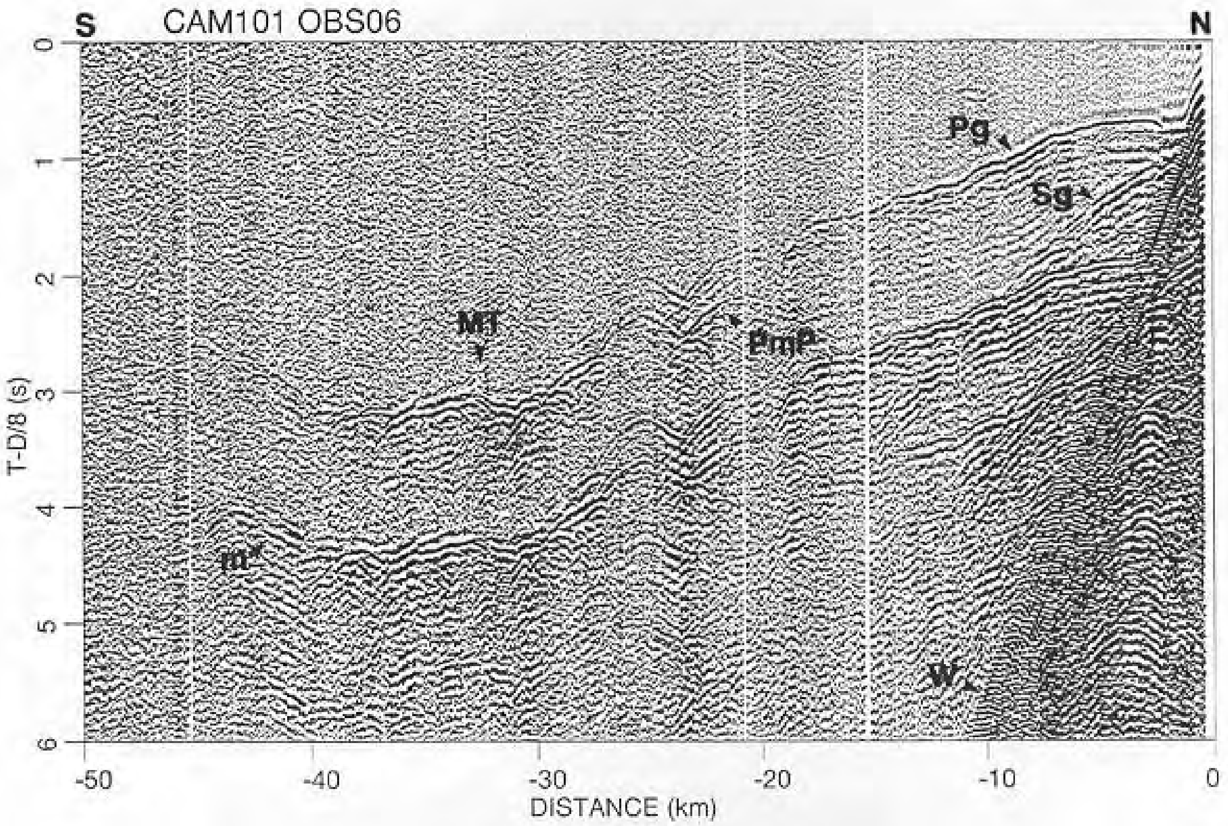

Figure 4. Wide-angle seismic section recorded at OBH06 on line CAM101 shot north-south down the eastern transverse ridge at the Atlantis II Fracture Zone. The OBH location is at 0 km offset on the northern side of the section. Phases identified are: W, direct water-wave; Pg and Sg, P-wave and S-wave turning rays in the crust; PmP, P-wave reflection off the Moho; MT, Moho triplication; and m sea floor multiple.

crustal thickness varies along the profile between 3.7 and 4.9 km. The average of 4.4 km is significantly less than the 7 km thickness typically observed for normal oceanic crust.

(2) A crustal thickness of 4.4 km is probably a minimum for normal ridges spreading at 16 mm/yr because there is likely to be an additional reduction in mantle melting along CAM101 due to its proximity to the Atlantis II Fracture Zone. Also, 735B appears to be located on tectonically thinned crust where upper crustal basalts have been removed by extensional faulting (Dick et al, 1991).

(3) Since the modelled profile lies along a flow line, the observed lateral variations in crustal thickness correspond to temporal variations. It appears that the volume of melt generated or available at the ridge axis adjacent to the fracture zone has varied with time. If a section of upper crustal basalts, removed from a portion of the profile by tectonics (Dick et al., 1991) is restored, it is possible that the original lateral crustal thickness variations were larger than observed at present.

References

Bown, J. W., and R. S. White, Variation with spreading rate of oceanic crustal thickness and geochemistry, Earth Planet. Sci. Lett., 121, 435-449, 1994.

Dick, H. J. B., H. Schouten, P. S. Meyer, D. G. Gallo, H. Bergh, R. Tyce, P. Patriat, K. T. M. Johnson, J. Snow and A. Fisher, Tectonic evolution of the Atlantis II Fracture Zone, Proc. ODP Sci. Res., 118, 359-398, 1991.

Francis, T. J. G., and R. W. Raitt, Seismic refraction measurements in the southern Indian Ocean, J. Geophys. Res., 72, 3015-3041, 1967.

Iturrino, G. J., and N. I. Christensen, Reflectivity modelling of the layer 3 gabbroic sequence drilled at the Atlantis II Fracture Zone, Proc. ODP Sci. Res., 118, 245-251, 1991.

Jackson, H. R., I. Reid and R. K. H. Falconer, Crustal structure near the Arctic mid-ocean ridge, J. Geophys. Res., 87, 1773-1783, 1982.

Osler, J. C., and K. E. Louden, Crustal structure of an extinct rift axis in the Labrador Sea: preliminary results from a seismic refraction survey, Earth Planet. Sci. Lett., 108, 243-258, 1992.

Patriat, P., and J. Segoufin, Reconstruction of the Central Indian Ocean, Tectonophysics, 155, 211-234, 1988.

Swift, S. A., H. Hoskins and R. A. Stephen, Seismic stratigraphy in a transverse ridge, Atlantis II Fracture Zone, Proc. ODP Sci. Res., 118, 219-226, 1991.

White, R. S., D. McKenzie and R. K. O'Nions, Oceanic crustal thickness from seismic measurements and rare earth element inversions, J. Geophys. Res., 97, 19683-19715, 1992.

MODE '94

Active Hydrothermal Systems of a Super-fast Spreading Ridge, Southern East Pacific Rise (13°58'S to 18°26'S)

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Introduction

A series of 15 dives designed to evaluate heat and material fluxes from active hydrothermal vents were successfully performed with the deep-sea manned submersible Shinkai 6500 of the Japan Marine Science and Technology Center, at the super-fast spreading center portion of the East Pacific Rise. This report summaries Leg 4 of MODE '94 (Mid Ocean ridge Diving Expedition) which is part of the Ridge Flux Project funded by the Science and Technology Agency of Japan, in collaboration with the NOAA/VENTS program. An earlier cruise (Leg 3) also comprised 15 dives as part of the Ridge Flux Project and performed similar tasks to those described here for Leg 4; some of the Leg 3 dive sites were re-visited during Leg 4. As a precursor to both Legs 3 and 4, an extensive CTDTN tow-yo survey was conducted during the Ridge Flux *RV Melville* cruise in December 1993, during which extensive hydrothermal plumes were mapped along much of the super-fast spreading ridge axis.

The 36 day cruise started in Valparaiso (Chile) on 25 October and ended in Papeete (Tahiti) on 29 November1994. During this cruise detailed submersible investigations were made at the following sites; RM04 (13°58'S), 24 (17°26'S), 23 (17°35'S), 29 (18°10-11'S), OSC-1822 (18°22'S) and 28 (18°26'S;) (see Fig. 1). Hydrothermal fluid sam-

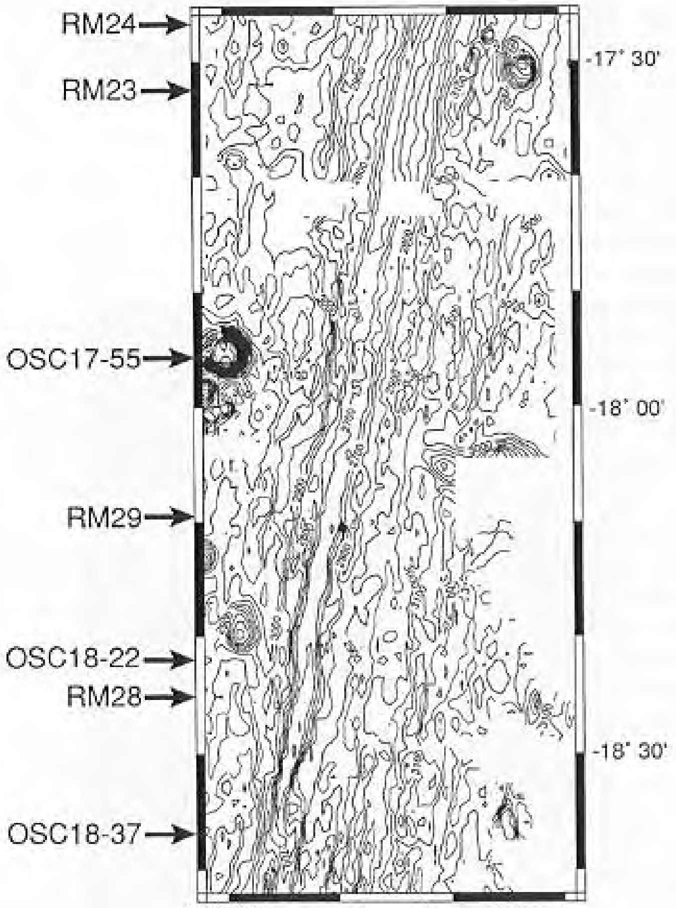

Figure 1. Bathymetric map of the southern East Pacific Rise area, including the various sites visited during MODE '94 Legs 3 and 4 mentioned in the text. The exception is the RM04 site which is located to the north of RM24. Arrows signify the location of the cross-sections shown in Figure 2. OSC= overlapping spreading center; RM= ridge Melville (i.e., site delineated during the *R/V Melville* cruise of December 1993.

ples, rocks, sediments, biological samples and geophysical measurements were obtained during Leg 4, together with video and still photographic visual records along the submersible's track lines. Bathymetric and magnetic data along the *R/V Yokosuka* track lines were obtained at night.

Objectives

The four main objectives of this cruise were; (1) to detail observations of the seafloor, including the mapping of cracks, fissures, and faults along and across normal ridge crest, as well as an overlapping spreading center (OSC), in order to obtain a cross-sectional overview and topographical and geological data pertaining to the super-fast spreading center, (2) to sample hydrothermal end-member fluids, including diffuse fluids, so that we could characterize the various types of venting along this part of the East Pacific Rise and in so doing, better understand their relationship to the extensive overlying plumes, (3) to analyze by geophysical means, the precise crustal and upper mantle structures in the area and conduct heat flow measurements to better constrain the dynamics of super-fast ridge-related processes, and (4) to conduct surface ship swath mapping with a multi narrow-beam echo sounder, together with a proton and three component magnetometer, along this super-fast spreading segment of the southern East Pacific Rise.

Titanium piston gas-tight samplers and an eight cylinder pump sampling system array were used to collect the hydrothermal fluid samples, and combined with SUAVE (a Submersible system Used to Assess Vent Emission), formed the sampling basis by which end-member samples of focused and diffuse vent fluids were collected. Fixed volume Niskin bottles were used to sample the hydrothermal plumes. An ocean bottom seismometer hydrophone (OBSH) array coupled with an air gun system were used to obtain the seismic data. Long-term and short-term heat flow measurements using a 'Zabuton'-type setup were utilized for the heat flow studies.

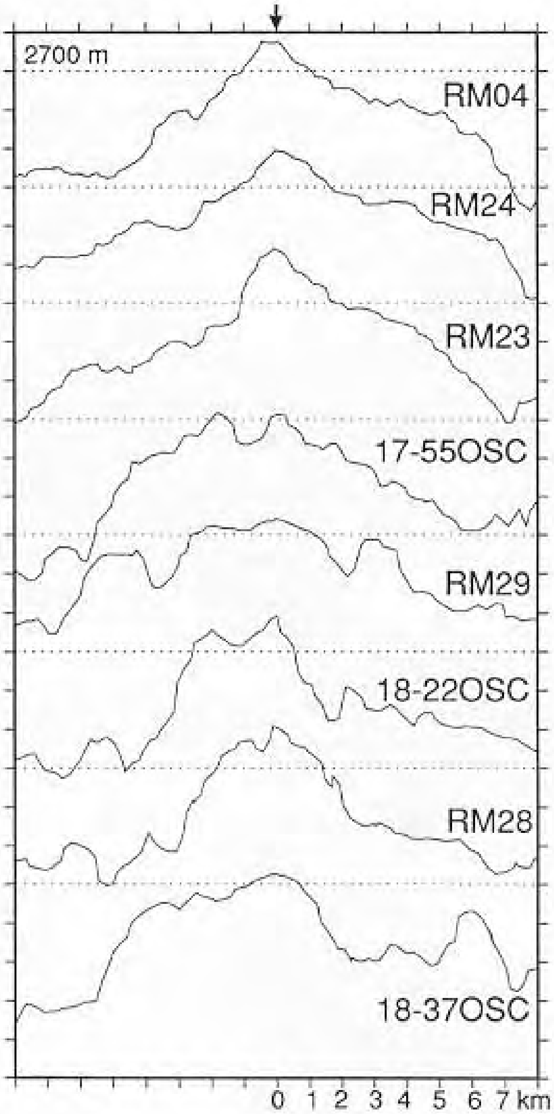

Figure 2. Cross-axis profiles of the southern East Pacific Rise in selected areas (see Fig. 1 for site locations). The small arrow at the top of the figure signifies the position of the ridge crest. The dotted line which transects each of the cross-sections marks the 2700 m water depth at each site. The tick marks on the vertical axis correspond to intervals of 100 m water depth. The RM28 site is the most mature of the ridge crestal areas visited during Leg 4, whereas those of RM23 and RM24 represent the most primitive stage of ridge formation in the area.

Summary of the results

Topography and geology

A topographic survey was conducted between 13°53' and 20° S using the HS-10 multi-narrow beam system which resulted in bathymetric data along 3760 nautical miles of ridge crest and adjacent areas. Precise topographic and back scattering image maps were drawn for the following survey areas (from north to south); RM04, RM24, RM23, OSC-1755, RM29, OSC-1822, RM28 and OSC-1837 (see Fig. 1). The morphology of the ridge crestal area is different in each of the mapped regions (Fig. 2). Consideration of the morphological and geological features of each area enabled us to order them in terms of relative maturity. For example, the RM23 and 24 sites (Fig. 2) represent the most primitive stage of ridge formation, with at least three different ages of basalt, few fissures, and no grabens (Fig. 3a). The RM04 site is a more mature site, with grabens 20-40 m wide and 10 m deep. The RM29 site

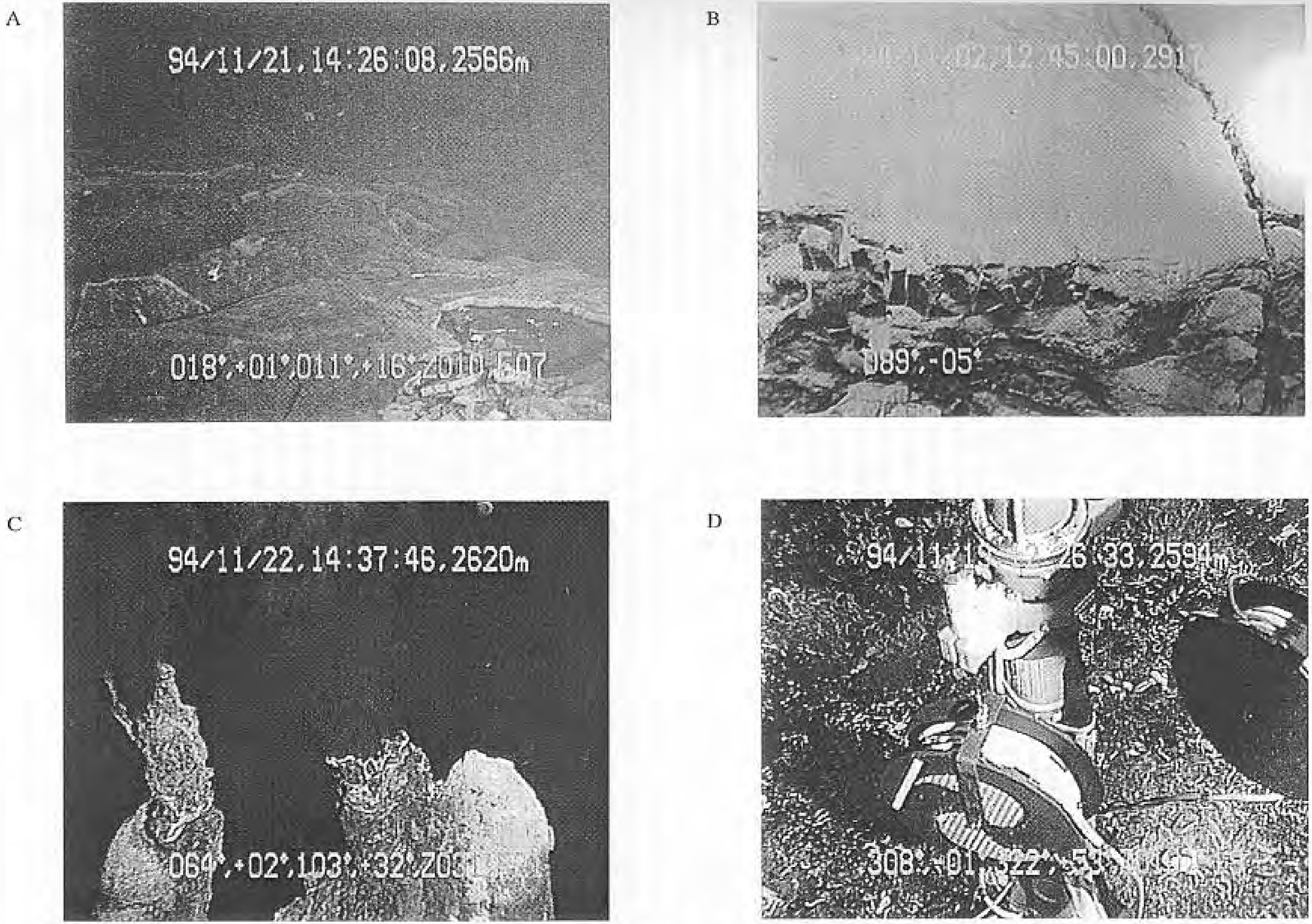

Figure 3. Selected photographs of the study area. (a) Collapse structures of lava flows at RM24, (b) Open fissures, cracks, and sediment cover at OSC-220, (c) Close-up view of two vents at the top of the 348°C Pagoda chimney, RM04, and (d) Deployment of a cable-type heat flow meter at RM23.

is older still, having a small rift and a gash, ~50 m wide. Finally, the RM28 site appears to be the oldest site within the study area, with a large axial graben that is more than 150 m wide (Fig. 2).

Mid-ocean ridges with fast rates of spreading have overlapping spreading centers as the most prominent form of ridge crest segmentation. During Leg 4 we traversed three overlapping spreading centers at 17°55'S, 18°22'S and 18°37'S (Fig. 2).

The rocks of the flank regions are dominated by sedimented pillow lavas which form combinations of gentle and steep slopes, and groove and spur structures (Fig. 3b). Near the crestal summit, pillow lobes, tubes and fingers predominate, forming slightly steeper slopes. In the crestal areas, sheet flows are platy, and ropy lavas thinly dusted by sediments are commonplace. Cavern and collapse structures—like those of the Hawaiian lava lakes—were also noted. Pillar structures were also frequently encountered.

At least nine active hydrothermal vents with focused and diffuse flows were found at the RM28, RM29, RM24 and RM04 sites (see Fig. 3c). The maximum temperature measured from a black smoker was 374°C at the Shirakaba vent (RM04). The chimneys are oriented both north-to south and east-west within graben and rift structures. Thirty-six basalt samples, 6 push core sediment samples, 13 filtration sediment samples, together with 13 sulfide chimney samples were collected from a variety of sites including hydrothermal vents, ridge crest, flanks and slopes.

Geophysics

Three new heat flow instruments (long-term heat-flow monitoring system with Zabuton sensors, long-term heat-flow monitoring system with cable sensors, and Zabuton-type heat flow meter) were developed in order to obtain heat flow data from the ridge axis where conventional heat flow measurement techniques have failed, due largely to thin sediment cover. The long-term heat-flow monitoring system with Zabuton sensors and Zabuton-type heat flow meter were successfully deployed on lightly sedimented pillow basalt in the central graben of the RM28 site. The long-term heat-flow monitoring system with cable sensors attached to two cables, each 23 m in length, was deployed at a diffuse vent site on the ridge crest of RM23 (Fig. 3d). The latter instrument will record continuous heat flow measurements over a one year period.

Seven OBSH's were deployed within an area 5 nautical miles in diameter at OSC-1822. All of the OBSH's were successfully recovered with each having recorded high quality, continuous data, over periods between 11 and 16 days. A seismic experiment using the airgun-OBS array system was conducted at night and during non-diving days, between 1-6 November 1994. Seven airgun lines with lengths between 30 and 40 nautical miles were surveyed to delineate small-scale seismic velocity structures beneath OSC-1822. A 20 liter airgun with a firing interval of 40 seconds at a ship speed of 4 knots provided a spatial resolution of about 80 m. The total number of the shots fired amounted to 8155.

A portable hydrophone recorder was used to record micro-tremors related to hydrothermal activity and was deployed within a few meters of the 343°C Dragon Teeth black smoker, at RM28. The portable hydrophone recorder was recovered during a later dive and was found to have successfully recorded 6 hours of data.

Other surface ship geophysical measurements, such as multibeam bathymetry and magnetics, were carried out between dive operations and during the maintenance days of the *Shinkai 6500*, and covered approximately 3800 nautical miles on-and-off the ridge axis of the south East Pacific Rise, between 13° 53' and 20° S.

Geochemistry

Samples of focused and diffuse vent fluids were collected for determination of end-member concentrations of gaseous and ionic chemical species. Titanium piston, titanium gas-tight, and 8-chamber acrylic pump (ORI) samplers were used with a Pt resistance temperature probe to assure that samples of high-integrity were obtained. Focused fluids collected from venting sites at RM28, RM29 and RM04 define a wide range of end-member chemistries. For example, the RM28 and RM04 sites have chloride end-member concentrations that are significantly lower than that of seawater (<25%) and high concentrations of gases (e.g. up to 20 mmol/kg H_2S at RM28), suggesting that they contain a significant fraction of a phase-separated, condensed vapor. Conversely, fluids from the RM29 site have chloride concentrations significantly higher than that of seawater (>150%) and low gas contents, consistent with being a phase-separated brine. However, conjugate phases of chloride-depleted, gas-rich fluids and chloride-enriched, gas-poor fluids were never detected at any one site. High metal concentrations were observed at all of the focused sites, with extreme dissolved Fe/Mn ratios of ~9 recorded at RM04. Diffuse fluids were also collected from the RM28, RM04 and RM24 sites. Further samples were collected from buoyant plumes at all of the the above mentioned sites. The buoyant plume samples were low in pH (7.2 ~ 7.6) and high in hydrogen sulfide concentration relative to ambient sea water. A comprehensive set of fluid and plume particle data from the 372°C Kasuga Shrine black smoker (RM28) was collected during Leg 4. Temperature, Mn and Fe measurements were made in-situ at both diffuse vents and in the buoyant and neutrally buoyant plumes by SUAVE. The SUAVE determinations will be used to compare metal/heat ratios in sources to plumes measured at these sites during the *R/V Melville* Ridge Flux cruise.

Finally, an on-line filtration system was adapted to the ORI pump sample system. A total of 13 hydrothermal related sediment samples—ranging from pure sulfide sediments through to various Fe-oxide sediments—were successfully recovered from hydrothermal sites at RM28 and RM04.

Biology

Microbial sampling at both high temperature chimney and shimmering sites was performed in order to estimate microbial biomass and activity with direct enumeration and incubation, respectively, and should help to elucidate the reasons for heterogeneous distribution of organisms around hydrothermal vent systems.

JOIDES - Ocean Drilling Program at the Ridge Crest

Ocean Drilling Program Reveals the Subsurface Nature of the TAG Hydrothermal Mound

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The TAG hydrothermal field is located on the Mid-Atlantic Ridge at 26°N between the Atlantis and the Kane fracture zones (Fig. 1). The field extends over an area of at least 25 km^2 along the eastern wall of the median valley in the center of a 40 km-long ridge segment between 25°55'N and 26°17'N and consists of presently active low- and high-temperature zones as well as a number of relict deposits (Rona et al., 1993). Massive sulfides, black smokers and vent biota of the active TAG hydrothermal mound were discovered in 1985 (Rona et al., 1986), although first indications of hydrothermal activity in the area were documented much earlier (Rona et al., 1975).

The TAG active mound at 26°08'N, 44°49'W is a large (3-5 million tons), mature massive sulfide deposit and represents one of the closest modern analogs of ancient ophiolite-hosted massive sulfide deposits on land. A unique feature of TAG is the almost circular shape of the active mound which measures about 200 m diameter and 30-40 m in height. The TAG mound occurs at the junction between the rift-valley floor and the east wall and lies on oceanic crust at least 100,000 years old, based on a spreading half rate of 13 mm/yr to the east (McGregor et al., 1977). Recent bathymetry data indicate that the morphology of the mound is characterized by two relatively flat platforms at depths of 3650 and 3645 m which may represent two major phases of hydrothermal activity (Humphris et al., 1994).

The surface morphology and mineralogy of the TAG mound have been described in detail by Thompson et al. (1988), Herzig et al. (1991), Rona et al. (1993), and Tivey et al. (1995). A cluster of black smoker chimneys (Black Smoker Complex, Fig. 2) emitting fluids up to 363°C and consisting mainly of chalcopyrite and anhydrite is located on the upper platform northwest of the center of the mound on top of a 10-15 m high, 20-30 m diameter cone. The surface of this cone is covered by a 3-6 cm thick plate-like layer of massive chalcopyrite and marcasite, and large blocks of corroded massive anhydrite. Lower-temperature, sphalerite dominated white smoker chimneys with fluid temperatures of 260°-300°C (Kremlin area, Fig. 2) occur about 50-70 m southeast of the Black Smoker Complex. The Kremlin fluids have a low pH (3 at 23°C), which is unusual for white smokers, and they are thought to be derived from the black smoker fluids by a combination of conductive cooling (keeping the pH low) and mixing with seawater in the subsurface (Tivey et al., 1995).

Geochronological studies suggest that the TAG mound is on the order of 40,000-50,000 years old and that hydrothermal activity has been intermittent over the past 20,000 years. High-temperature pulses occurred about every 5000-6000 years and the present black smokers have been active for at least 50 years (Lalou et al., 1990, 1993).

Leg 158 of the Ocean Drilling Program was designed to investigate for the first time the subsurface nature of a volcanic-hosted, sediment-free, active hydrothermal system at the modern seafloor. Important issues that were addressed include the nature of water-rock and seawater-hydrothermal fluid interactions, geochemical fluxes, and associated alteration and mineralization. Between September 29 and November 22, 1994 a total of seventeen holes were drilled in five areas (TAG-1 to TAG-5, Fig. 2) across the TAG mound, including the active Black Smoker Complex and the white smoker Kremlin area. Drilling in the TAG-1 (Black Smoker Complex), TAG-2 (Kremlin), and TAG-4 (west of the Black Smoker Complex) areas revealed a northwest-southeast cross-section of the mound with a maximum penetration of 125 m. This was complemented by drilling south (TAG-3) and north (TAG-5) of the Black Smoker Complex in order to delineate lateral heterogeneity of the sulfide deposit, and the extent and nature of the underlying stockwork zone.

Recovery was highly variable, ranging from <1 to 63% with an average of about 12% (52 m of core out of 436 m total interval cored). Breccias of various types dominate the stratigraphy of the entire mound including the sulfide section and the upper part of the underlying stockwork zone. The complex assemblages of matrix and clast-supported breccias consisting of varying proportions of pyrite, anhydrite, and silica

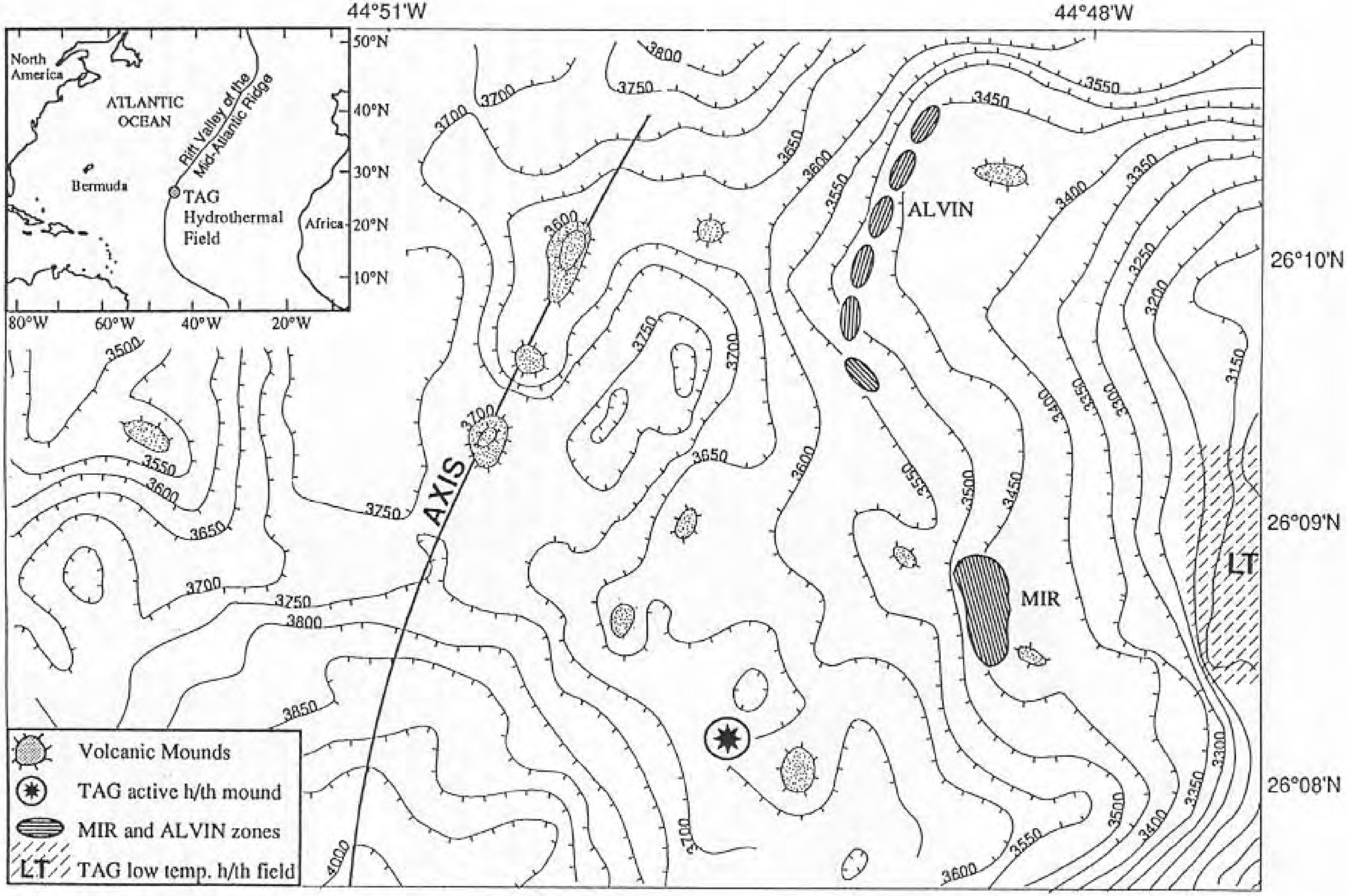

Figure 1. SeaBeam bathometry (50-m contour interval) of the TAG hydrothermal field, showing volcanic domes, the active TAG hydrothermal mound, the low-temperature hydrothermal field on the eastern rift-valley wall, and the Alvin and Mir relict hydrothermal zones (modified from Rona et al., 1993).

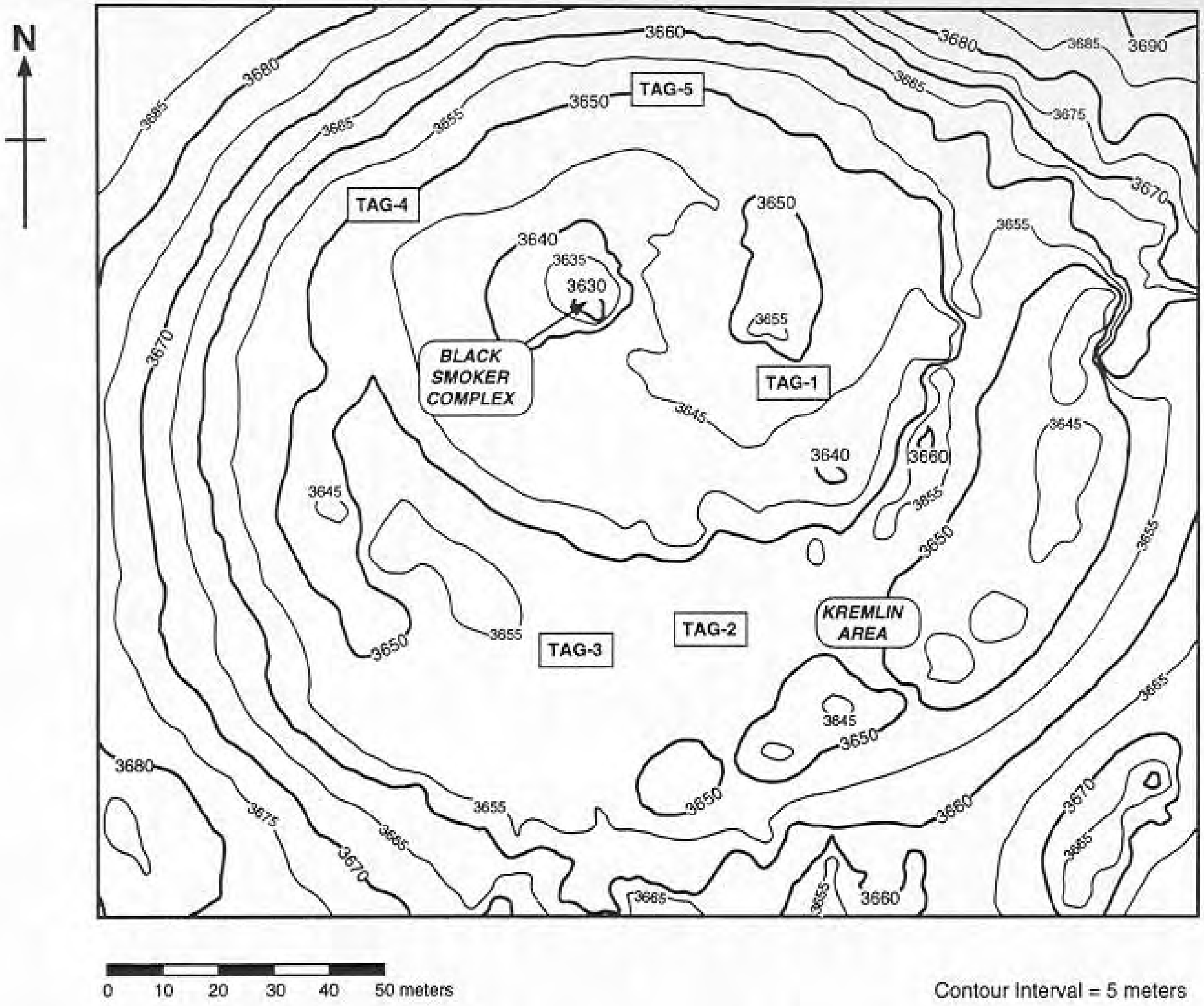

Figure 2. Bathymetry (5-m contour) of the active TAG mound showing the location of the ODP Leg 158 drilling areas TAG-1 to TAG-5.

is a product of the multistage development of the mound including episodes of chimney growth and collapse, mass-wasting, faulting, cementation, hydrothermal reworking, and replacement. The sulfide breccias that are now at the base of the mound likely accumulated at the seafloor through the collapse of large sulfide chimneys and by dissection of massive sulfides along active fault scarps and have since been buried, overprinted, replaced or cemented by quartz, sulfides, and sulfates during later hydrothermal events.

Based on the sequence of rock types recovered from each area, four major lithologic types were distinguished. The upper 10-20 m of the mound consist of massive pyrite and pyrite breccias. This is underlain (20-30 m) by an anhydrite-rich zone, consisting of matrix-supported pyrite-anhydrite breccias and pyrite-anhydrite-silica breccias, which is best developed in the TAG-1 area but was also found at TAG-5. At depths of about 40-45 m, quartz-pyrite mineralization and quartz veining increase and indicate the top of the stockwork zone. This suggests that the thickness of the mound in the TAG-1 area (Black Smoker Complex) is about 30-40 m. The sulfide assemblage is clearly dominated by pyrite with only minor amounts of chalcopyrite and sphalerite. Drilling in the TAG-2 area indicated that the thickness of the sulfide mound beneath the Kremlin is only about 25 m. The stockwork itself consists of quartz-pyrite breccias overlying silified wallrock breccias which grade into a quartz-chlorite zone below about 100 m depth. This zone contains abundant chloritized and only weakly mineralized basalt breccias consisting of 1-5 cm clasts of altered basalt in a matrix of quartz and pyrite.

The amount of anhydrite found in the TAG drill cores was unexpected. Anhydrite is most abundant between 15-40 m depth in the TAG-1 area east of the Black Smoker Complex. Here, the pyrite-anhydrite and pyrite-silica breccias are crosscut by massive anhydrite veins up to 45 cm in width. These veins comprise complex, multistage fracture fillings and cavity linings, some of which include fine-grained, disseminated pyrite and chalcopyrite, and trace amounts of hematite. The presence of anhydrite is interpreted as a product of seawater heating by mixing with high-temperature fluids of the central upflow zone to temperatures above 150°C. The driving force for seawater inflow is obviously the high velocity discharge of hot fluids at the Black Smoker Complex.

Drilling at the TAG mound has documented the complex nature of subsurface sulfide formation at seafloor spreading centers. Hydrothermal replacement, rather than sulfide precipitation at the seafloor, appears to be the dominating process of sulfide accumulation at TAG. A complex program of detailed studies on the TAG drill core will address a number of fundamental questions related to the formation and evolution of hydrothermal systems and massive sulfide deposits at the modern seafloor and their ancient analogs on land.

References

Herzig, P.M., M.D. Hannington, S.D. Scott, G. Maliotis, P.A. Rona and G. Thompson, Gold-rich seafloor gossans in the Troodos Ophiolite and on the Mid-Atlantic Ridge, Econ. Geol., 86, 1747-1755, 1991.

Humphris, S.E., M.C. Kleinrock and the Deep-TAG Team, Detailed morphology and the distribution of venting at the active TAG hydrothermal mound, 26°N, Mid-Atlantic Ridge, Eos, Trans. AGU, 75, 660, 1994.

Lalou, C., G. Thompson, M. Arnold, E. Brichet, E. Druffel and P.A. Rona, Geochronology of TAG and Snake Pit hydrothermal fields, Mid-Atlantic Ridge: Witness to a long and complex hydrothermal history, Earth Planet. Sci. Lett., 97, 113-128, 1990.

Lalou, C., J.L. Reyss, E. Brichet, M. Arnold, G. Thompson, Y. Fouquet and P.A. Rona, New age data for Mid-Atlantic Ridge hydrothermal sites: TAG and Snakepit geochronology revisited, J. Geophys. Res., 98, 9705-9713, 1993.

McGregor, B.A., C.G.A. Harrison, J.W. Lavelle and P.A. Rona, Magnetic anomaly pattern on the Mid-Atlantic Ridge crest at 26°N, J. Geophys. Res., 82, 231-238, 1977.

Rona, P.A., B.A. McGregor, P.R. Betzer, G.W. Bolger and D.C. Krause, Anomalous water temperature over Mid-Atlantic Ridge crest at 26° North latitude, Deep Sea Res., 22, 611-618, 1975.

Rona, P.A., G. Klinkhammer, T.A. Nelsen, J.A. Trefry and H. Elderfield, Black smokers, massive sulphides and vent biota at the Mid-Atlantic Ridge, Nature, 321, 33-37, 1986.

Rona, P.A., M.D. Hannington, C.V. Raman, G. Thompson, M.K. Tivey, S.E. Humphris, C. Lalou and S. Petersen, Active and relict seafloor hydrothermal mineralization at the TAG hydrothermal field, Mid-Atlantic Ridge, Econ. Geol., 18, 1989-2017, 1993.

Thompson, G., S.E. Humphris, B. Schroeder, M. Sulanowska and P.A. Rona, Active vents and massive sulfides at 26°N (TAG) and 23°N (Snakepit) on the Mid-Atlantic Ridge, Can. Mineral., 26, 697-711, 1988.

Tivey, M.K., S.E. Humphris, G. Thompson, M.D. Hannington and P.A. Rona, Deducing patterns of fluid flow and mixing within the active TAG mound using mineralogical and geochemical data, J. Geophys. Res., in press.

Preliminary Description of the Micro-scale Ecology of a Hydrothermal Vent Chimney at 9°50'N on the East Pacific Rise

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A preliminary effort was made to document the small-scale biological and environmental features of hydrothermal chimneys as part of an experiment conducted in October 1991, during the French-American HERO cruise on the East Pacific Rise at 9°50'N. Four dives were made at a depth of 2500 m with the submersible Nautile, in the area where American teams witnessed dramatic changes in hydrothermal activity some months before.

Site and sample description

A perviously undescribed active site (marker PP#5) was found on the upper part of the graben wall, and consisted of about 15 small spires. Half of them were inactive and most were less than 1 m high. The faunal assemblage was quite diverse for such a small and apparently young site. The site was, however, older than those found at the graben axis. Fauna included about 30 *Riftia pachyptila* tubeworms located on the northeastern flank of the mound, a few *Bathymodiolus thermophilus* mussels, bythograeid and galatheid crabs, and zoarcid fish, none being abundant. The limpet coverage on the *Riftia* tubes was not dense. Alvinellid worms were present but only *Alvinella pompejana* was actually seen and sampled. A few *A. pompejana* had built tubes on top of the mound, between the chimneys, but most of them covered the lower half of the highest spires.

One of the two biggest spires (ca 2.5 m high and 20 cm wide) was chosen for this study. It was active and half covered with 20-30 *A. pompejana*. The top section, a very fragile and powdery «beehive» structure, was destroyed during temperature measuremnets of the 330°C black-smoker fluid. Following this was a section without conspicuous fauna, but with a lot of small white «flakes» believed to be elemental sulfur or amorphous silica. These flakes were so light that it was impossible to sample them along with the chimney. The first *A. pompejana* appeared 40-50 cm from the top, where temperature did not exceed 40°C. In this third and lower part of the chimney, tubes were sparse and directly in contact with the chimney walls. They had apparently been built up vertically. Temperature, pH and sulfide (S_2) concentration were measured along the chimney walls to document the physical-chemical gradient.

A significant part of the spire was sampled by the submersible and brought back to the surface in the Nautile's insulated basket. On board, subsampling was conducted in sterile conditions along and across the chimney.

Mineralogy

When looking at a cross-section of the chimney, the mineralogy appeared to be somewhat atypical due to the supposed young age of the site. The mineral zonation across sections was weak, with (1) a very thin dark external layer in the *A. pompejana* zone, then (2) a small wall of indurated sulfides, and (3) a large central part made of very powdery sulfides. Hydrothermal fluid is supposed to have circulated through the whole central part, as no differentiated pipe could be found. The minerals were analysed by X-ray diffraction. In the thin external layer (1), elemental sulfur, opal (SiO_2) and marcasite (FeS_2) were abundant. The wall (2) was primarily made of sphalerite (ZnS), and in the central part (3), the dominant minerals were sphalerite and pyrrhotite (FeS). The dominant iron sulfide in this chimney was pyrrhotite, more stable than pyrite (FeS_2) in very anoxic conditions. There was no anhydrite ($CaSO_4$), which usually precipitates when seawater diffuses within the chimney walls and meets the 160°C isotherm. We assume here that the wall was too impermiable to let the seawater reach this isotherm.

Morphologies and densities of microorganisms

Examination of the samples under the scanning electron microscope (SEM) revealed a very sharp gradient in microbial density and diversity. Outside the wall in the *Alvinella* zone, the microorganisms were very abundant, displaying a lot of different morphological types, and especially filamentous ones. Within the wall of the chimney, only rods and cocci were observed in every sample. In the central part, isolated microbial cells were sometimes observed, but in such low numbers that the possibility of contamination cannot be ruled out.

To quantify microbial abundances in the samples, standard methods of direct counting with a fluorescence microscope have been adapted to the samples' specificity, i.e. mainly, having small amounts of microorganisms within a large mineral fraction. A protocol was developed to extract and count the cells from chimney samples (Chevaldonné and Godfroy, in preparation). Outside the chimney in the *Alvinella* zone, densities reached 109 cells/g of chimney (dry weight), whereas they fell dramatically to 104 in the wall. In the central part, counts were not very statistically valid, but we can say that densities were lower than or equivalent to 103. Contamination due to the sampling procedure cannot be disregareded in this instance since the counts were at the limit of resolution of the counting technique.

Lipid analysis

A lipid analysis of the samples was then performed with the objectives of (1) quantifying the main groups of microorganisms (i.e. Bacteria and Archaea), and (2) identifying metabolic types. Examination of the ester-linked phospholipid fatty acids (PLFA) of bacterial origin was conducted through the preparation of pentafluorobenzyl (PFB) esters and subsequent gas chromatography (GC) analysis with an Electron Capture Detector (ECD). Glycerol ethers from archaeal origin were analyzed with iodide derivatives and subsequent GC and GC/Mass Spectrometry. The results showed that Bacteria were not present in every sample, while archaeal markers were found everywhere. Bacteria seemed to mostly dominate the outer thin crust of the chimney (> 105 cells/g of dry weight). They were significantly present in the chimney wall, and totally absent in the central part. Conversely, only traces of Archaea could be detected in the external crust, while they reached densities as high as 107-109 cells/g within the wall, and they were the only microorganisms detected in the central part (values must be regareded with caution, as conversion factors are not well established for Archaea). Lipid signatures also indicated that, for Bacteria, sulphate-reducing microorganisms predominated over other metabolic types. Archaeal lipid markers could not be related to any specific metabolic type.

Enrichment cultures

Enrichment cultures were made on several types of media and under different temperature and pH conditions. Positive cultures were generally obtained only from complex sulfur-containing organic media. A qualitative hybridization of the DNA of these enrichment cultures with the DNA of reference strains, demonstrated that most of them belonged to the archaeal order Thermococcales. Enrichments on a medium for thermophilic autotrophic sulfur-dependent bacteria at 60° and 90°C were negative, although microorganisms of various morphological types were present in the sample. Enrichments on a medium for methanogens at 60° and 90°C were negative except in one case, at 60°C for a sample from the outer crust.

Summary

In summary, the chimney was made of three main parts:

- The thin outer layer with *Alvinella pompejana* where microbial density and diversity was high. Microorganisms were mainly Bacteria.
- In the chimney wall, microbial density is much lower, but there were significant amounts of both Archaea and Bacteria.
- Within the center of the chimney, there were indications of microbial occurrence (only Archaea?) but quantification was difficult and contamination possible.

An extensive use of quantitative and qualitative molecular techniques applied to this kind of studies has recently been initiated to further investigate chimney microbial life (Chevaldonné and Godfroy, unpublished data).

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A New System for Sampling and Monitoring Hydrothermal Fluids: Hydro-Bottom-Station

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Introduction

With the growing number of discoveries, detailed geochemical studies of submarine hydrothermal areas have increased significantly in recent years. These studies concentrate mainly of hydrothermal precipitates, hard rocks and sediments from active chimney fields. Another major point of interest are the discharged hydrothermal fluids. However, sampling of vent waters has only been possible by the use of submersibles and, therefore, only a relatively small number of water analyses are available. Furthermore, sampling efforts generally concentrate only on fluids from active chimneys, while it must be kept in mind that two types of hydrothermal fluid discharge exist: (1) a disperse type, which is recognised by such effects as shimmering water and color changes in ocean floor sediments, and (2) a focused type, commonly known to form black and white smokers. Chemical studies of hydrothermal fluids have concentrated on active chimneys and little is known about the chemistry of fluids from disperse discharge sites, These areas are, however, of particular interest since disperse emanation represents not only a major amount of hydrothermal fluids quantitatively, but also plays an important role in the formation process of extensive mineralized zones within the uppermost oceanic lithosphere. Sampling and measurement of disperse discharged hydrothermal fluids will also provide useful information for the balancing of chemical fluxes in active hydrothermal areas.

Since the currently used water sampling and measuring systems do not allow controlled water sampling directly from hydrothermal emanation centers, we have developed a concept for sampling and monitoring hydrothermal fluids from disperse low-to-medium temperature emanation sites.

Concept

The Hydro-Bottom-Station (HBS) consists of seven main components (Fig. 1): tripod, hydraulic water samplers, sampling unit, temperature sensors, acoustic flow meters, central control unit for on-line data transmission and an on-line color camera system. The components are independently housed to provide flexibility in mounting capabilities for different experiment designs. The central control unit is designed for the use of an optical cable combined with power transmission to allow on-line real-time two-way data transmission and to provide the HBS-System with power. Since the operation of deep-sea submersibles is rather expensive, we developed a TV-controlled device which, in combination with differential GPS, will provide a good and relatively inexpensive alternative for hydrothermal fluid collection.

Tripod

The tripod consists of chemical and mechanical, as well as temperature resistant material, to aid in the accurate determination of trace metals in the collected fluids. The upper instrument cage holds the hydraulic sampler unit and the control units. The frame is modular and can be assembled on the working deck of a research vessel.

Hydraulic water samplers, sampling unit

The hydraulic water samplers are operated with a hydraulic piston system and are triggered from the control unit on board the vessel. The sampling unit below the water samplers holds the sampling tubes which are connected with the valve controlled water inlets. The sampling unit is movable and is lowered to the seafloor after positioning of the device. The adjustable water inlets are equally spaced (at 0, 10, 20, 30, 40, and 50 cm) to provide a sample profile above the emanation site. The design of the water inlets follows the hydrodynamic concept of the BIOPROBE-System water inlets of Thomsen et al. (1994).

Temperature sensors, acoustic flow meters, color camera system

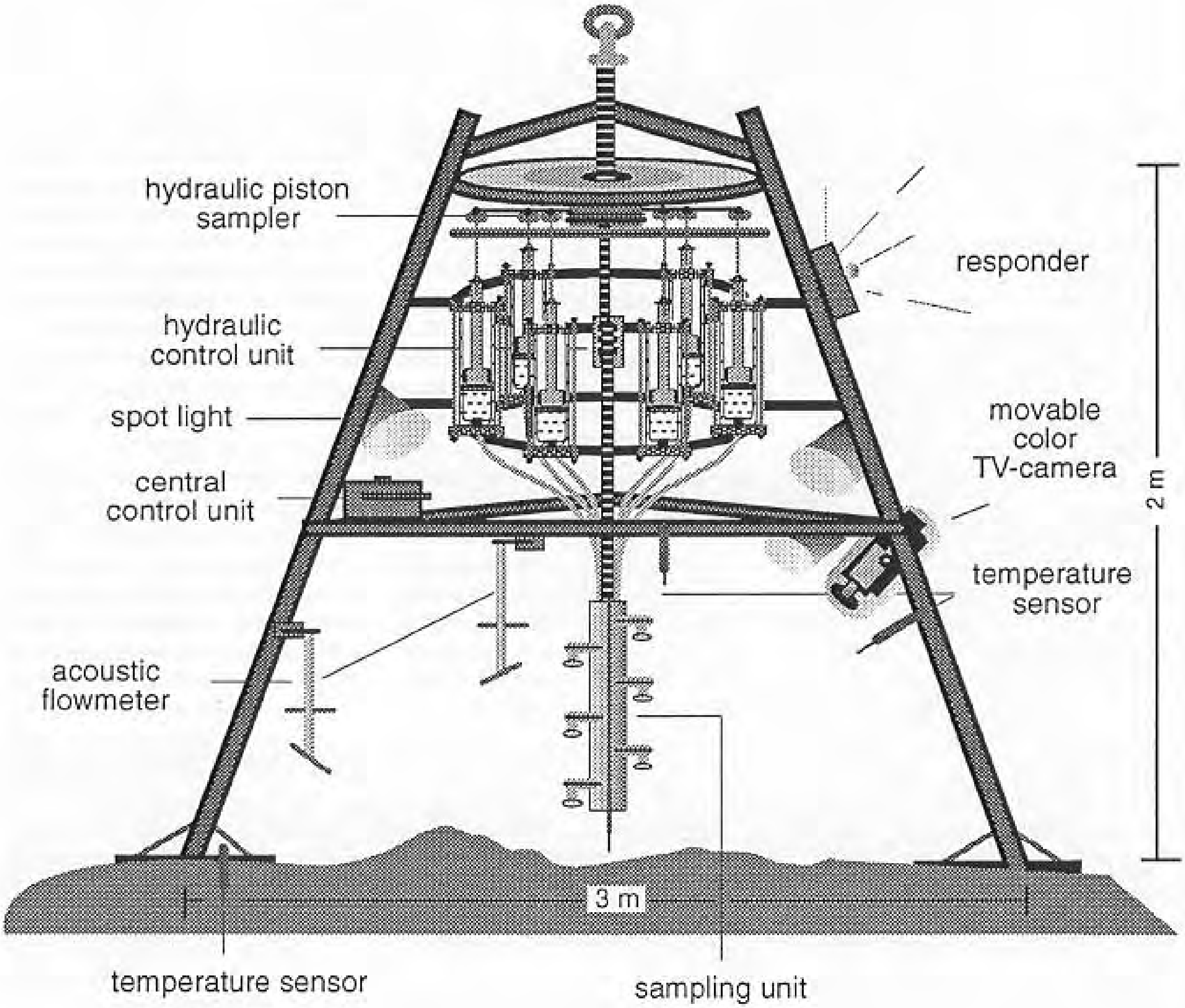
With the availability of optical data transmission in early 1996, the HBS-System will be able to use 32 bi-directional data channels which allow the integration of temperature sensors, a CTD probe and acoustic flow meters into an on-line monitoring system. The swivel-mounted color camera system is designed to locate the disperse hydrothermal emanation centers during the positioning of the HBS-System and for the production of high quality TV images.

After the installation of the new optical cable on the *R/V Sonne* and an anticipated construction time of about one and one half years the Hydro-Bottom-Station will be available by mid-1996. An initial deployment is planned during our HYDROFLUX II project in the North Fiji Basin, following earlier test operations.

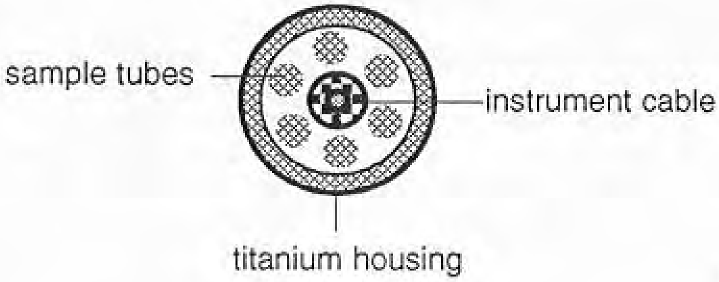
References

Thomsen, L., G. Graf, V. Martens and E. Steen, An instrument for sampling water from the benthic boundary layer, Continental Shelf Research, 14, 7/8, 871-882, 1994.

HYDRO - BOTTOM STATION (HBS)



Sampling Unit
(cross-section)



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Geophysical Study along the Easter-Salas y Gómez Volcanic Ridge (Southeast Pacific)

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Introduction

In Spring 1994, a geophysical experiment onboard *R/V Hesperides* was carried out around Rapanui (Easter Island). The study area is situated between Getu Seamount (star in the local language) which is a young seamount within the Easter-Salas y Gómez Volcanic Ridge (ESG), and the southern edge of the Easter Microplate situated west of Rapanui. The objective of this survey was to image and delineate deep crustal structures related to the ESG and the microplate. A detailed swath mapping, gravity and magnetic survey over the Getu Seamount was conducted. In addition, 400 km of multichannel seismic data (MSC) were recorded around Rapanui with simultaneous recording of the airgun shots from the *R/V Hesperides* in digital portable seismic stations deployed on the island. This area was also surveyed with swath mapping, magnetic and gravity measurements along most of the lines. In this note we report some preliminary results concerning the deep crustal structure on Rapanui and some gravity modelling of Getu Seamount.

Geological framework

The Easter microplate, one of the Southeast Pacific microplates, located between 23°and 27°S, in the axial part of the East Pacific Rise (EPR) has been extensively studied (see references in Naar and Hey, 1991). Surrounding the microplate are the ESG Ridge to the east (Pilger and Handschumacher, 1981) and the Pitcairn hot line to the west (Duncan and Clague, 1985). The microplate is located in a broad shallow region of the EPR north of the fast-spreading Pacific-Nazca plate boundary where a large-scale reorganization is presently occurring (Handschumacher et al., 1981; Hey et al., 1985; Francheteau et al., 1988; Searle et al., 1989; Naar and Hey, 1991). Side scan sonar and backscatter records show a large volcanic area north and northwest of Rapanui (Hagen et al., 1990). This broad chain of clustered volcanoes extends past Rapanui and Salas y Gómez Island and connects with the aseismic Nazca Ridge. These large areas of recent volcanism are important to the different proposed models that explain the origin of ESG Ridge. The eastern boundary of the microplate is well defined as a robust ridge with fast spreading and with a possible interaction with the "Easter hotspot" (Schilling et al., 1985; Naar and Hey, 1986). Bonatti et al. (1977) suggested an active mantle hotline along the Chain as an alternative for the fixed hotspot hypothesis (Morgan, 1972) that is not able to explain the contemporaneous age volcanism along the chain (Pilger and Handschumacher, 1981). Maia and Diament (1991) analyzing the geoid for different waveband show that ESG is associated with a remarkably continuous lineation interpreted as a high concentration of topographic features within a 25-100 km waveband. Recently, Woods and Okal (1994) proposed a thin crust along the ESG ridge after a surface waves analysis and suggested that the ESG is not a typical hotspot chain but may have been formed by another mechanism, perhaps by a leaky fracture zone. This study brings new geophysical insight to the area.

Data acquisition

The geophysical survey PASO-94 (Dañobeitia et al., 1995) has been designed to investigate the 3-D geophysical structure of an isolated young volcano of the ESG (Fig. 1): the Getu Seamount (26°52'S, 106°55'W). A total of 600 km of high resolution Simrad multibeam bathymetry were acquired together with gravity and magnetic data along 11 profiles forming a 'star shape' over the seamount. A total of 400 km of MSC data around Rapanui were recorded (11 profiles, Fig. 1). Along all these profiles we recorded simultaneously gravity, magnetic and swath bathymetry. Moreover, the airgun shots of the *R/V Hesperides* were also recorded at three sites on the island (Fig. 1).

Description of the data and preliminary results

Gravity

Preliminary modelling of the recently acquired 3-D bathymetry and gravity data over the Getu Seamount (Fig. 2), reveals a conspicuous low density value of the bulk of the seamount (average of 2.3 Kg/m^3) with a slight increase towards the seamount flanks (average of 2.4 Kg/m^3; Canales et al., 1995). The deepest part of the volcano shows a high lateral heterogeneity ranging from 2.5 to 3.1 Kg/m^3, which suggests a high degree of structural complexity of the ESG (Bonatti et al., 1977). The low density of the bulk of the volcano may possibly be associated with hydrothermal circulation processes through the highly fractured summit. Convection cells controlled by pre-existing zones of lithospheric weakness could explain the episodic volcanism along the ESG (Maia and Diament, 1991).

Multichannel Seismic

The interesting crustal structures imaged by the MCS (Fig. 1), suggest a complex tectonic history. The N-S seismic profile (Fig. 3) is characterized by two principal southward dipping reflections. Backscatter and swath bathymetry information is imperative to differentiate between intracrustal events and out-plane reflections caused by highly reflective topographic relief.

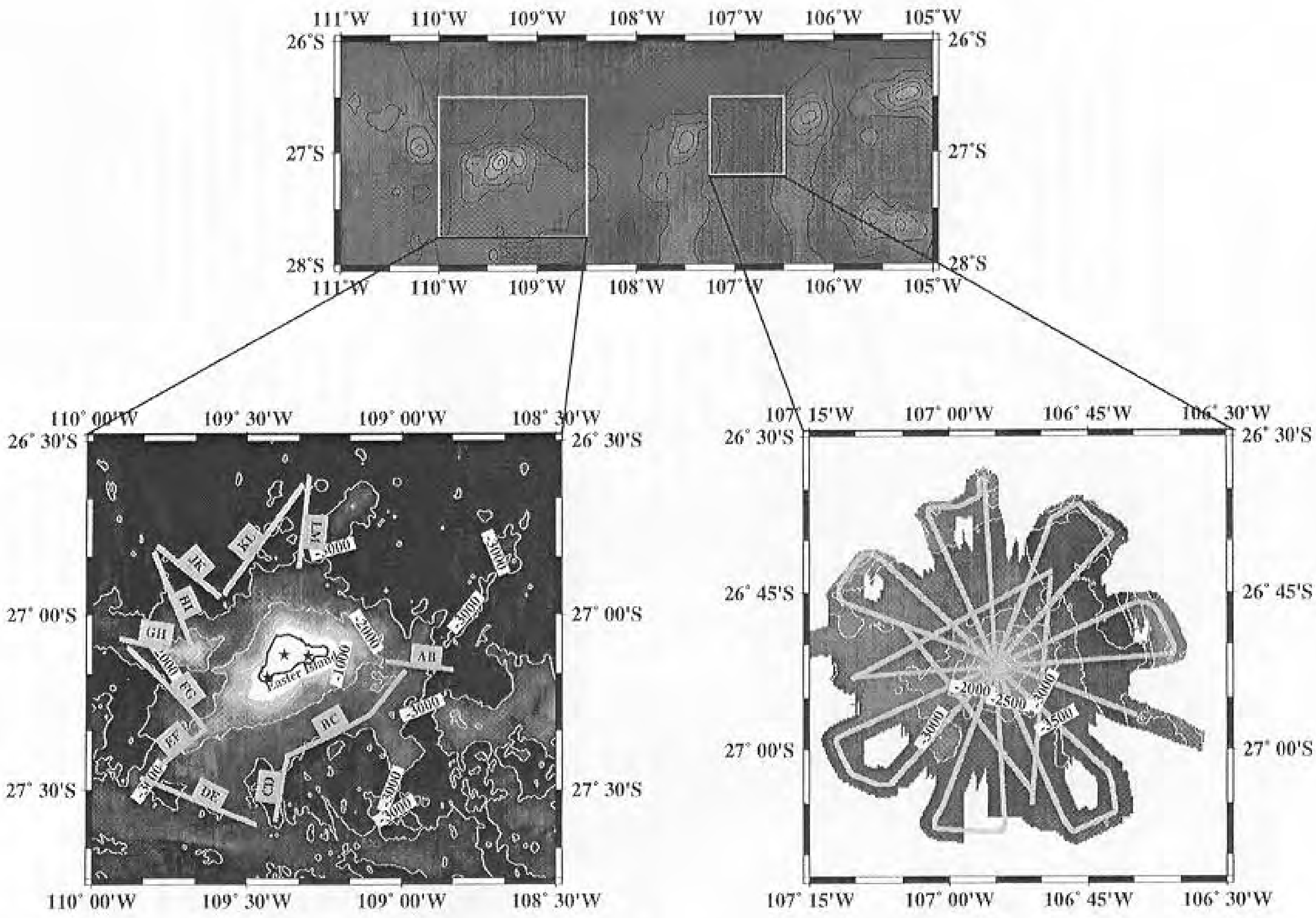

Figure 1. Location map showing the track-lines around Rapanui (left) and Getu Seamount (right). The MCS lines are marked as thick lines around the island. The stars show the location of the land-stations that recorded the shots from the *R/V Hesperides*.

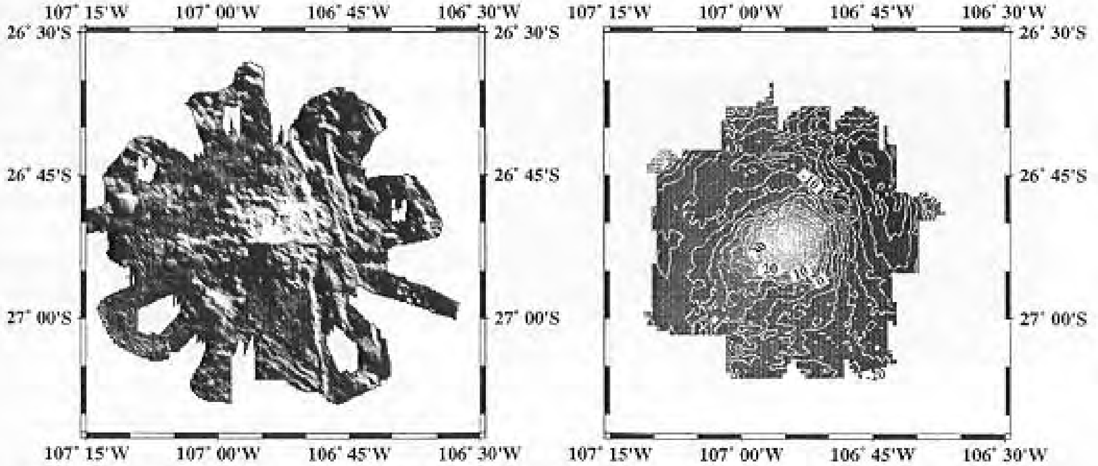

Figure 2: A 3-D view of the bathymetry (left) and free-air anomalies (right) over Getu Seamount (contour interval 10 mGal).

The northern reflection (b1) cuts the crust and merges at about 6.5 s with a relatively strong and coherent reflection. The other principal event (b2) is less pronounced although it has a similar reflectivity pattern. These reflections are made up of 3-4 packages and may be associated with volcano/tectonic processes that could be coeval with the most recent volcanic activity north of Rapanui. Whether these upper reflections mark the top of a broken basement or a volcanic level is unclear. However, the surface faulting observed on the seismic images supports the notion of a large degree of tectonism. The backscatter and bathymetry along this profile show a striking NNW-SSE seafloor fabric which together with the south or southeastward dipping reflections coincide with the direction of the pseudofault (Naar and Hey, 1991) that connects Easter microplate with Rapanui. This may indicate that the genesis of Easter microplate could be related to the hotspot ESG ridge interaction (Hagen et al., 1990).

Wide Angle Seismic Data

The shots for the MCS profiles were recorded on land by three 3-component digital stations. Therefore, the land recording consists of in-line and fan profiles, providing information on velocity-depth distribution as well as on lateral variation of structures. Unfortunately, due to logistic problems, the data set lacks the near offset (0-22 km) range. The generalized Radon was used to transform the data from time-offset (t, x) domain to intercept time-ray parameter (McMechan and Ottolini, 1980). The plane wave decomposition (tau, p) plots show well constrained ellipses. The slant stack showed that the most prominent wide-angle phase observed in the receiver gathers, is mapped at 7.6 s (normal incidence). This phase was interpreted as the reflection PmP from the crust-mantle transition (Fig. 4). A one-dimensional velocity-depth function (Fig. 4) was obtained for Vaitea station (27°07'S, 109°22'W) by using a linearized inversion scheme (Bessanova et al., 1974; Garmany, 1979). A relatively low average crustal velocity of 5.7-6.3 km/s characterizes the entire 15 km ± 3 km crust (beneath the seafloor). The crust mantle transition is defined by a velocity increase up to 7.7 km/s ± 0.3 km/s. The (tau, p) results suggest an approximately 3 km thick layer located at the crust/mantle transition with a velocity gradient from 7.7 km/s to 8.1 km/s. Therefore, the one-dimensional velocity functions suggest a relatively thick crust (15 km) close to Rapanui. The 2-D modelling using the approach of Zelt and Smith (1992) seems to indicate a slight thinning of the crust towards the ocean.

Discussion

Our preliminary results indicate that the crustal structure surrounding Rapanui is complex and might be related to the initial rift propagation, that formed the microplate superimposed upon by hotspot volcanism. The present evidence of a rather thick crust near Rapanui favour the existence of a hotspot type of volcano, instead of the thin crust model of Woods and Okal (1994). However, their surface wave results provide an estimation of the average thickness between EPR and South America, but may not be able to resolve the small-scale structure of the area. Further analysis of our different data sets will be able to delineate the crustal structure surrounding Getu and Rapanui volcanos.

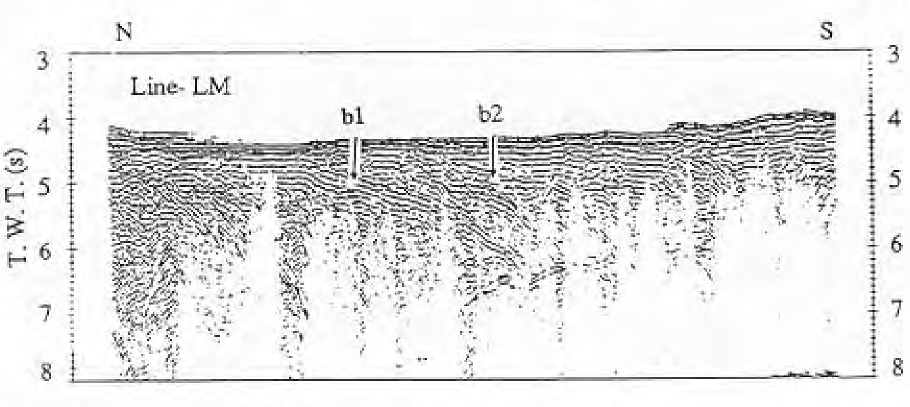

Figure 3. MCS profile LM. The main reflections are labelled by letters (see text for explanation).

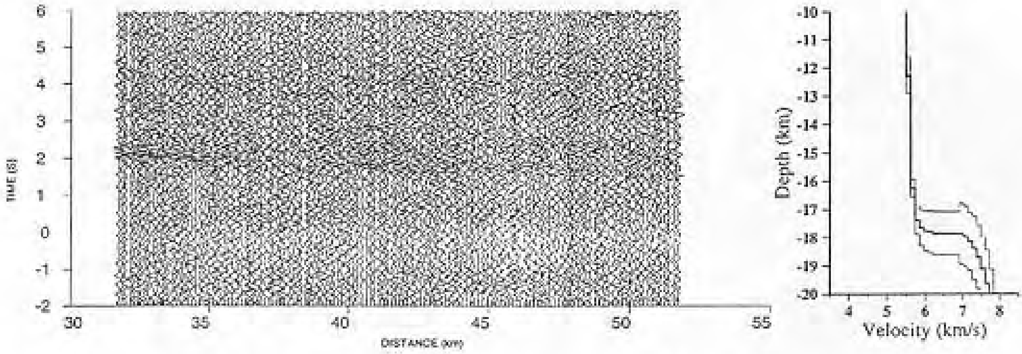

Figure 4: Example of 1-D velocity-depth functions obtained in the station Vaitea at Rapanui, after profile CD. The record-section of which is shown with a velocity reduction of 6 km/s.

Acknowledgements

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References

Bessanova, E.N., V.M Fishman, V.Z. Ryaboyi and G.A. Sitnikova, The tau method for inversion of travel times part I: deep seismic sounding data, Geophys. J. R. Astr. Soc., 47, 59-72, 1974.

Bonatti, E., C.G.A. Harrison, D.E. Fischer, J. Honnorez, J.G. Schilling, J.J. Stipp and M. Zentilli, Easter volcanic chain (Southeast Pacific): a mantle hotline, J. Geophys. Res., 82, 2457-2475, 1977.

Canales, J.P., J.J. Dañobeitia and the PASO-94 Scientific Party, A 3-D geophysical characterization of a seamount at the Easter-Salas-y-Gómez Chain (Nazca Plate), EGS, XX General Assembly, Hamburg, 1995.

Dañobeitia, J.J, J. Gallart and the PASO-94 Scientific Party, Geophysical investigation at the Easter Island (South Pacific), EGS, XX General Assembly, Hamburg, 1995.

Duncan, R.A., and D.A. Clague, Pacific plate motions recorded by linear volcanic chains, In: A.E.M Nairn, F.G. Stelhi and S. Uyeda (eds), The Ocean Basins and Margins. Plenum Press, New York and London, 89-121, 1985.

Francheteau, J., P. Patriat, J. Segoufin, R. Armijo, M. Doucoure, A. Yelles-Chaouche, J. Zukin, S. Calmant, D.F. Naar and R. Searle, Pito and Orongo fracture zone: The northern and southern boundaries of the Easter microplate (Southeast Pacific), Earth Planet. Sci. Lett., 89, 363-374, 1988.

Garmany, J., J.A. Orcutt and R.L. Parker, Travel time inversion: a geometric approach, J. Geophys. Res., 84, 3615-3622, 1979.

Hagen, R.A., N.A. Baker, D.F. Naar and R.N. Hey, A SeaMark II survey of recent submarine volcanism near Easter Island, Mar. Geophys. Res., 12, 297-315, 1990.

Handschumacher, D.W., R.H. Pilger, J.A. Foreman and J.R. Campbell, Structure and evolution of the Easter plate, Mem. Geol. Soc. Am., 154, 63-76, 1981.

Hey, R.N., D.F. Naar, M.C. Kleinrock, J. Phipps Morgan, E. Morales and J.G. Schilling, Microplate tectonics along a superfast seafloor spreading system near Easter Island, Nature, 317, 320-325, 1985.

Maia, M. and M. Diament, An analysis of the altimetric geoid in various wavebands in the Central Pacific Ocean: constraints on the origin of intraplate features, Tectonphysics, 133-153, 1991.

McMechan, G.A. and R. Ottolini, Direct observation of p-t curve in slant-stacked wavefield, Bull. Seism. Soc. Am., 70, 775-790, 1980.

Morgan, W.J., Convection plumes in the lower mantle, Nature, 230, 42-43, 1972.

Naar, D.F., and R.N. Hey, Fast rift propagation along the East Pacific Rise near Easter Island, J. Geophys. Res., 91, 3425-3438, 1986.

Naar, D.F., and R.N. Hey, Tectonic evolution of the Easter Microplate, J. Geophys. Res., 96, 7961-7993, 1991.

Pilger, R.H. and D.W. Handschumacher, The fixed hotspot hypothesis and origin of the Easter-Salas-y-Gómez-Nazca trace, Geol. Soc. Am. Bull., 92, 437-446, 1981.

Schilling, J.-G., H. Sigurdsson, A.N. Davis and R.N. Hey, Easter microplate evoltion, Nature, 317, 325-331, 1985.

Searle, R.C., R.I. Rusby, J. Engeln, R.N. Hey, J. Zukin, P.M. Hunter, T.P. LeBas, H.J. Hoffman and R. Livermore, Comprenhensive sonar imaging of the Easter Microplate, Nature, 341, 701-705, 1989.

Wessel, P. and R.B. Smith, Free software helps map and display data, Eos Trans. Agu, 72, 441, 445-446, 1992.

Woods, M.T., and E.A. Okal, The structure of the Nazca ridge and Sala y Gómez seamount chain from the dispersion of Rayleigh waves, Geophys. J. Int, 117, 205-222, 1994.

Zelt, C.A., and R.B. Smith, Seismic travel time inversion for 2-D crustal velocity structure, Geophys. J. Int., 108, 16-34, 1992.

Sonar Mapping of an Axial High at a Slow Spreading Ridge: Speiss Ridge at the Bouvet Triple Junction

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Speiss Ridge is the most westerly segment of the Southwest Indian Ridge, running to within 100 km of the Mid-Atlantic Ridge at the Bouvet Triple Junction (Sclater et al., 1976). It is an unusual feature because it has a pronounced axial high, rising to within 700 m of sealevel, and yet it occurs on one of the world's slowest spreading ridges (half rate 7-8 mm/yr). Speiss Ridge may represent an effect of a locally enriched mantle on ridge morphology (Le Roex et al., 1983), which opposes the trend towards increasingly deep rift valleys at slow spreading ridges. The ridge has been mapped with the H-MR1 reconnaissance sidescan sonar during a successful expedition on *James Clark Ross* to the South Atlantic in January and February, 1995.

Figure 1 shows a preliminary map of the ridge's bathymetry, acquired with the H-MR1 sonar. Although it is roughly elongated NW-SE, perpendicular to the plate spreading direction, the ridge is otherwise very broad. The sonar images of Speiss Ridge have a markedly different character to those from the Reykjanes Ridge, which is the often-cited example of a slow-spreading ridge affected by a hot spot. While the Reykjanes has chains of seamounts forming large en echelon ridges and with near-axis faulting breaking up those ridges (Searle et al., 1981), the summit of Speiss Ridge has randomly distributed seamounts and much less evidence of faulting. Furthermore, analogies with the East Pacific Rise, which is often compared to hot spot dominated ridges, may also not be appropriate here. Unlike the East Pacific Rise, which commonly has low-relief ridge-parallel abyssal hills and a small summit graben, the sonar data of Speiss Ridge show much less of a faulted abyssal hill fabric and no evidence for an axial rift.

References

Le Roex, A.P., H.J.B. Dick, A.J. Erlank, A.M. Reid, F.A. Frey and S.R. Hart, Geochemistry, mineralogy and petrogenesis of lavas erupted along the Southwest Indian Ridge between the Bouvet Triple Junction and 11° East, J. Pet. 24, 267-318, 1983.

Sclater, J.G., C. Bowin, R. Hey, H. Hoskins, J. Peirce, J. Phillips and C. Tapscott, The Bouvet Triple Junction, J. Geophys. Res. 81, 1857-1869, 1976.

Searle, R.C., and A.S. Laughton, Fine-scale sonar study of tectonics and volcanism on the Reykjanes Ridge, Oceanologica Acta, Proceedings 26th International Geological Congress, Geology of oceans symposium, Paris, 7-17 July 1980, pp 5-13, 1981.

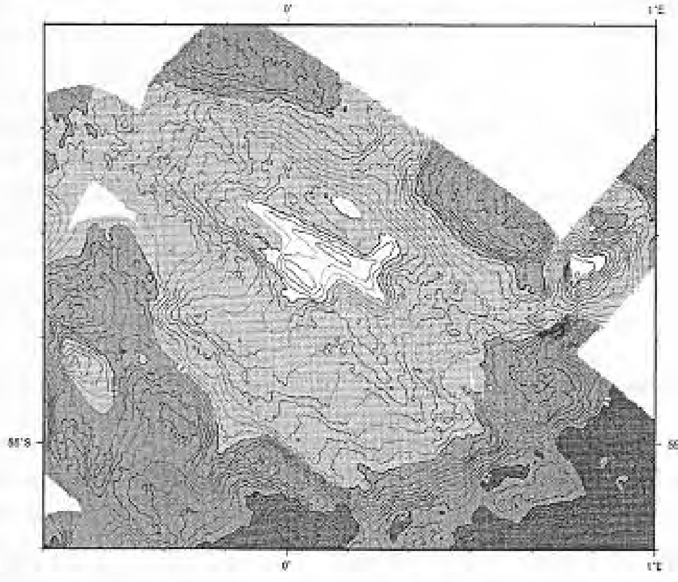

Figure 1. Bathymetry over Speiss Ridge produced using the H-MR1 sidescan sonar. Contour interval is 100 m and interpolated gaps between lines are shown with dotted contours. Grey intervals every 1000 m.

Geophysical Experiments During the MUSE Experiment

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Summary

In May and June of 1994 the *R/V New Horizon* sailed on the two legs of the MUSE experiment (chief scientists: Webb and Hildebrand). We report here the early results of geophysical investigations at two sites on the Juan de Fuca Ridge. Sixteen ocean bottom seismometers (OBS) were deployed on the Coaxial segment to detect the micro-earthquakes following in the aftermath of an eruption of this segment in June 1993 (Fox, 1993). An extensive series of airgun lines were shot to the OBSs. Preliminary results from the refraction experiment show significant variations in structure along axis. Bottom explosive shots provide constraints on shallow structure. A series of seafloor compliance measurements revealed a shallow magma chamber under the northern rift zone of Axial segment, while no significant melt was detected under the Coaxial segment. The Cleft segment has also experienced a recent eruption (in 1986; Baker et al, 1987). This site is the focus of a long term geodectic survey. On bottom absolute gravimeter measurements were made on two seafloor monuments. The measurements will be repeated at these sites in later years to monitor vertical uplift along the Cleft segment. An active source electromagnetic survey using the "MOSES" technique was also conducted at two sites on the Cleft segment to study electrical conductivity in the shallow crust.

Coaxial segment

The Coaxial segment, located just north of Axial Volcano, has come under intense scrutiny following the eruption in June 1993. The eruption was monitored in real time by the NOAA VENTS group in Newport, OR using data from the US Navy SOSUS arrays; the first acoustic monitoring of a ridge axis eruption. The seismicity measured by the SOSUS arrays propagated northward along the strike of the ridge axis over the course of several days, with a final burst of seismicity at the northern end of the segment (Fox, 1993). The scientific community responded to this event as researchers from many disciplines worked to augment and divert existing cruise legs toward the eruption site. ROPOS (remotely operated vehicle operated by Institute of Ocean Sciences, Canada) and Deep Tow surveys confirmed the existence of fresh basalts, shimmering water, and other indications of a recent eruption at the northern end of the segment (Embley, 1993; Spiess and Hildebrand, 1993). As a result of these efforts, an unprecedented geophysical dataset is emerging on this

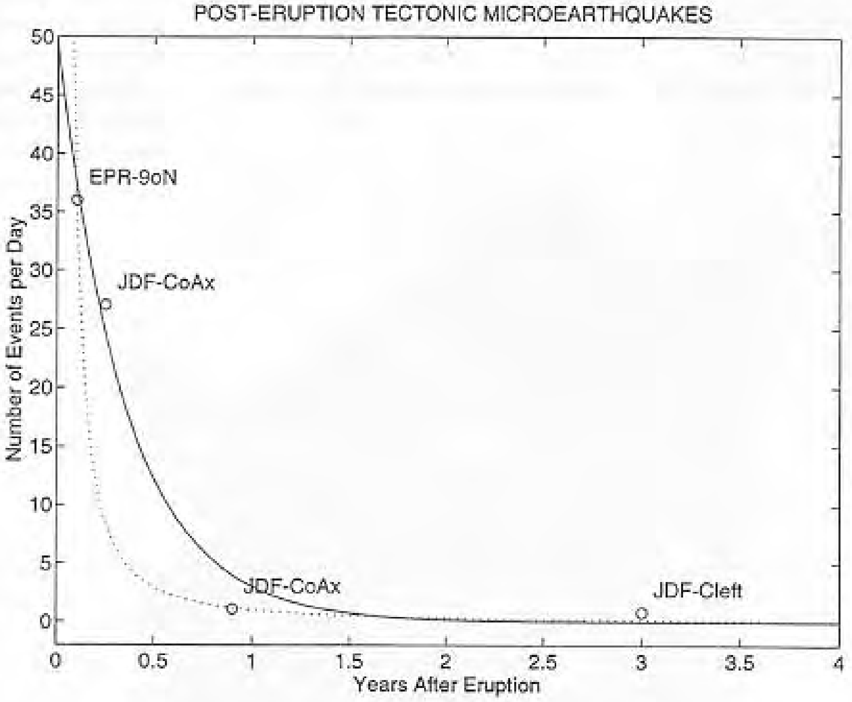

Figure 1 Time dependence of microseismicity following mid-ocean ridge eruptions. An exponential (dotted line) and 1/time relationship are plotted with the data. Data are from the East Pacific Rise (9°N), and the Coaxial and Cleft segments of the Juan de Fuca Ridge. The majority of seismicity occurs less than a year after the eruption.

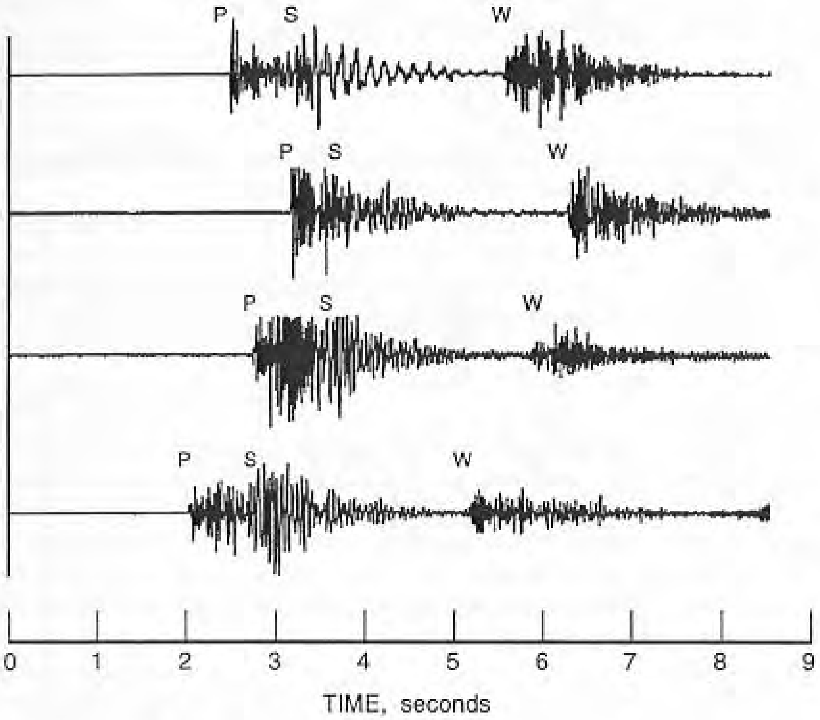

Figure 2 Microearthquake signal as recorded on the vertical component of four instruments near the eruption site of the Coaxial segment. Distinct compressional (P) and shear (S) arrivals are observed along with the first reflection of the compressional wave off the sea surface (W). Hypocentral locations for these events may constrain the location of the subsurface dike.

eruption that should provide new insight into the generation of oceanic crust.

Micro-earthquake study of Coaxial segment

In September of 1994, within three months of the eruption, we deployed an array of six ocean bottom seismometers over the northern eruption site from the *R/V Melville*. A line of micro-earthquakes were detected that appeared to be associated with the intruded dike and constrained its location. Sea surface reflections from these events have been used to determine well constrained estimates of hypocenter depth. The micro-earthquakes provide the only direct evidence of the subsurface location of this dike. The refraction experiment will not resolve the narrow dike. An average of 27 micro-earthquakes per day were detected during this six day deployment. Preliminary analysis puts the locations of these events on the rift zone to the south of the eruption site, supporting the hypothesis of lateral dike propagation along the ridge strike (Sohn et al., 1993).

The primary goal of the recent MUSE leg was to reoccupy the eruption site to provide time series documentation of any changes in the nature, magnitude, and frequency of seismic events related to the eruption. Towards this end, two arrays of OBSs were deployed concurrently on the Coaxial segment during MUSE. One array reoccupied the northern eruption site, and another array was deployed on the ridge axis approximately 28 km to the south, near the origin of the events detected by SOSUS. About one micro-earthquake per day was measured over the eruption site, a marked decrease in seismicity just 8 months after the previous deployment, and 11 months after the eruption. These results indicate that seismicity associated with stress equilibration after the dike intrusion at the ridge crest fails off rapidly after an eruption. The data from four cruises roughly follows the known l/time relationship (Fig. 1) for aftershock sequences from continental earthquakes (Hildebrand, 1994). Distinct, high frequency body wave arrivals were observed on all of the instruments for most of the micro-earthquakes (Fig. 2). This should allow for accurate hypocenter determinations for the data from this new data set and should provide new constraints on location of the dike.

Seismic survey of Coaxial segment

A multi-line seismic refraction survey was conducted over the northern and southern arrays using 5723 airgun shots and 21 explosive bottom shots. The data set includes 20,000 unique ray paths. A new method was developed to allow for bathymetric corrections to be made for shots over regions of rough topography, and as a result, cross-axis lines that in the past have been unusable over slower spreading ridges have yielded interesting data. Preliminary results have been compiled for the shots to the southern array, and some initial observations are possible. Ridge-parallel anisotropy is clearly evident in the data, with initial estimates of about 30-40% azimuthal anisotropy for compressional waves. Seismic layer 2B appears to be anomalously slow compared to values found for other segments of the Juan de Fuca Ridge (e.g. McDonald, 1994), perhaps as a result of fracturing from the lateral intrusions that

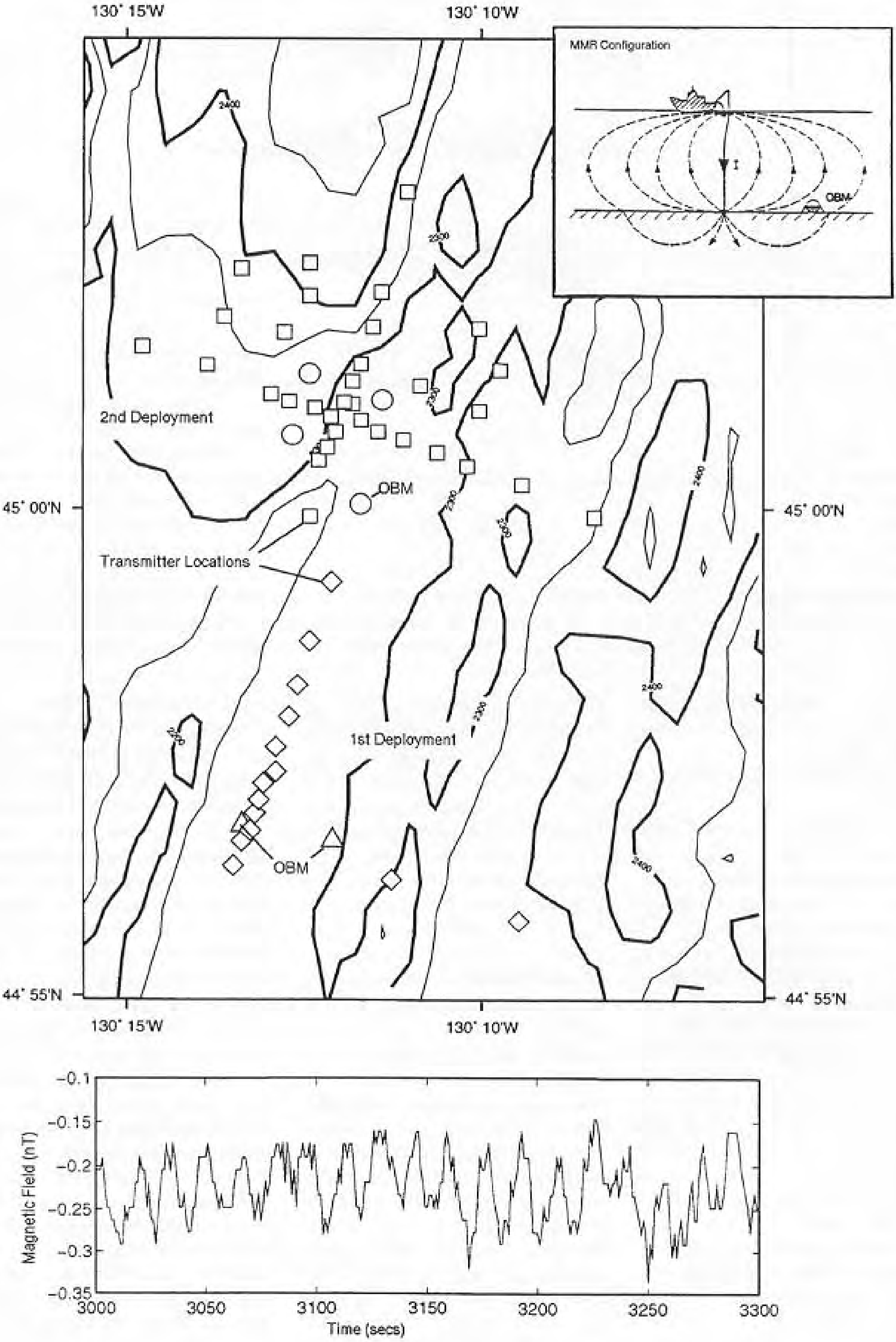

Figure 3 Bathymetry of the northern Cleft segment showing the 1st and 2nd deployment patterns. Inset: MMR experiment configuration. Below: Time series measurement made by Ocean Bottom Magnetometers (OBM).

may be the driving force behind spreading at this segment. A sharp interface at the layer 2B/2C boundary is also evident in the dataset, and may allow for a map of the depth to the gabbros over large portions of this segment.

Possibly the most interesting result to emerge from the refraction work to date is the fact that there is a distinct transition from slow to fast arrivals observed at about 46°20'N, moving south to north along the axial valley. This pattern persists after anisotropy is removed from the dataset, and most likely represents a thinning of seismic layer 2A to the north of 46°20'N. More analysis is required to interpret this result, but it seems likely that we have imaged an interesting subsurface feature of the Coaxial segment, perhaps related to the transition from Axial segment morphology in the south to Northern Symmetrical segment morphology in the north.

Shear velocity structure of Coaxial segment

Two long period seismometers based on LaCoste Romberg gravimeters were deployed at a series of sites during the cruise to measure seafloor compliance, the deformation of the ocean floor under long wavelength pressure signals from ocean infragravity waves. Shear velocity profiles under sites on the Coaxial and Axial segments from 46°12'N to 46°23'N were determined from these measurements using non-linear geophysical inverse methods (Crawford et al., 1994). Seafloor compliance, the transfer function between seafloor pressure and displacement, is sensitive to crustal shear velocity structure to a depth of 5000 mbsf. Shear velocity profiles constructed from the compliance data show a region of low shear velocity approximately 2500 mbsf beneath the North Rift Zone of Axial volcano. No low shear velocity zone appears to exist beneath the Coaxial segment. The inverse method applied determines the smoothest (minimum structure) shear velocity profiles that fit the compliance data. Models that show relative minimums of shear velocity in the crust, do not fit monotonic profiles. Small regions of partial melt might not be detected, but we believe a magma chamber large enough to supply 30 km of dike propagation would be seen. Earthquake locations determined from SOSUS array data show activity over a 30 km long section of the Axial segment. The compliance data indicate that either the Coaxial segment magma chamber is several kilometers south of the measurements or the magma for the eruption originated under the North Rift Zone of Axial volcano.

Electromagnetic survey of Cleft segment

At mid-ocean ridges the presence of shallow dike intrusions, variations in the thickness of the extrusive layer, hydrothermal circulation in the crust, and crack induced anisotropy, all have an influence over the extent of seawater penetration into the crust. This, in turn, has an impact on the bulk crustal resistivity. Techniques that measure crustal resistivity structure, known as controlled source electromagnetic methods (CSEM) have been developed over the last 15 years or so in an attempt to provide further constraints on crustal structure, beyond those provided by other geophysical techniques. The magnetometric resistivity (MMR) sounding technique is one such method that has been successfully used in a search for hydrothermal features buried in the sediments of the Middle Valley of the Juan de Fuca Ridge (e.g. Nobe et al., 1986, 1992). Two MMR soundings of the Cleft segment near 45°N were made at a site of recent volcanism by a group from the University of Toronto during MUSE.

An MMR experiment involves measuring the magnetic field created by a long vertical bipole source. A low-frequency current of about 15 A, generated by a source on board the ship, is passed between two electrodes; one at the sea surface and one vertically below at the seafloor. The method is essentially galvanic, and does not rely on the inductive processes of other CSEM techniques (Young and Cox, 1981; Cox et al., 1986; Evans et al., 1991, 1994). While other resistivity techniques have poor sensitivity to the structure of a resistive seafloor, the MMR method is capable of identifying the seafloor resistivity, on the order of the water depth even when the source-receiver offset is short.

Over a layered Earth, the magnetic field generated by the bipole source possesses an azimuthal symmetry and decreases with distance from the source approximately as $1/r^2$. If the current transmitted is known, then the amplitude of the magnetic field at sites remote to the source can be used to estimate the bulk electrical conductivity of the seafloor. Deviations in the magnetic field from uniformity can provide insight into large-scale heterogeneity and anisotropy.

Two surveys were completed. An outline of the experiment is shown in Figure 3. The first deployment was at the northern end of the Cleft segment, where a recent sheet flow and low temperature hydrothermal activity along the eastern edge of the flow have been documented. Two ocean bottom magnetometers (OBM) from the University of Toronto were deployed so as to straddle the neovolcanic zone at 44°56.65'N. The OBM to the west of the neovolcanic zone was site targeted to land on the large fresh sheet flow described by Embley and Chadwick (1994). The second OBM was sited some 500 m to the south-east. A series of transmitter stations were completed in a strike parallel line beginning some 2 km to the south of the two receivers and continuing northwards along a track perpendicular to the line joining the two receivers. Fourteen stations were completed along this line that eventually extended about 5 km to the north of the receivers. Two more stations were completed to the east of the OBMs at distances of about 3 km and 5 km.

The second survey focused on the overlapping spreading center (OSC) at the northern end of the Cleft segment. This region was chosen for several reasons. There is evidence from seismic refraction studies of substantial crustal thickening from east to west through the OSC (McDonald et al., 1994). The complex tectonic processes that shape the OSC will result in a pattern of seafloor faults and fissures that should have an anisotropic signature in the electrical resistivity structure. The site also shows evidence of recent volcanism; a large fresh pillow flow is situated near the center of our array (Embley and Chadwick, 1994). Four OBMs were deployed - two from Toronto and two from SIO. Thirty four transmitter stations were achieved, over a forty eight hour period, in a pattern designed to optimize both the range and azimuthal coverage around the receivers.

The time series measured by the OBMs are strongly affected by natural geomagnetic variations caused by charged particles in the ionosphere and magnetosphere. These natural signals can also be used to examine the resistivity structure beneath the seafloor, and at greater depths within the upper mantle. The method used is known as Vertical Gradient Sounding (VGS; e.g. Ferguson and Edwards, 1994). The VGS data from MUSE will be used by Marion Jegen in Toronto in an ongoing project looking at the mantle resistivity structure at various sites along the Juan de Fuca Ridge.

Absolute gravity of Cleft segment

Mark Zumberge and Eric Canuteson of SIO deployed the recently developed Ocean Bottom Absolute Gravity Meter and made the first ever absolute gravity measurements on a MOR. Three benchmarks were established in what is expected to develop into a network of about ten sites on the South Cleft segment. The benchmark locations are:

44°40.97'N, 130°24.29'W;
44°39.30'N, 130°22.33'W;
44°37.80'N, 130°18.80'W.

Gravity data were collected at two of the benchmarks, and the third benchmark was emplaced but no data were taken. Absolute gravity data have been used successfully on land for vertical geodetic purposes and we plan to measure vertical deformation on the Juan de Fuca Ridge over long time periods with this new instrument.

References

Baker, E.T., G.J. Massoth and R.A. Freely, Cataclysmic venting on the Juan de Fuca Ridge, Nature, 329, 149-151, 1987.

Cox, C.S., C.S. Constable, A.D. Chave and S.C. Webb, Controlled source electromagnetic sounding of the oceanic lithosphere, Nature, 320, 52-54, 1986.

Crawford, W.C., S.C. Webb and J.A. Hildebrand, The Coaxial segment crustal magma source, Eos Trans., AGU, 75, 44,1994.

Embley, R.W., W.W. Chadwick, I.R. Jonasson, S. Petersen, D. Butterfield, V. Tunnicliffe, and K. Juniper, Geologic inferences from a response to the first remotely detected eruption on the mid-ocean ridge: Coaxial segment, Juan de Fuca Ridge, Eos Trans., AGU, 74, 43, 1993.

Embley, R.W., and W.W. Chadwick, Volcanic and hydrothermal processes associated with a recent phase of seafloor spreading at the northern Cleft segment; Juan de Fuca Ridge, J. Geophys. Res., 99, 4741-4760, 1994.

Evans, R.L., S.C. Constable, M.C. Sinha, C.S. Cox and M.J. Unsworth, Upper crustal resistivity structure of the East Pacific Rise near 13°N, Geophys. Res. Letts., 18, 1917-1920, 1991.

Evans, R.L., S.C. Constable, M.C. Sinha and M.J. Unsworth, On the electrical nature of the axial melt zone at 13°N on the East Pacific Rise, J. Geophys. Res., 99, 577-588, 1994.

Ferguson, I.J., and R.N. Edwards, Electromagnetic mode conversion by surface conductivity anomalies: applications for conductivity sounding, Geophys. J. Int., 117, 48-68, 1994.

Fox, C., Detection and response to a seafloor spreading event, RIDGE Events, 4, 2, 1993.

Hildebrand, J.A., S.C. Webb, M.A. McDonald and R.A. Sohn, Microearthquake temporal variability following ridge crest volcanic eruptions, Eos Trans., AGU, 75, 44,1994.

McDonald, M.A., S.C. Webb, J.A. Hildebrand, B.D. Cornuelle and C.G. Fox, Seismic structure and anisotropy of the Juan de Fuca Ridge at 45°N, J. Geophys. Res., 99, 4857-4873, 1994.

Nobes, D.C., L.K. Law and R.N. Edwards, The determination of resistivity and porosity of the sediment and fractured basalt layers near the Juan de Fuca Ridge, Geophys. J.R. Astr., 86, 289-317, 1986.

Nobes, D.C., L.K. Law and R.N. Edwards, Results of a seafloor electromagnetic survey over a sedimented hydrothermal area on the Juan de Fuca Ridge, Geophys. J. Int., 110, 333-346, 1992.

Sohn, R.A., S.C. Webb, J.A. Hildebrand and W.C. Crawford, Ocean bottom seismometer studies of a recent volcanic eruption on the Juan de Fuca Ridge, Eos Trans., AGU, 74, 43, 1993.

Spiess, F.N., and J.A. Hildebrand, Deep Tow studies of recent activity on the Juan de Fuca Ridge, Eos Trans., AGU, 74, 43, 1993.

Young, P.D., and C.S. Cox, Electromagnetic active source sounding near the East Pacific Rise, Geophys. Res. Letts., 8, 1043-1046, 1981.

An 800 km Survey of the Active Spreading Axis in the northern North Fiji Basin: Results of the NOFI cruise of the R/V l'Atalante over the South Pandora and Tripartite Ridges (August-September 1994)

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Abstract

The objectives of the NOFI cruise of the *R/V l'Atalante* were the bathymetric, structural and geophysical survey of the spreading axis of the northern region of the North Fiji Basin. The study area lies between 171°E to 178°E and 13°E to 15°S. The N075°E to N110°E trending South Pandora and Tripartite active ridges were mapped in detail over a total distance of 800 km using the multibeam, SIMRAD EM12-dual echo sounder of the *R/V l'Atalante*. The active axis of both ridges is divided into 80 to 120 km long segments and corresponds either to a deep graben or to a voluminous volcanic massif. The offsets between segments are 10 to 30 km long and corresponds to discontinuities of various type (OSC, simple offsets, propagating rift,...). The Tripartite Ridge appears to be a very recent feature which has propagated into older oceanic crust.

Introduction

Recent detailed surveys of mid-oceanic ridges in the ocean basins as well as in back-arc basins have shown that the geometry of the active axis may be highly unstable. Such instability is revealed by a nonlinear pattern of the active spreading centers, frequent discontinuities and changes of trend of the axis, and rapid variability of the morphological characteristics across and along strike.

The NOFI cruise is the first operation of the French-Japanese NEW STARMER co-operative program to the study active spreading systems in back-arc basins of the South West Pacific. The objectives of the cruise concerned the geology of the active spreading axis in poorly explored areas of the North Fiji Basin (NB), one of the largest and most evolved back-arc basin of the South West Pacific. High variability in spreading geometries has been established in an earlier study of the 800 km long, N-S trending, central spreading ridge (CSR) of the North Fiji Basin (Auzende et al., 1988; 1988b, 1994; Maillet et al., 1986; Lafoy et al., 1990; Ruellan et al., 1989; de Alteriis et al., 1993; Tanahashi et al., 1994), but no complete surveys were available in the northern region of the basin where an E-W trending active spreading center including the South Pandora Ridge (SPR) and the Tripartite Ridge was known to exist (see Pelletier et al., 1993 for references).

The SPR is part of the Hazel Holme Fracture Zone as previously defined by Chase (1971). It corresponds to a broad arch, trending globally east-west (Fig. 1) and appears as a pair of ridges flanking an axial trough with several offsets (Fig. 2 & 3; Kroenke et al., 1994). The existence of an active spreading center in the South Pandora Ridge region, was established from magnetic anomalies analysis by Lapouille (1986). The strong east-west linear fabric of the SPR was clearly revealed by sonar imagery (Price and Kroenke, 1991; Tiffin et al., 1991; Jarvis et al., 1993). The SPR region is seismically active, and fresh to very fresh pillow basalts have been dredged along the ridge at several locations (Sinton et al., 1991; Price et al., 1990; Eissen et al., 1994). The SPR bifurcates to the east forming two branches: the Tripartite Ridge and the Rotuma Ridge. The Tripartite Ridge (TR), an elongated feature, trending N110°E (Fig. 1), has been interpreted as a very young spreading axis (Kroenke et al., 1994; Price et al., 1990; Price and Kroenke, 1991). The Rotuma Ridge, a volcanic ridge trending N075°E, consists of aligned seamounts. The Island of Rotuma, 14 km long, at the eastern tip of the Rotuma Ridge, exposes very fresh alkali basalts of late Pleistocene and Recent age (Woodhall, 1987).

Preliminary Results of the NOFI cruise

The operations conducted during the NOFI cruise (August 25th-September 19th 1994) included

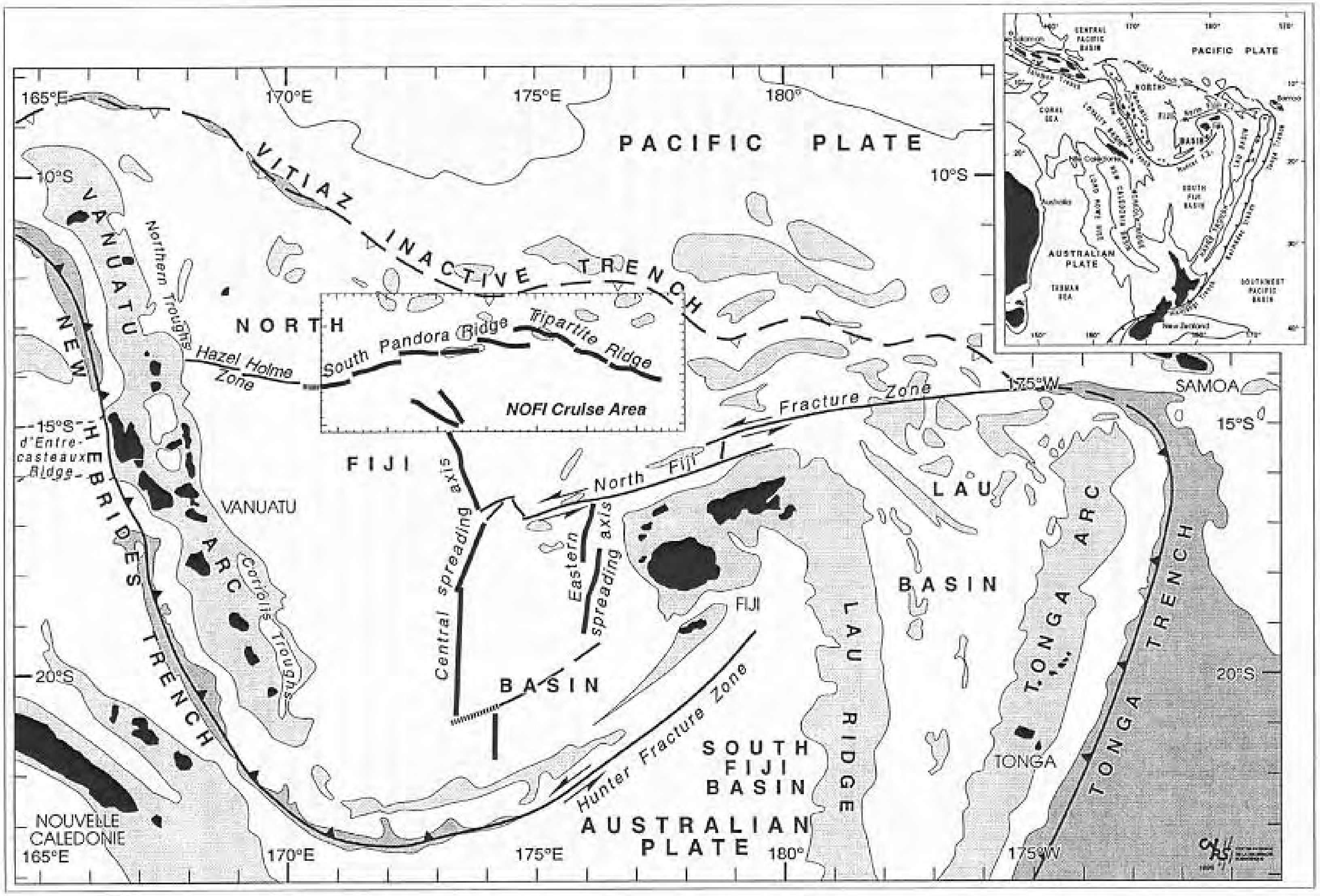

Figure 1. The North Fiji basin in the SW Pacific, the active spreading axis (black lines) and the NOFI survey area (SPR: South Pandora Ridge, TR : Tripartite Ridge, HHR : Hazel Holmes Ridge).

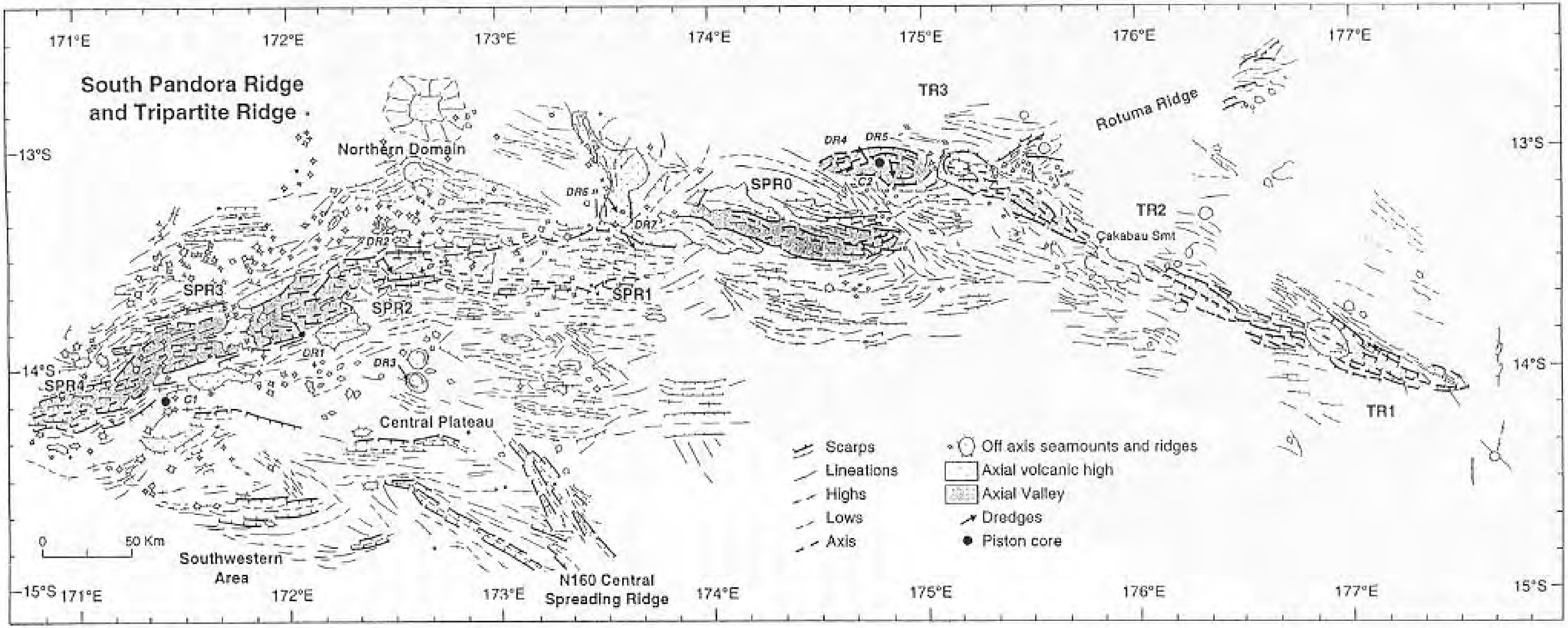

Figure 2. Structural sketch of the South Pandora, Tripartite and Rotuma Ridges after preliminary interpretation of the bathymetric and imagery data collected during the NOFI cruise. Labels SPR0, to SPR4 and TR1 to TR3 correspond to the successive axial segments briefly decribed in text.

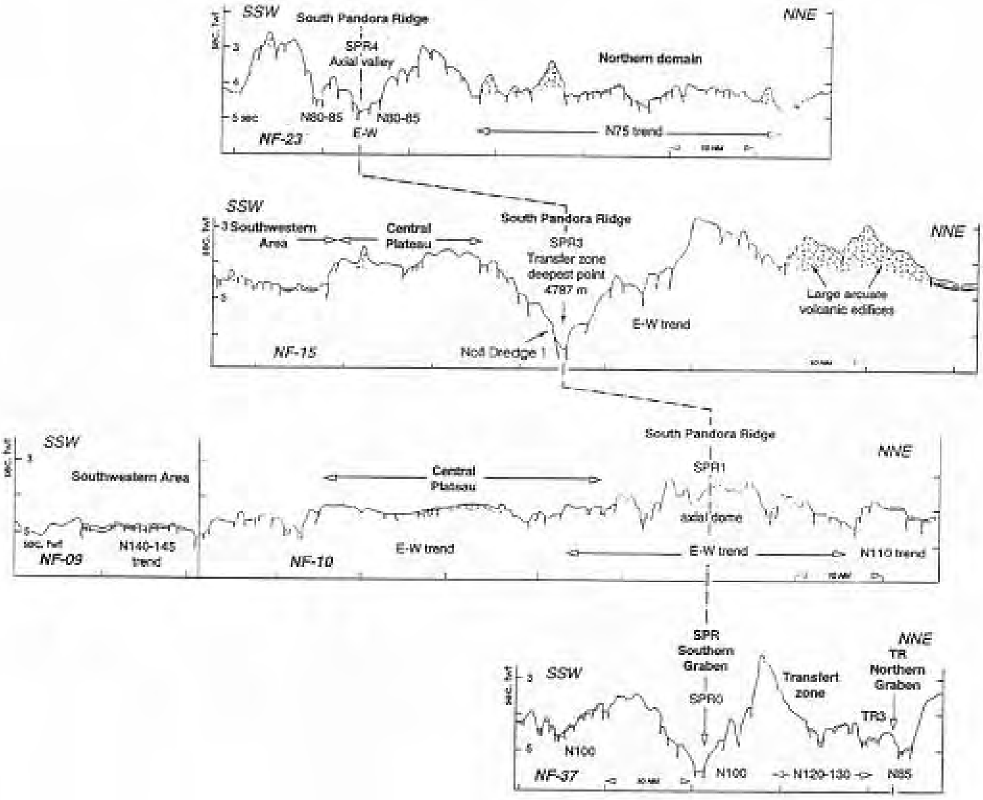

Figure 3. Interpretations of selected seismic reflection profiles across the South Pandora Ridge obtained during the NOFI cruise showing two opposite axial morphologies: a shallow axial volcanic dome (lower section : profile NF9) and a deep axial graben (upper sections : profiles NF10 and NF11).

SIMRAD EM12-dual bathymetric swath mapping, underway geophysics (airgun 6-channel seismic profiling, magnetics and gravity), dredging and piston coring in the northern part of the NFB between 171°E-178°E and 13°S-15°S. The active spreading centers of both the Pandora and Tripartite Ridges were surveyed continuously over a distance of 800 km along axis. Two contiguous, full-coverage boxes of bathymetric and acoustic imagery were obtained. The first one, between 170°40'E and 174°E over the SPR, has an average width of 250 km, the second one over the SPR-TR junction, between 174°E and 175°50'E has a width of 130 km (Fig. 2).

The South Pandora and Tripartite Ridges axial domains are characterized by high reflectivity terrains forming a dark, broad arch oriented E-W which was observed continuously, along the entire 800 km length of the mapped area, from 170°40' to 178°E.

Acoustic high reflectivity of the seafloor is related to the lack of sedimentary cover as well as to recent volcanic eruptions and to tectonic disruptions (Fig. 4). This confirms that the axis is tectonically and volcanically active. The mean direction of the western portion of the axial zone is N070°E whereas it trends N090°E in the central part and N110°E to the east. The major changes in the direction of the ridge occur at several discontinuities showing various geometrical patterns, suggesting complex transform relay zones. The average width of the active domain is 20 km and corresponds either to bathymetric highs or to deep elongated grabens located on top of the regional dome forming the South Pandora and Tripartite Ridges (Fig. 3). The bathymetric highs represent volcanic constructions, locally faulted and rifted, which appear to totally obstruct the axial valley. Such highs reach considerable sizes (e.g. 30-40 km at base, and culminates at -400 m depth as Cakabau Seamount) especially along the Tripartite axis. The grabens show the typical morphology of slow spreading axis, with two steep walls flanking a 10 to 20 km wide and 3000 m to 4800 m deep axial valley. Lateral volcanic ridges are present on both sides of the graben. The southern and northern plateaux (around 3000 m deep) bordering the South Pandora Ridge are characterized by the occurrence of numerous volcanoes ranging in diameter from one to several kilometers. The plateaux are covered by a very thin sedimentary cover.

According to bathymetry and imagery analysis, the axial domain of the SPR can be divided into 5 main, first-order segments, from east to west: segments SPR0, SPR1, SPR2, SPR3 and SPR4 (Fig. 2).

The E-W trending segment SPR0 is 100 km long. It consists of a graben flanked by two volcanic highs which culminates at less than 2000 m depth at its western end. The width of the graben varies from 10 km to 25 km with a maximum depth of 4100 m. A neovolcanic ridge is present between the two volcanic highs at the western tip of segment SPR0. Segment SPR1 is character-

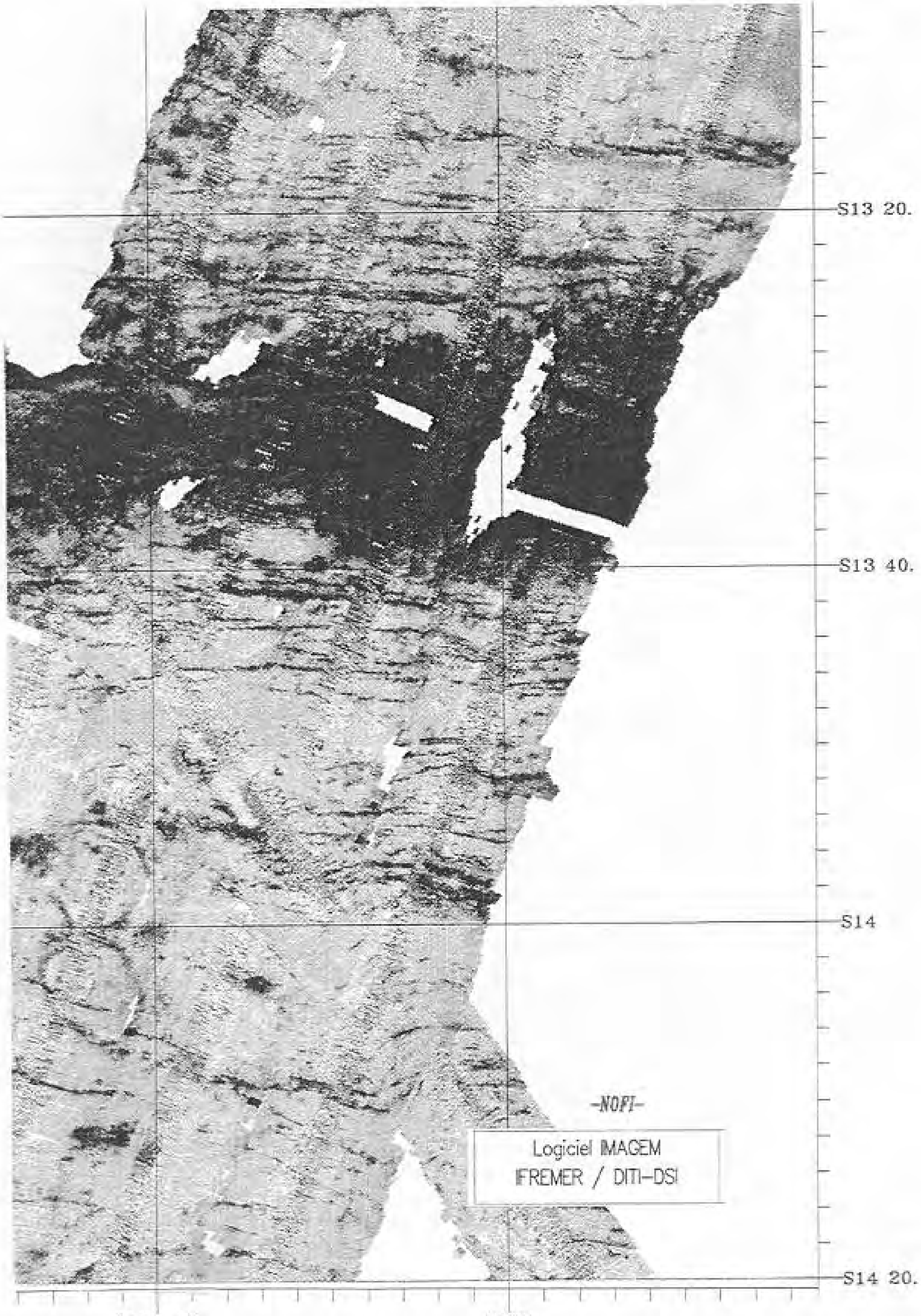

Figure 4. An example of imagry data recorded during the NOFI cruise over the South Pandora Ridge. Four parallel lines and one transverse line are shown. The axial active zone corresponds to the black areas, that is to active tectonized regions, or areas with reduce to absent sedimentary cover, or recently emplaced lava flows. The ridge parallel fabric as well as two off-axis volcanoes (both 10 km diameter) are clearly outlined.

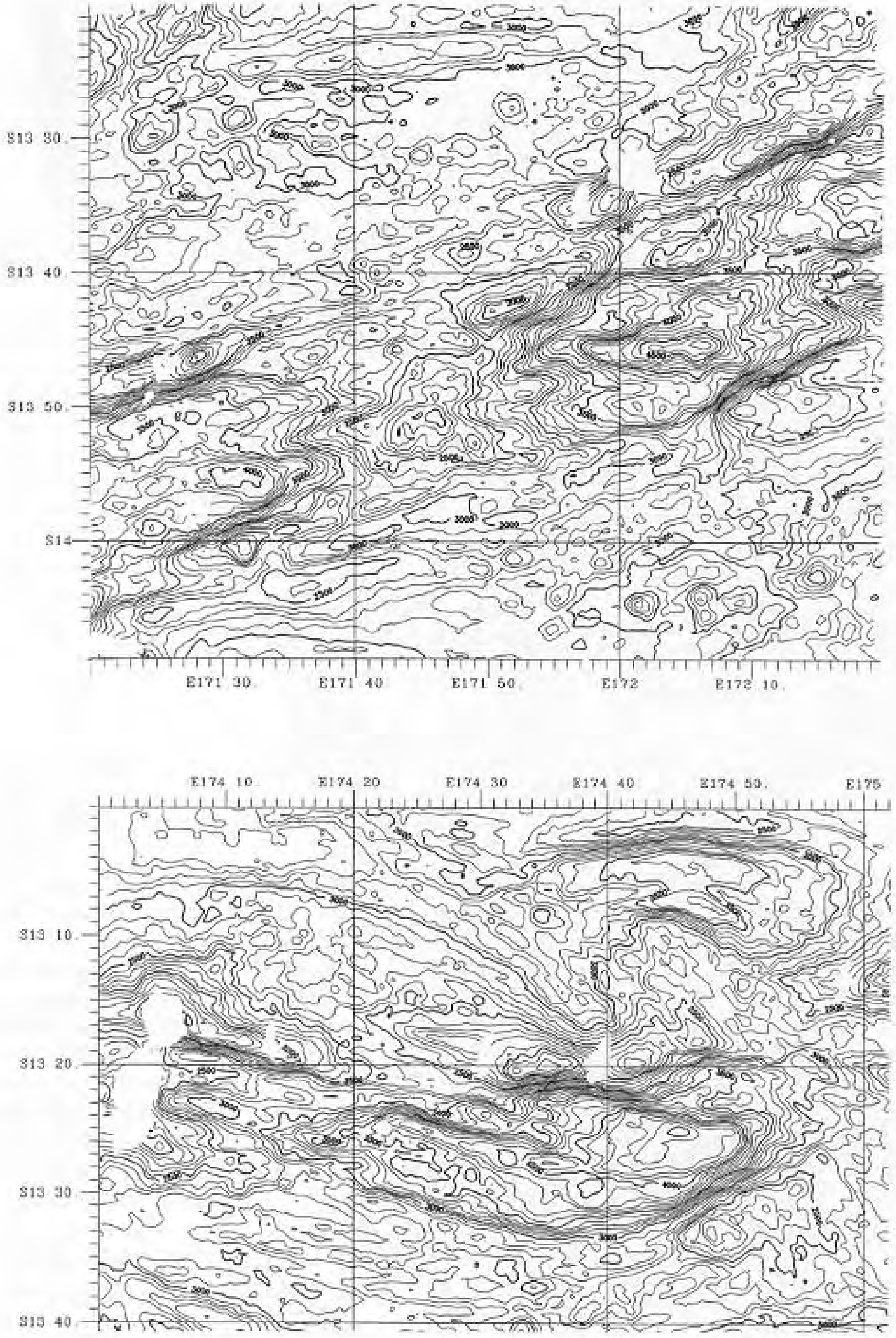

Figure 5. Details of bathymetric map obtained during the NOFI cruise. The upper map shows an entire segment of the South Pandora Ridge (Segment SPR3). The mapped area is about 100 km wide. The center of the segment corresponds to a strongly rifted volcanic massif flanked by two deep grabens. The segment trends N075°E, but the internal fabric shows N090°E orientations. The lower map shows the junction area between the Tripartite and the Pandora Ridges. The northern curved graben belongs to the Tripartite Ridge, whereas the southern graben is the easternmost feature of the South Pandora Ridge. The area showing oblique fabric observed between both grabens could be the equivalent of the transferred lithosphere located at the junction between dying and propagating rifts.

ized by the presence of an axial volcanic high culminating at 1200 m depth. This E-W elongated feature is 25 to 35 km wide, and is clearly rifted by two sets of faults trending N090°E and N100°E-N110°E respectively. At its northern edge, the volcanic high connects to a north-south trending ridge, itself connecting to the southernmost seamount belonging to the Horizon Bank complex. Segment SPR2 shows a bathymetric transverse section similar to those described at slow-spreading ridges, and consists of a 10 to 12 km wide, E-W trending graben flanked by 2 sharp lateral-ridges. The depth of the axial valley floor varies from 2400 m at the eastern end to 4200 m at the western end. Segment SPR3 is oriented N075°E, thus marking a clear change in the global trend of the SPR. It consists of a median volcanic high flanked by two deep grabens, both 30 km wide (Fig. 5). Segment SPR4 is located at the western edge of the mapped area and has not yet been mapped completely. It is at least 60 km long and probably extends farther west with the same orientation. It shows a complex axial valley bounded by non-continuous lateral ridges trending N075°E, N090°E and N105°E.

The discontinuities between segments SPR0-SPR1, SPR2-SPR3 and SPR3-SPR4 correspond to areas showing complex pattern of oblique structures suggesting off-axis deformation with offsets of 10 to 30 km. This indicates that these junctions cannot be regarded as typical transform faults, but must be considered as complex relay zones where diffuse transfer of extensional motion occurs between the segments.

The Tripartite Ridge (TR) is 340 km long, and extends from 174°30'E to 177°30'E with a N110°E general trend (Fig. 2). The axial domain consists of a succession of three main segments showing a sigmoidal-shape, from east to west: TR1, TR2 and TR3.

Segment TR1 is located between 176°30'E and 177°30'E. It is 120 km long and trends N105°E. From east to west the axial valley floor morphology consists of an eastern graben, a volcanic high, and a western graben. The segment is flanked by two lateral ridges. The northern ridge, trending N125°E, is 160 km long and is remarkably continuous, with its highest part (reaching about 2000 m) observed along the TR1a graben. Segment TR2 is 70 km long, and is composed of the Cakabau Seamount (culminating at less than 200 m depth) and an associated graben located on its eastern edge. Segment TR3, located between 174°35'E and 175°45'E is 150 km long and is composed of a central volcanic massif flanked by two axial grabens. The western, curved graben narrows westwards from 15 km to 8 km width.

The SPR-TR junction corresponds to a major discontinuity with 25 km offset located at 174°40'E (Fig. 5). The general geometry is similar to large-scale OSC, composed of the westernmost graben of the Tripartite Ridge and a opposite graben belonging to the tip of segment SPR0, also showing a curved outline. The seafloor between the two arms exhibits a N140°E oriented, oblique fabric. This feature shows close similarities with the pattern observed west of the Fiji Islands where the spreading axis consists of two overlapping active grabens probably representing a propagating rift and a failed rift respectively (Huchon et al., 1994). A wide region lying between the two rifts and showing a fan-shaped fabric is supposed to represent the transferred lithosphere (Auzende et al., 1994).

Preliminary analysis of 6-channels seismic reflection profiles carried out during the NOFI cruise indicate that the Tripartire Ridge is a very young feature, devoid of sedimentary cover, which is propagating into an older oceanic domain showing a 0.1 s-thick sedimentary cover affected by normal faulting. By contrast, the South Pandora Ridge shows a very thin to absent sedimentary cover over a distance of 100 km from both sides of the active zone. This suggests that spreading along the SPR has been occurring for a few Ma.

The magnetic anomaly profiles show long continuous lineations along the spreading axis of SPR. According to our very preliminary interpretation of magnetic anomalies, the spreading rate along the SPR axis is very slow (2 to 1.5 cm/yr full rate).

Conclusions

The survey of the South Pandora and Tripartite Ridges conducted during the NOFI cruise reveals that the active axis is divided into well-defined segments with lengths ranging from 80 to 120 km. The active zone is typically 10-20 km wide and corresponds either to deep grabens or to shallow, rifted volcanic edifices. This demonstrates that even in back-arc environments, and along spreading centers with slow to very slow spreading rates, the wave-length of the segmentation, as well as the morphotectonic and volcanic characteristics of the axial domain show sizes and distribution similar to that found along slow-spreading axis of large oceans. This indicates that physical parameters which characterize the deep mantle processes accompanying oceanic spreading have similar expressions in evolved back-arc basins and in very large, old oceans.

References

Auzende, J.M., J.P. Eissen, Y. Lafoy, P. Gente and J.L. Charlou, Seafloor spreading in the North Fiji Basin (Southwest Pacific), Tectonophysics, 146, 317-351, 1988a.

Auzende, J.M., Y. Lafoy and B. Marsset, Recent geodynamic evolution of the North Fiji Basin (SW Pacific), Geology, 16, 925-929, 1988b.

Auzende, J.M., B. Pelletier and J.P. Eissen, The North Fiji Basin: geology, structure and geodynamic evolution, B. Taylor (ed), 1994.

Chase, C.G., Tectonic history of the Fiji plateau, Geol. Soc. Am. Bull., 82, 3087-3110, 1971.

de Alteriis, G., E. Ruellan, J.M. Auzend, H. Ondréas, V. Bendel, E. Gracia-Mont, Y. Lagabrielle, P. Huchon and M. Tanahashi, Propagating rifts in the North Fiji Basin (Southwest Pacific), Geology, 17, 583-586, 1993.

Eissen, J.P., M. Nohara, J. Cotten and K. Hirose, The North Fiji Basin basalts and their magma sources. Part 1. Trace and rare earth element constraints, Marine Geology, Special issue, (Starmer project: J.M. Auzende and T. Urabe, eds.), 116, 153-178, 1994.

Huchon, P., E. Gracia, E. Ruellan, M. Joshima and J.M. Auzende, Kinematics of active spreading in the central North Fiji Basin (SW Pacific), Marine Geology, Special issue, Starmer project: J.M. Auzende and T. Urabe (eds.), 116, 69-88, 1994.

Jarvis, P., L. Kroenke, R. Price, and P. Maillet, GLORIA imagery of sea floor structures in the northern North Fiji Basin, Geo-Marine Letters, 13, 90-97, 1993.

Johnson, K.T.M. and J.M. Sinton, Petrology, tectonic setting and the formation of back-arc basin basalts in the North Fiji Basin, Geol. Jb., D92, 517-545, 1990.

Kroenke, L.W. and J.V. Eade, (eds), Geological Investigations of the North Fiji Basin, Circum-Pacific Council for Energy and Mineral Resources, Earth Science Series, Am. Assoc. Pet. Geol. Houston, Texas, 300 p, 1990.

Lafoy, Y., J.M. Auzende, E. Ruellan, P. Huchon and E. Honza, The 16°40'S triple jonction in the North Fiji Basin, Marine Geophys. Res., 12, 285-296, 1990.

Lapouille, A., Present-day opening of the northwestern part of the North Fiji Basin (Soutwest Pacific), South Pacific Marine Geol. Notes, Tech. Sec., CCOP/SOPAC, Suva, 3, 2, 23-27, 1986.

Maillet, P., J.P. Eissen and 6 others, La dorsale active du bassin Nord-Fidjien entre 20°S et 20°53'S: signature magnétique et morphologique, C.R. Acad. Sci. Paris, 302, II, 135-140, 1986.

Pelletier, B., Y. Lafoy and F. Missegue, Morphostructure and magnetic fabric of the Northwestern North Fiji Basin, Geophys. Res. Lett., 20(12), 1151-1154, 1993.

Price, R.C., and L.W. Kroenke, Tectonics and magma genesis in the northern North Fiji Basin, Marine Geology, 98, 241-258, 1991.

Price, R.C., L.E. Johnson and A.J. Crawford, Basalts of the North Fiji basin: the generation of back arc basin magmas by mixing of depleted and enriched mantle sources, Contrib. Mineral. Petrol., 105, 106-121, 1990.

Ruellan, E., J.M. Auzende, E. Honza, et al., L'accrétion dans le bassin Nord Fidjien méridional: premier résultats de la campagne franco-japonaise STARMER/KAIYO 88. Comptes Rendus Acad. Sc. Paris, 309, 1247-1254, 1989.

Seward, D., Fission cracks dates of basalts from the North Fiji Basin, in L.W. Kroenke and J.V. Eade (eds.), Basin Formation, Ridge Crest Processes and Metalogenesis in the North Fiji Basin, Circum Pacific Council for Energy and Mineral Resources, Earth Science Series, 12, 151-153, 1990.

Sinton J.M., K.T.M. Johnson, R.C. Price, H. Staudigel and A. Zindler, Petrology of submarine lavas of the Lau and North Fiji Basins, in L.W. Kroenke and J.V. Eade (eds.), Basin Formation, Ridge Crest Processes, and Metallogenesis in the Fiji Basin, Circum-Pacific Council for Energy and Mineral Resources., Earth Science Series, 12, Houston, Texas, 1994.

Tanahashi, M., K. Kisimoto, M. Joshima, P. Jarvis, Y. Iwabuchi, E. Ruellan and J.M. Auzende, 800 km long N-S spreading system of the North Fiji Basin. Marine Geology, Special issue, Starmer project: J.M. Auzende and T. Urabe (eds.), 5-24, 1994.

Tiffin, D.L., J.H. Clarke, P. Hill, P. Jarvis, D. Johnson, P. Maillet, L. Parson and R. Price, GLORIA data from the North Fiji and Lau Basins: a summary of results, Starmer Symposium, abstract, 1991.

Woodhall, D., Geology of Rotuma, Miner. Res. Dept. Fiji Bull., 8, 40 p, 1987.

HYFIFLUX Cruise: German-French Cooperation for the Study of Hydrothermalism and Related Tectonism, Magmatism and Biology of the Active Ridges of the North Fiji Basin (SW Pacific)

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and the Scientific Party[4] *of the HYFIFLUX cruise.*

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The HYFIFLUX Cruise on the German *R/V SONNE*, was organized within the framework of an international co-operative project between the Free University of Berlin (P. Halbach), IFREMER (J.-M. Auzende) and other German universities. It is a multidisciplinary program for the study of hydrothermalism and associated geological, geochemical and biological processes in the North Fiji Basin (SW Pacific). The oceanic accretion in the North Fiji Basin (NFB) is characterised by a double spreading system (Auzende et al., 1994) with one spreading axis located in the median part of the basin (Central Spreading Ridge, CSR) and the second one located immediately west of the Fiji platform (West Fiji Ridge, WFR).

One aim of the HYFIFLUX cruise was the detailed mapping of the area between the previously mapped part of the West Fiji Ridge (*R/V Jean Charcot*), and the North Fiji Fracture Zone (NFFZ), using the Hydrosweep multibeam system with a swath width of two times the water depth. The other objective was the detailed mapping and sampling of the active and inactive hydrothermal sites located at the northern tip of the N15° segment of the Central Spreading Ridge. For this purpose the *R/V Sonne* was equipped with a video-photo deep tow system (EXPLOS), and various sampling tools such as TV Grab, multipiston corer, water sampling multiprobe, etc. The TV Grab is a rock sampling system similar to a giant pair of "sugar tongs" equipped with a TV camera attached at its middle. This camera allows to precisely identify and to select the sampling sites.

Results of HYFIFLUX cruise.

Mapping of the junction of the West Fiji Ridge with the North Fiji Fracture Zone

During the HYFIFLUX Cruise, complete multi-beam coverage of the WFR was obtained from 17°10'S up to its junction with the NFFZ. The 3D view map in Figure 1 shows the general bathymetry and structure of the area. Two principal domains can be identified: the spreading zone and the junction zone between the WFR and the NFFZ.

The spreading zone in this area is characterised by two axial segments. From 17°10'S to 16°51'S the spreading zone shows a deep graben with depths ranging from 3400 to 3100 m with a fairly uniform width of 4500-5000 m. It is bounded by steep walls from 3100 to 2800 m depth. In its southern part from 17°S to 17°10'S the graben deepens towards its axis. Between 16°51'S and 17°S the graben is divided in two symmetrical grabens by an axial dome 100 to 200 m high and 2 km wide which has been explored by deep tow profiling (see below). At 16°51'S a transverse fault crosses the whole area and offsets the oceanic crust structures indicating a left-lateral strike-slip motion (Fig. 1). Only the western wall of the spreading axis is unaffected by this transverse faulting. This allows us to conclude that the structure of the western wall is more recent than the strike-slip motion. North of the fault the axial graben narrows to 2.5 km width and has a more complex structure with asymmetric ridges and depressions distributed along the axis.

The junction zone between the WFR and the NFFZ is characterised by the curvature of all the structures. Towards the east the spreading axis graben abuts in a deep (more than 4000 m), wide (about 10 km) elongated E-W trending depression. To the west, the spreading axis is bound by an elongate E-W trending massif which rises to less than 2000 m depth; it is 10 km wide. To the north the area is limited by a steep EW scarp about 1000 m high. These different features constitute the junction between the WFR and the NFFZ. This junction could be interpreted as a RFF triple junction. The curvature of the spreading axis towards the east confirms the left-lateral motion of the NFFZ previously demonstrated (Falvey, 1978; Brocher and Holmes, 1985; Auzende et al., 1986; among others).

Deep towed survey of the West Fiji Ridge

Four deep towed EXPLOS runs were carried out during the HYFIFLUX cruise in an area centered at 16°55'S and 176°07'E, on both sides and on the top of the axial ridge. The axial ridge is discontinuous, 100-200 m high and 2 km wide, located in the central part of the main

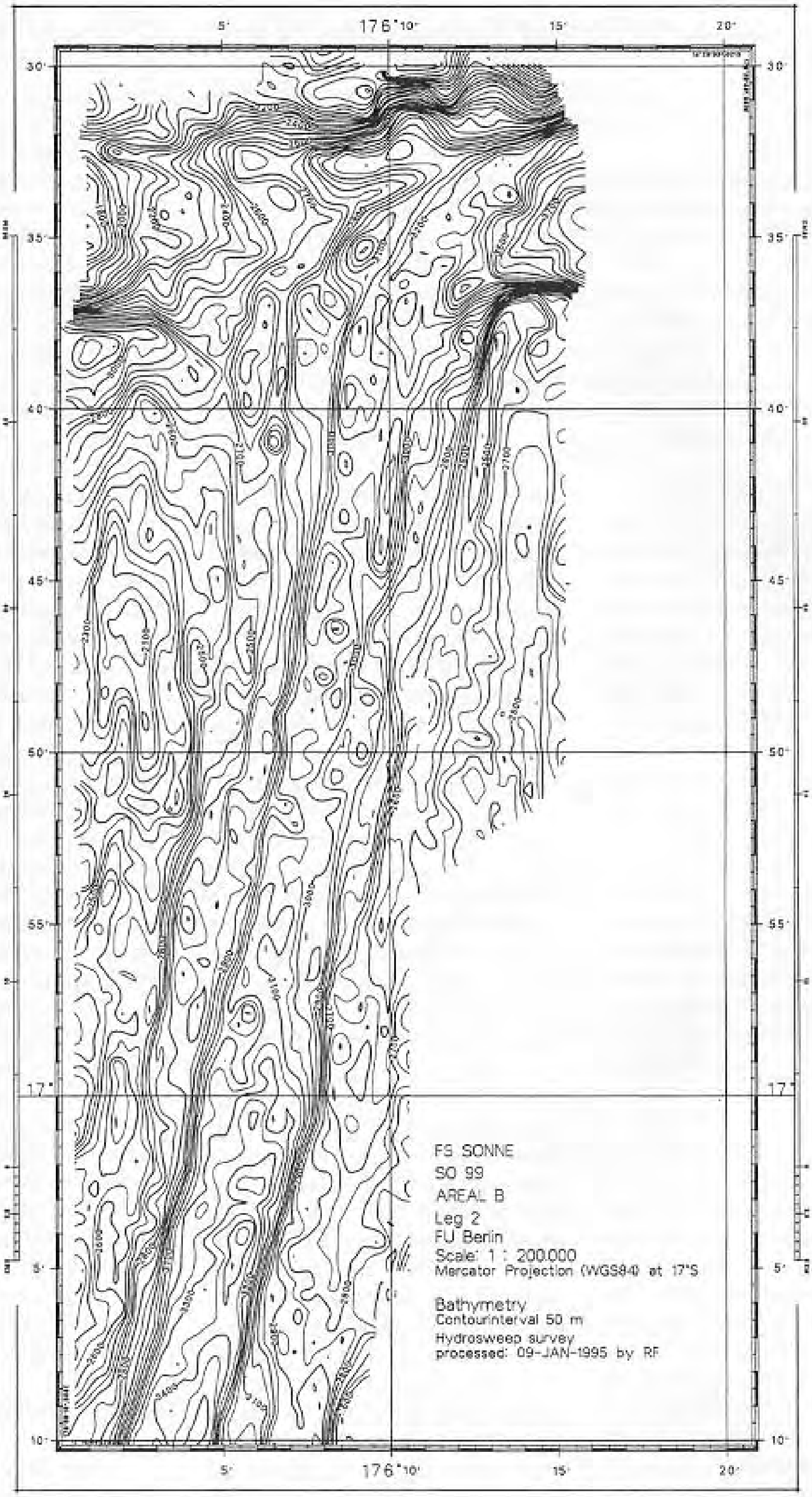

Figure 1 Bathymetric map of the northern part of the West Fifi Ridge and its junction with the Noth Fiji fracture zone; the junction is interpreted as an RFF triple junction. At 16°51'S a transverse fault crosses the whole area and offsets the oceanic crustal structures left laterally. Contour interval 50 m.

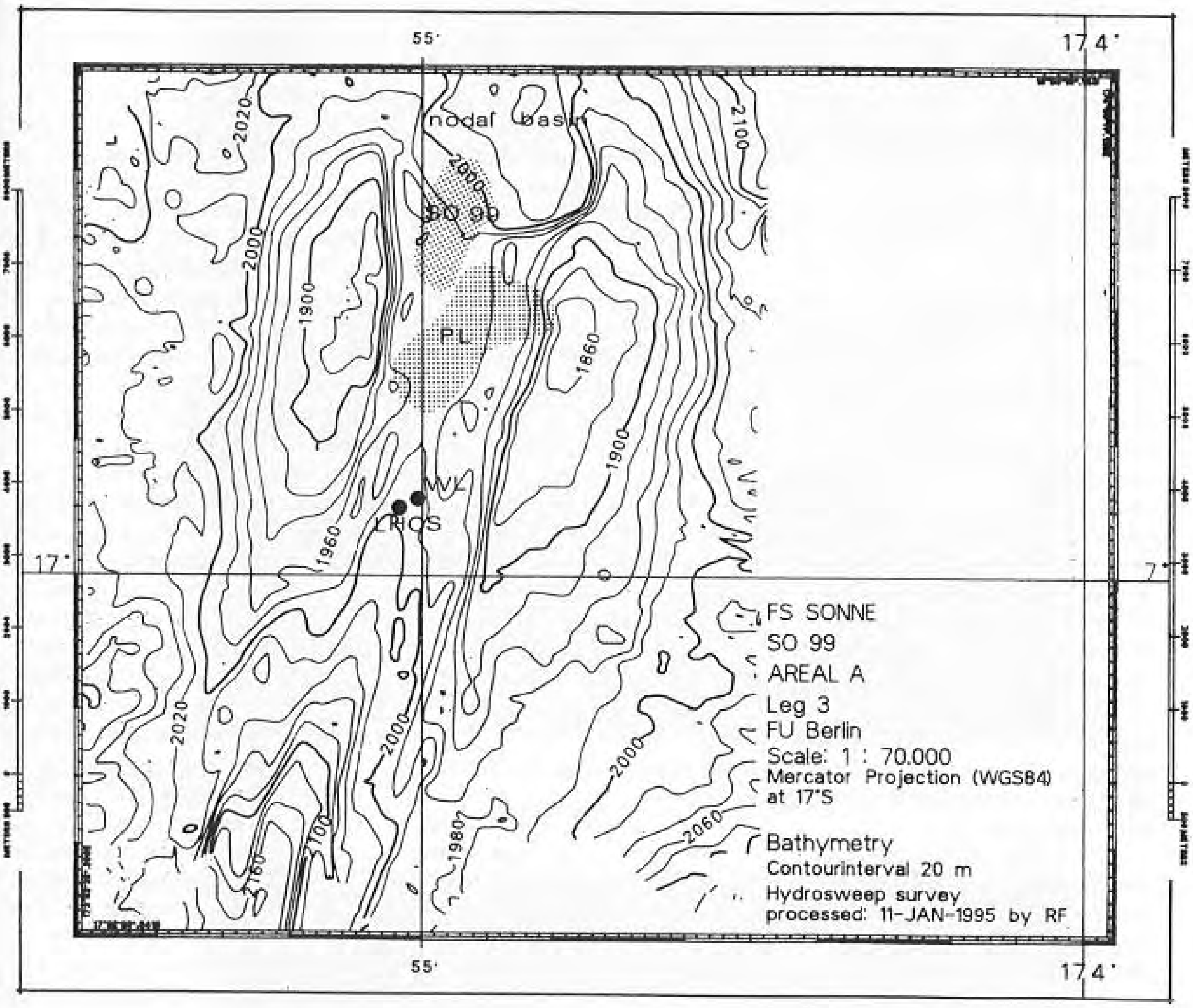

Figure 2 Bathymetric map of the northern part of the Central Fiji Ridge (N15° Segment) with the location of the new SO 99 field, Père Lachaise, the Whitte Lady and the LHOS hydrothermal sites. The SO 99 field is lacated immediately south of the round nodal basin of the triple point. Contour interval 20 m.

WFR graben, and bound by two symmetrical depressions. The deep tow surveys confirm that this part of the WFR is magmatically and tectonically active. The sea floor is covered by glassy basaltic pillows and tubes. On the top of the axial ridge and in the deepest part of the lateral depressions the pillows are covered by a thin sedimentary film, the thickness of which does not exceed 1 or 2 cm. In its middle part the axial ridge is cut by a graben, a few tens of meters wide, few meters deep, in which the lava is particularly fresh. The axial ridge is bound by active steep normal faults cutting pillow and tube lavas. At the foot of these faults large amounts of talus were observed and sampled by TV Grab.

No direct evidence of hydrothermal activity or deposits was detected during deep tow runs. The only indication of possible hydrothermal activity is given by temperature anomalies recorded on the deep tow tracks, along the eastern fault bounding of the axial ridge. Crossing this fault the temperature which was on average 2.084°C increased up to 2.131°C. This observation was made at two different places both located on the fault suggesting that at least low temperature waters are percolating through the fault bounding axial ridge.

Hydrothermal activity at the Central Spreading Ridge.

The first evidence of hydrothermal activity in the North Fiji Basin was the methane and manganese anomalies measured in the waters sampled during the SEAPSO III cruise aboard the *R/V Jean Charcot* (Auzende et al., 1986, 1988). Following this cruise other investigators obtained data confirming this activity (Craig et al., 1987; Grimaud et al., 1991, Ishibashi et al., 1994). The active White Lady hydrothermal site (Fig. 2) was discovered and sampled during the Starmer Nautile cruise (Auzende et al., 1991). The sulfides of the White Lady mound and Père Lachaise site (Fig. 2) were sampled during different cruises of the Starmer French-Japanese joint project and also by the Sonne 66 cruise. They were thoroughly studied by various investigators resulting in a large body of knowledge concerning the processes involved in their emplacement (Bendel, 1993; Halbach et al., 1991; Bendel et al., 1993)

The previously explored hydrothermally active sites on the NFB Central Spreading Ridge are probably representative of only a part of the total hydrothermal activity. The hydrocasts taken all along the ridge axis during the Starmer project suggest widespread hydrothermal activity with indications that it may, in some places, be very strong but unstable.

One of the main characteristics of the NFB ridge axis hydrothermal waters sampled by Nautile and Shinkai 6500 at the White Lady site, is their low salinity, which suggests that the fluids have undergone phase separation by boiling (Grimaud et al., 1991; Ishibashi et al., 1994). Such a phase separation would result in the formation of one vapour-like phase with low salinity and one liquid-like phase with high salinity (brine). Dissolved metal-species will be depleted in the vapor but phase separation will not significantly modify the elemental ratios as observed in the White Lady waters. The NFB hydrothermal waters could result from three-component mixing including normal seawater, low-salinity fluid from condensed vapor and brine.

EXPLOS survey of the Sonne 99 field

During the HYFIFLUX cruise 12 deep tow (EXPLOS) profiles were carried out northwest and west of the Père Lachaise area (between 16°58'S and 16°55'S). They confirm the existence of a 2 km wide graben opening to the north into a circular basin, 2100 m deep and 5 km in diameter which can be interpreted as a nodal basin marking the 16°50'S Triple Junction (Lafoy et al., 1990). The graben contains intensely fractured and fissured lava tubes, pillows and lakes near its axis. The principal observed trend of faulting is N015°E, which is parallel to the trend of the segment on which the area is located. Trends of N160°E and N045°E were also observed. The EXPLOS exploration allowed us to define the limits of the Père Lachaise fossil hydrothermal field previously explored by Nautile (Bendel, 1993). To the west and northwest of Père Lachaise, a new, very extensive hydrothermal field was discovered between 16°58'S and 16°57'S (SONNE 99 field; Fig. 2). It is an elongated deposit, 500 m wide and about 600 m long, with numerous fossil chimneys and several active chimneys (Fig 3) on the top of several mounds which reach heights of up to 6 m high. The chimneys are mostly located on the slopes or near the foot of the graben walls. Structurally the field is separated from the Père Lachaise site by an E-W to SW-NE trending smooth saddle and bound on its southern side by a normal fault, and to the north by the round nodal basin of the triple point. Another distinctive feature of the Père Lachaise site is the freshness and morphology of the lavas. In the SONNE 99 field the lava seems to be younger than that found at Père Lachaise. Also, there are many recent lava flows and scoriated lava instead of pillows and tubes.

A temperature anomaly was detected by the thermal probe installed at the EXPLOS-sledge, on the western edge of the deposit. In the same area, gastropods tests were observed concentrated at the foot of a large chimney. From video and photo observations they appear to be similar to those sampled by Nautile at the foot of White Lady site (Desbruyères et al., 1994). The highest temperature elevation (+0.35°C, measured about 3.5 m above the seafloor) and several weaker temperature anomalies as well as the presence of gastropods tests suggest that present-day, probably low temperature hydrothermalism exists in this area. The fluids emitted in this field are always translucent.

Rock, sulfide and water sampling in the Sonne 99 field

Nine TV Grab stations samples were obtained in the Sonne 99 field. A collection of volcanic rocks and massive sulfides was obtained at these stations. Overall, volcanic rocks sampled in this area are essentially aphyric basalts with extremely fresh glasses. They are dense with consistent grain size and no phenochrysts. While slight hydrothermal alteration of the basalts is observed in the White Lady and Père Lachaise sites, no macroscopically visible alteration was detected in the

Figure 3 Bottom photograph taken by the EXPLOS sledge of the SO 99 field showing the top view of a chimney structure. The chimney is about 3 m high. Remnents of hydrothermal fauna are still visable at its top. The scale weight is 25 cm long.

Figure 4 Bottom photograph taken by the EXPLOS sledge of the LHOS site showing a mussel bed (*Bathymodiolus*) partially covered by bacterial mats. Several gallateids (*Munidopsis*) may be observed towards the left of the photo. The scale weight is 25 cm long.

Figure 5 Bottom photograph taken by the EXPLOS sledge at the LHOS site: a large bed with numerous gastropods (*Alviniconcha hessleri*) and some mussels (*Bathymodiolus*) are observed. The gastropods are covered by bacterial mats. Some gallatheids are also observed. Small colonies of sessile barnacles (*Neolepas*) along the edges of the basaltic blocks are observed. The scale weight is 25 cm long.

Sonne 99 field. Most basalts from the N15° segment are depleted in LIL elements and have low trace element concentrations, for example, of Sr, Rb, Zr and Ba, which is characteristic of depleted N-MORB. However, basalts collected from immediately south of the triple junction show geochemical signatures transitional towards E-MORB or OIB (Eissen et al., 1994; Nohare et al., 1995). The basalt samples from the SO 99 field show a similar geochemical trend and are significantly enriched in K_2O, TiO_2, Sr, Rb, Zr, Nb and Ba (shipboard XRF-analyses data: K_2O: ~1.1 %, TiO_2: ~2.1 %; Sr: ~400 ppm ; Rb: ~29 ppm; Zr: ~210 ppm; Nb: ~44 ppm; Ba: ~270 ppm). The same samples are depleted in Cu (70-80 ppm) whereas the N-MORB samples have Cu concentrations of 140-150 ppm.

The sediment coring performed on- and off-axis, all suggest that the sedimentation in the area is very low. Cores taken in the symmetrical off-axis basins, where the age of the crust is supposed to be about 1.2 Ma from magnetic anomalies interpretation, give sedimentation rates ranging from 0.3 cm/1000 yr to up to 0.9 cm/1000 yr. Closer to the axis the sedimentation rates increase to up to more than 1 cm/1000 yr. This increase could be related to the effect of hydrothermal precipitates (Dekov and Kupsov, 1994). Most of the sulfides which were recovered (more than 1000 kg all told) were pieces of chimneys. Some were massive, consisting mainly of markasite and sphalerite. The Fe-sulfides are often intergrown with mm- to cm-sized anhydrite grains. Large amounts of well crystallized wurzite-rich areas are covered by smithsonite. Underneath a manganese crust of 2-3 mm thickness a yellow mineral was identified as greenockite. Smithsonite and greenockite are considered to be late-stage hydrothermal products. Another type of mineral assemblage is a highly altered basalt breccia (mm- to cm-sized fragments) which is cemented by pyrite, markasite and sphalerite. Frequent barite mineralisation reflects probably the enriched Ba-contents of the underlying basalts. Gypsum as well as zeolite crystals appear as last stage precipitates. Copper mineralisation which is abundant in the Père Lachaise field was not as frequently observed in SO 99 field sulphide samples. Chalcopyrite was typically observed as mm-thick fissure fillings in the inner part of the of the chimney fragments where the pyrite is strongly recrystallized. The alteration and weathering of the ores is less pronounced than in the Père Lachaise field.

Biological observations in the SO 99 field and at the LHOS site

The principal objective of the biological investigation to map the animal communities by the video-controlled EXPLOS deep-towed system. The first location investigated in detail was the Sonne 99 field in the northern part of the central graben system. A preliminary analysis of the fauna on board showed that most of the animals are not strictly related to the hydrothermal activity. However, suspension feeders (gorgonarian, crinoids, sponges) were found to be more abundant in the areas where the geological observations indicted were still slightly active. Of special interest is a euplectellid sponge, described by Desbruyères et al. (1994) as clustering at the outskirts of active vents in this basin. In one instance a galatheid of the genus *Munidopsis* was seen in such an area. Thus, a certain activity level can be confirmed for this area. The detailed analysis of the seafloor slides will allow better characterisation of individual areas. Some biological samples were obtained by picking up selected pieces of substrate with the TV-grab. Some of the dominant organisms as Crinoids, Orphiurids and Gorgonarians were collected and will facilitate the interpretation of the EXPLOS images. The second area was located in the highly hydrothermally active LHOS-field which yielded a species composition like the one described by Desbruyères et al. (1994). Very patchy occurrences of the dominant species were observed. *Bathymodiolus, Neolepas, Munidopsis, Alviniconcha* and *Alvinellides* were common, but very often not in the same spot. The euplectellid sponge was regularly present at the outskirts of the vent field. At least three species of fish were observed at the vents or nearby. Again, a few samples were taken with the TV-controlled grab. In addition to the known species, an as yet unidentified clam was collected, which does not appear in any earlier reports of vent fauna. Samples were fixed for taxonomic analysis and tissues were preserved of all animals collected for various investigations, especially for examination of bacterial symbiosis.

Sediment material recovered was washed through sieves and fractions >5 mm were preserved for macrobenthos analysis. In addition, samples for Meiobenthos investigations were taken. The close co-operation between geologists and biologists will continue during laboratory study and evaluation of the samples and data.

One important issue to be addressed is detailed definition of the link between geochemical (inorganic) and biological (organic) processes. We also plan to carry out a further research cruise in the White Lady area to investigate in particular the fluid chemistry and microbiology.

References

de Alteris, G., E. Ruellan, J.M. Auzende, H. Ondréas, V. Bendel, E. Gracia-Mont, Y. Lagabrielle, P. Huchon and M. Tanahashi, Propagating rifts in the North Fiji Basin (Southwest Pacific), Geology, 21, 583-586, 1993.

Auzende, J.M., J.P. Eissen, J.P. Caprais, P. Gente, S. Gueneley, F. Harmegnies, Y. Lagabrielle, A. Lapouille, C. Lefèvre, P. Maillet, J.P. Mazé, H. Ondréas, A. Schaaf and R. Singh, Accrétion océanique dans la partie méridionale du bassin Nord-Fidjien : résultats préliminaires de la campagne océanographique SEAPSO III du *N.O. Jean Charcot* (décembre 1985), C.R. Acad. Sci. Paris, 303, 93-98, 1986.

Auzende, J.M., J.P. Eissen, Y. Lafoy, P. Gente and J.L. Charlou, Seafloor spreading in the North Fiji Basin (Southwest Pacific), Tectonophysics, 146, 317-351, 1988.

Auzende, J.M., T. Urabe, V. Bendel, C. Deplus, J.P. Eissen, D. Grimaud, P. Huchon, J. Ishibash, M. Joshima, Y. Lagabrielle, C.

Mével, J. Naka, E. Ruellan, T. Tanaka and M. Tanahashi, In situ geological and geochemical study of an active hydrothermal site on the North Fiji Basin Ridge, Mar. Geol., 98, 259-269, 1991.

Auzende, J.M., B. Pelletier and Y. Lafoy, Twin active spreading ridges in the North Fiji Basin (S.W. Pacific), Geology, 22, 63-66, 1994.

Bendel, V., Cadre géologique et composition des minéralisations hydrothermales en contexte arrière-arc : exemple de la dorsale du Bassin Nord Fidjien, Thèse Univ. Brest, France, 259 p, 1993.

Bendel, V., Y. Fouquet, J.M. Auzende, Y. Lagabrielle, D. Grimaud and T. Urabe, Metallogenesis at a triple junction system: the White Lady hydrothermal field (North Fiji Back-Arc Basin, SW Pacific), Economical Geology, 88, 2237-2249, 1993.

Brocher, T.M., and R. Holmes, The marine geology of sedimentary basins south of Viti Levu, Fiji, in T.M. Brocher, (ed), Investigations of the Northern Melanesian Borderland, Circum- Pacific Council for Energy and Mineral Resources, Earth Science Series, 3, Houston, Texas, 123-138, 1985.

Chase, C.G., Tectonic history of the Fiji Plateau, Geol. Soc. Am. Bull., 82, 3087-3110, 1971.

Desbruyères D., A-M. Alayse-Danet, S. Ohta and the Scientific parties of Biolau and Starmer cruises, Deep-sea hydrothermal communities in the Southwestern Pacific back-arc basins (the North Fiji and Lau Basins): composition, microdistribution and food web, in: the North Fiji Basin (SW Pacific), J.M. Auzende and T. Urabe (eds), Marine Geology, STARMER Special Issue, 116, 1/2, 227-242, 1994.

Eissen, J.-P., M. Nohara, J. Cotten and K. Hirose, North Fiji Basin basalts and their magma sources: Part I. Incompatible element constrains. Marine Geology, 116, 153-178, 1994.

Falvey, D.A., Analysis of paleomagnetic data from the New Hebrides, Bull. Aust. Soc. Explor. Geophys., 9, 3, 117-123, 1978.

Grimaud, D., J.I. Ishibashi, Y. Lagabrielle, J.M. Auzende and T. Urabe, Chemistry of hydrothermal fluids from the 17°S active site on the North Fiji Basin ridge (SW Pacific), Chemical Geology, 93, 209-218, 1991.

Halbach, P., A. Koschinsky, P. Dreßen, B. Pracejus and S. Bubilete, Geowissenschaftliche Untersuchungen und lagerstättenkundliche Bewertung der Erzkrusten des zentralen Pazifiks südlich des Äquators (SO 66); Hydrothermale Mineralisationen aus Areal x (White Lady area, NFB).- BMFT- Bericht, Clausthal- Zellerfeld, 176- 182, 1981.

Hamburger, M.W. and B.L. Isacks, Diffuse back-arc deformation in the Southwestern Pacific, Nature, 332, 599-604, 1988.

Ishibashi, J., D. Grimaud, Y. Nojiri, J.M. Auzende and T. Urabe, Fluctuation of chemical compositions of the phase-separated hydrothermal fluid from the North Fiji Basin, in the North Fiji Basin (SW Pacific), J.M. Auzende and T. Urabe (eds), Marine Geology, STARMER Special Issue, 1994.

Lafoy, Y., J.M. Auzende, E. Ruellan, P. Huchon and E. Honza, The 16°40'S Triple Junction in the North Fiji Basin (SW Pacific), Mar. Geophys. Res., 12, 285-296, 1990.

Louat, R. and B. Pelletier, Seismotectonic and present-day relative plate motions in the New Hebrides-North Fiji Basin region, Tectonophysics, 167, 41-55, 1989.

Maillet, P., J.P. Eissen, A. Lapouille, M. Monzier, V. Baleivanualal, J. Butscher, F. Gallois and M. Lardy, La dorsale active du bassin Nord-Fidjien entre 20°S et 20°53'S : signature magnétique et morphologique, C.R. Acad. Sci. Paris, 302, II, 135-140, 1986.

Nohara, M., K. Hirose, J.-P. Eissen, T. Urabe and M. Joshima, The North Fiji Basin basalts and their magma sources: Part II. Sr-Nd isotopic and trace element constrains, Marine Geology 116, 179- 195, 1994.

Pelletier, B., and R. Louat, Mouvement relatif des plaques dans le Sud-Ouest Pacifique, C.R. Acad. Sci. Paris, 308, 123-130, 1989.

The InterRidge Office is currently accepting submittal of articles for the next issue of *InterRidge News* to be published in October 1995.

Ridge crest researchers are encouraged to submit their findings as short articles (1-4 printed pages with up to 3 figures).

Appropriate topics include:

- preliminary results of ridge crest cruises, particularly involving multi-national co-operation
- technical or engineering developments capable of enhancing ridge crest investigations.

Submission:

- Prefered submission method/format is as via the Internet as an attached RTF file.
- Please check this issue for reference style.

Articles must arrive in the InterRidge Office no later than 30 September 1995.

World Ridge Cruise Schedule

Country	PI	Institution	Name/Location	Research Objectives	Ship	Dates
Canada	Juniper	Univ. du Québec	**BioROPOS 94 I:** Endeavor Segment, Juan de Fuca Ridge	ROPOS ROV, establishment of a biological observatory	John Tully	June/July '94
Canada	Scott	Univ. of Toronto	**BioROPOS 94 II:** Explorer Ridge, Juan de Fuca Ridge	Electromagnetic survey of the hydrothermal vent site with ROPOS	John Tully	July '94
Canada/ USA	Evans/Webb	Univ of Toronto/ SIO	Middle Valley Juan de Fuca Ridge	Electromagnetic mapping of shallow crustal structural variability	Meville	June '94
Canada/ USA	Juniper/ Fisher	Univ. du Québec Penn State Univ.	**BioROPOS 95:** Endeavour Segment, Juan de Fuca Ridge	Biology, hydrothermal vents	John Tulley/ ROPOS	July '95
Canada	Edwards/ Scott	Univ. of Toronto	**GeoCanRidge IV:** Southern Explorer Ridge		John Tulley/ ROPOS	July '95
Canada	Thomson	IOS	Endeavour & Coaxial Segments Juan de Fuca Ridge	Hydrothermal plume fluxes biogeochemical links w/ upper water column	Endeavour	July '95
France (FARA)	Fouquet	IFREMER/ Brest	**DIVA 1:** 37°10'N MAR (Lucky Strike Segment)	Hydrothermal site submersible sampling: petro. hydrochem.	Nadir/Nautile	May '94
France (FARA)	Desbruyères	IFREMER/ Brest	**DIVA 2:** 37°10'N MAR (Lucky Strike Segment)	Hydrothermal site submersible sampling: biology hydrochem	Nadir/Nautile	June-Aug '94
France	Lagabrielle/ Reullan	IFREMER/ Brest	**NOFI:** Northern Fijian Basin	Bathymetry (EM12), grav, dredging, magnetics, seismics, hydrology	Atalante	Sept '94
France	Bideau/ Hekinian	IFREMER	**OCEANAUT:** Central North Atlantic	Petrologic and geochemical variations along a slow-spreading ridge	Nadir/Nautile	July '95

France	Tapponnier/ Huchon	IPG Paris ENS	**TADJOURADEN 1:** Gulf of Tadjoura	Continental rifting, initiation of seafloor accretion	Atalante	Aug '95
France	Patriat	IPG Paris	**GALLIENI**: Southwest Indian Ridge	Structure and evolution of an ultra-slow spreading ridge	Atalante	Sept '95
France	Prieur	Univ. de Brest	**MICROSMOKE 95:** N. Atlantic 23°22'N, 45° 57'W - Snakepit	Microbiology, hydrothermal vents	Nadir/Nautile	Nov '95
France	Deplus	IPG Paris	**SAMUDRA**: Northeast Indian Ocean	Oblique subduction, fossil ridge	Atalante	Nov '95
France	Géli	IFREMER	**PACANTARTIC**: Antarctic-Pacific Ridge	Geophysics, geochemistry	Atalante	Jan/Feb '96
Germany/ US	Herzig/ Humphries	Berakademie Freiberg/WHOI	**ODP Leg 158:** TAG Area Mid-Atlantic Ridge	Drilling a hydrothermal system	JOIDES Resolution	Oct./Nov '94
Germany	Devey	University of Kiel	**Poseiden:** Kolbeinsey Ridge 68.5° - 70°N	Bathymetry, rock sampling, geochemistry	Hesperides	1995 rescheduled
Germany	Stoffers	Univ. of Kiel	Red Sea	Hydrothemalism, sedimentation	Meteor	1995
Germany	Halbach/ Windoffer Giere	FU Berlin/ U. of Hamburg	**HYFIFLUX:** North Fiji Basin	Hydrothermalism, biology, fluxes	Sonne	Jan '95
Germany	Halbach	FU Berlin	**HYDROCK I:** Indian Ocean	Geophysics, mapping, sampling	Meteor	Nov '95
Japan MODE '94	Fujimoto/ Bryan	ORI/ JAMSTEC	**WMARK:** Western Kane FZ, MAR	15 dives, geophysics	Yokosuka/ Shinkai 6500	June/July 94
Japan MODE '94	Fujioka	JAMSTEC	TAG hydrothermal site, MAR	15 dives, geochemistry, geophysics	Yokosuka/ Shinkai 6500	July/Aug '94
Japan MODE '94	Urabe	Geological Survey of Japan	**EPR-1:** East Pacific Rise, 13°-18°S	15 dives, hydrothermal observations, geophysics, geochemistry	Yokosuka/ Shinkai 6500	Sept/Oct '94

Country	PI	Institution	Name/Location	Research Objectives	Ship	Date
Japan MODE '94	Fujioka	JAMSTEC	**EPR-2:** East Pacific Rise, 13°-18°S	15 dives, hydrothermal observations surveys geophysics, geochemistry	Yokosuka/ Shinkai 6500	Oct/Nov '94
Japan	Urabe	JAMSTEC/ Geological Survey of Japan	**Manus Basin Diving Experiment:** Manus Basin	15 dives, geochemistry, geophysics	Yokosuka/ Shinkai 6500	Oct/Nov '95
Japan (Ridge-Flux)	Kinoshita	STA	S-EPR: East Pacific Rise, 13°-18°S	Morphological survey	TAMU 2	Late 1995
Japan	Taira/ Ishii	ORI/ Univ. of Tokyo	Mariana Arc, Mariana Trough	Rock sampling, geophysics		June/July 95
United Kingdom	Searle	University of Durham	Reykjanes Ridge,	Geophysics	Charles Darwin	June/July '94
United Kingdom	German/ Parson	IOSDL	**HEAT:** Mid-Atlantic Ridge: Azores	Hydrothermal exploration, geophysics	Charles Darwin	Aug/Sept '94
United Kingdom	German/ Elderfield/ Sinha	IOSDL/ Cambridge	**BRIDGET:** Mid-Atlantic Ridge: Azores	Deep-towed detection and sampling of hydrothermal activity, trials	Charles Darwin	Sept '94
United Kingdom	Elderfield	University of Cambridge	Mid-Atlantic Ridge, Broken Spur 29°N	Geochemistry	Charles Darwin	Sept. '94
United Kingdom	Livermore/ Mitchell/ Larter	British Antarctic Survey/ Univ. of Durham	East Scotia Sea, South American-Antarctic Ridge, Bouvet Triple Junction	Infuence of subduction on ridge crest processes, tectonics of the Bouvet Triple Junction	James Clark Ross	Jan/Feb '95
United Kingdom	Elderfield	University of Cambridge	**BRAVEX/94:** Mid-Atlantic Ridge Broken Spur and TAG	Geophysics, diving, geochemistry	Kheldysh	Aug/Sept '94
United Kingdom	Murton	IOSDL	**MARFLUX:** MAR 29°N Broken Spur hydrotherm. site	Integrated fluxes experiment	Charles Darwin	Aug/Sept '95

United Kingdom	Searle	University of Durham	Mid-Atlantic Ridge: 29°N axial segment	Geophysics	Charles Darwin	1996/97 provisional
United Kingdom	Sinha/ Peirce	Cambridge/ Durham	Lau Basin	Geophysics	Ewing	Oct/Nov '95 provisional
USA (RIDGE)	Cannon/ Joyce	NOAA/ WHOI	Juan de Fuca Ridge	Hydrodynamic of water circulation at a hydrothermal vent site	Wecoma	1994
USA (RIDGE)	Von Damm/ Lilley	U New Hampshire U of Washington	East Pacific Rise 9°N	Temporal evolution of hydrothermal, volcanic and geological properties	Alvin	1994
USA (MG&G)	Kadko	University of Miami	North Clef, Juan de Fuca Ridge	Radioisotopes, temporal variability	Alvin	1994
USA (MG&G)	Batiza	University of Hawaii	East Pacific Rise 12°N	Hyaloclastites	Alvin	1995
USA (MG&G)	Mottl	University of Hawaii	Juan de Fuca Ridge	Off-axis Hydrothermal venting	Alvin	1995
USA (RIDGE)	Delaney	University of Washington	Juan de Fuca Ridge	Hydrothermal systems	Alvin	1995
USA (RIDGE)	Johnson/ Delaney	University of Washington	Juan de Fuca Ridge	Coaxial eruption response and time dependent changes in young crust	Alvin	1995
USA (MG&G)	Tivey	WHOI	Juan de Fuca Ridge	Magnetic Polarity boundary	Alvin	1995
USA (ODP)	Detrick	WHOI	Galapagos Ridge	Crustal structure at ODP hole 504B	Ewing	1994
USA (MG&G)	McClain/ Orcutt	UCSD	Clipperton Fracture Zone East Pacific Rise	information not available	Ewing	1994
USA (RIDGE)	Detrick	WHOI	Mid-Atlantic Ridge	Seismic experiment	Ewing	1996

Country	PI	Institution	Name/Location	Research Objectives	Ship	Date
USA (ODP)	Kleinrock	Vanderbilt Univ.	Mid-Atlantic Ridge	TAG - ARGO & AMS-120	Knorr	1994
USA (RIDGE)	Spiess	Scripps Inst. of Oceanography	Juan de Fuca Ridge	Seafloor strain measurements	Large	94/95/96
USA (MG&G)	Lonsdale/ Bloomer	Scripps Inst. of Oceanography	Eltanin transform East Pacific Rise	Mapping	Melville	1994
USA (MG&G)	Phipps Morgan Orcutt	Scripps Inst. of Oceanography	Australian-Antarctic Discorcance	Crustal structure	Meville	1994
USA (MG&G)	Lonsdale	Scripps Inst. of Oceanography	Pacific-Antarctic Ridge	Off-axis to origin	Meville	1994/5
USA (MGG/ RIDGE)	Christie/ Cochran et al.	Oregon State Univ/LDEO	Southeast Indian Ridge: 90° to 120°E	Geochemistry and geophysics	Melville	Dec 95 Mar 95
USA (RIDGE	Grindlay/ Madsen et al.	Univ Porto Rico Univ of Delaware	Southwest Indian Ridge: 15°E to 35°E	Geophysics	Melville	1995

InterRidge Workshop Summaries

Global Studies Workshop:

Arctic Ridges: Results and Planning

Kiel, Germany; 15-17 November, 1995

Convenors: Marcus Langseth and Roland Rihm

The InterRidge Workshop on Arctic Ridges attracted over 40 scientists from eight countries to GEOMAR in Kiel, Germany to discuss current knowledge, scientific issues and the needs for future exploration of the mid-ocean ridge system in the Arctic region. Participants met for three grey and rainy days from November 15 to 17. In the next few years InterRidge plans to focus efforts on the Arctic ridge system, which is defined as those segments of the mid-Atlantic ridge system from the Southern tip of the Kolbeinsey Ridge at the northern margin of Iceland to the termination of the Mid-Atlantic Ridge spreading system in the Laptev Shelf in the Arctic Ocean.

Three topics dominated the workshop sessions.

1. Collation and synthesis of existing data on the Arctic ridges.
2. Important scientific issues and opportunities.
3. Future exploration.

Synthesis of existing data:

One objective of the Arctic Ridges Workshop was to initiate a synthesis of geophysical, geological and biological data for the Arctic ridges system. The synthesis, which is being co-ordinated by Roland Rihm at GEOMAR (see Fig. 1), will provide the foundation for InterRidge endorsed field programs.

Two comprehensive efforts to compile data from the active ridges of the Arctic Region are nearing completion: (1) The Arctic Working Group at the Atlantic Geoscience Center (AGC), Dartmouth, Nova Scotia has compiled, seismic refraction data and sediment coring data and produced magnetic and bathymetric maps for the Norwegian-Greenland Sea and the Arctic Ocean (More information on the compilations by AGC can be found in the November 1994 issue of RIDGE Events). (2) The Norwegian Polar Institute is preparing to publish an atlas of the Norwegian-Greenland seafloor, with compilations of regional bathymetry, gravity, magnetics, seafloor echo character, core locations and heat flow. The atlas will spotlight swath-mapping imagery from Mohns, Knipovich and Molloy Ridges, Vesteris Seamount and the eastern margin of Greenland. For further information about the Norwegian Polar Institute atlas contact Annemor Brekke, Norwegian Polar Institute, P.O. Box 5072, Majorstua, N-0301 Oslo, Norway.

The Arctic Ocean has an order of magnitude less data than the ice-free seas to the south. One way coverage could be greatly increased in the Arctic Ocean would be to release the large sets of classified and unpublished data that was collected during the cold war by military aircraft and submarines to the civilian scientific community. The end of the cold war and the restructuring of Russia is opening up a window of opportunity to obtain and exchange these valuable data sets. The Arctic Ridges Workshop strongly encourages the relevant agencies in the United States and Russia to make these valuable data available to the international research community.

Scientific issues:

Almost every segment of the Arctic ridge System is anomalous in some way. The Kolbeinsey Ridge is anomalously shallow. A recent French survey of the axial valley of Mohns Ridge discovered short, en echelon spreading centers that are oblique to the trend of the axis. The Knipovich Ridge which is tucked-in against the Norwegian-Svalbaard Margin trends at about 75° to the trend of Mohns Ridge or 15° to the general spreading direction in the Norwegian-Greenland Sea. The Nansen-Gakkel Ridge, which is an extension of the Mid-Atlantic Ridge into the Arctic Ocean, is anomalously deep (ca. 3500 m), and it is the slowest spreading major ridge segment in the world oceans. These unique characteristics and settings of the Arctic ridge system pose intriguing scientific questions that are relevant to understanding the global ridge system.

Petrologists at the workshop stressed that the very slow spreading rate, especially in the Arctic Ocean segment, provided an ideal testing ground for models of magma generation from mantle of varying composition. For example, how does the chemistry of the Nansen-Gakkel Ridge fit into the global systematics of ocean ridges, and models for mantle melting? How does the pattern of mantle flow and melt delivery at ocean ridges change with spreading rate? Does the degree of mantle melting approach "near zero" conditions in the Nansen-Gakkel Ridge, and does this produce a chemical discontinuity in basalts erupted along the ridge? Is the distribution of chemical heterogeneity controlled by spreading rate or regional differences?

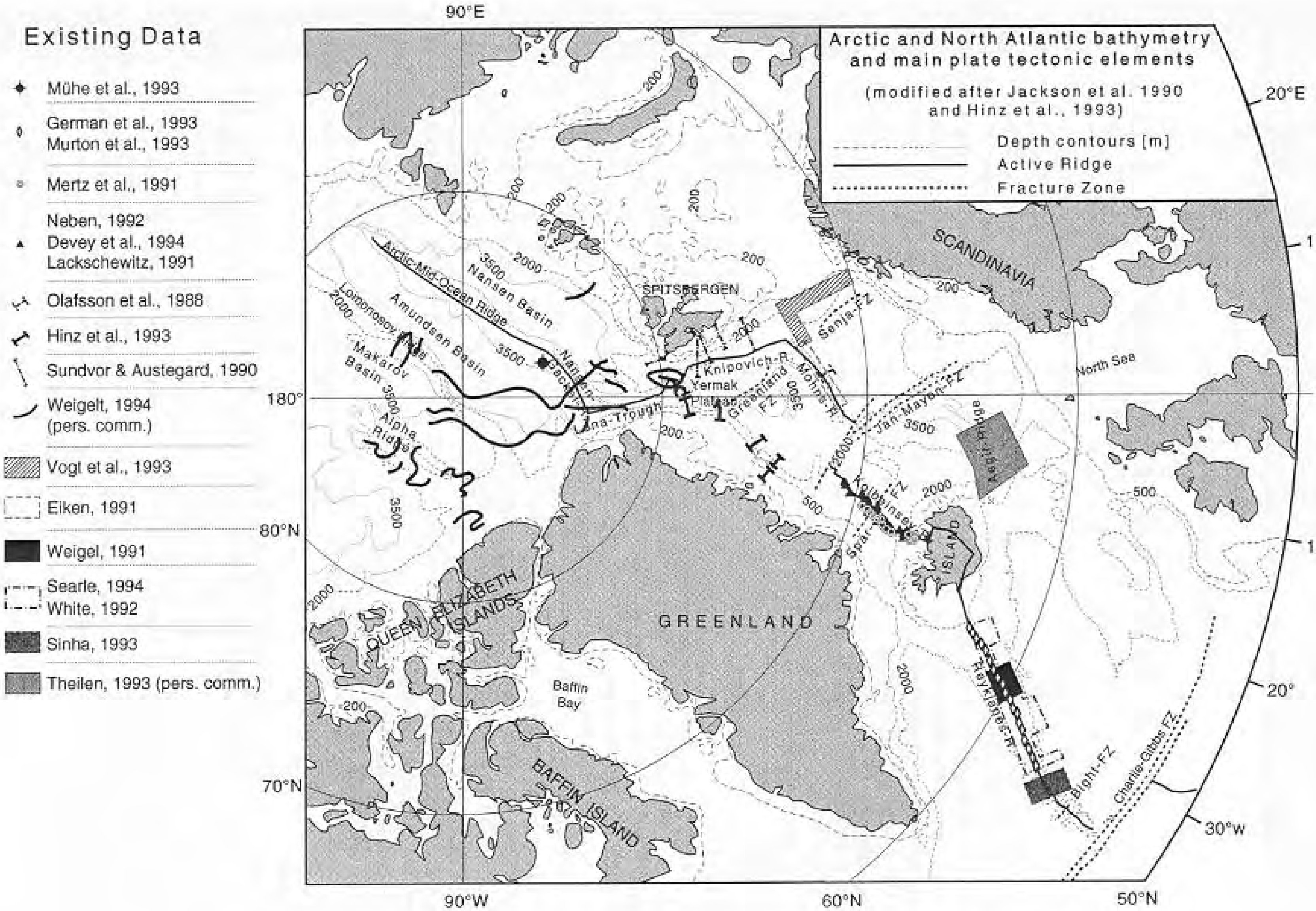

Figure 1. Areas where there is data coverage in the Arctic Ridges.

Biologists at the Workshop pointed out that the only documented biological community associated with hydrothermal venting in the Arctic ridge system is at the southern end of the Kolbeinsey Ridge in relatively shallow water, although some 'dead' bivalves were collected by *R/V Polarstern* in 1993 at the eastern end of the Nansen-Gakkel Ridge. Otherwise, the axis of the Arctic ridge system is totally unexplored as far as hydrothermal vents or hydrothermal vent communities are concerned.

There is great interest in learning more about the biology of the Arctic Ridge system because of its location at a "dead end" in the global ridge system. In addition, the Arctic ridge system is hydrographically isolated from the deep Atlantic, and presents a wide variety of axial depths and nutrient supplies. Biologists recommended studies of benthic and vent fauna that could help answer a number of globally significant questions: Has the vent fauna of the Arctic ridges evolved independently from the rest of the global ridge fauna? If so, what kinds of parallel evolution can be observed? What is the relative importance of selective pressures in hydrothermal vent communities? Biologists also see opportunities in the Arctic ridge system to learn how the taxonomic and trophic structure of vent communities change with depth.

Geophysicists at the Workshop expressed interest in the wide variety of tectonic and magmatic responses to seafloor spreading displayed by the different segments of the Arctic ridge system. Questions such as the variation of crustal thickness with spreading rate and the relation of tectonic style to temperature of the crust and upper mantle can be profitably addressed in the Arctic Ridge System, since it occupies the extreme end of the spreading rate spectrum. The distribution and temperatures of vents north of the Icelandic margin are completely unknown. Geothermal and hydrogeological studies in the highly variable environments of the Arctic ridge system will contribute to understanding ridge hydrothermal activity generally and provide estimates of the contribution of the Arctic ridges to the global heat and chemical flux.

Many of the questions of interest to geophysicists interweave with the interests of the petrologists and biologists. For example, exploration for axial vents will identify sites and define environmental parameters for studies of vent communities. The thickness of the crust determined from seismic surveys is directly related to mantle melt production. Definition of the structural style, in particular the highly fractured, slow spreading centers will provide petrologists targets to sample the lower crust and the mantle.

Sedimentologists and paleooceanographers have long standing interest in the Arctic for among other things its unique sedimentary environment, the history of ice in the Arctic, the Arctic's sensitivity to global climate change, and the Arctic Ocean's input to and impact on the global circulation of deep water in the Atlantic.

Future exploration:

The above is only a thin sampling of the important scientific issues posed by the Arctic ridge system and discussed at the Arctic Ridges Workshop. Over the last 15 years, reconnaissance sampling of the Mid-Atlantic Ridge north of Iceland has begun in earnest; in general, the intensity of sampling has decreased with distance north from Iceland. Only a few geophysical traverses have been made across the Nansen-Gakkel ridge, and two meager samples of igneous rock have been dredges from the ridge axis.

The RIDGE program has employed and perfected a wide range of exploratory techniques and tools, such as seismic tomography and swath-mapping to image the seafloor morphology and the subseafloor structure of the axial zone of mid-ocean ridges. Deep submersibles have been used vigorously to study the axial neovolcanic zone, hydrothermal vents and vent communities. Extensive sampling of the ridges has been carried out using dredges, JOIDES Ocean Drilling capability, submersibles and remotely operated vehicles (ROVs). In the next decade we need to focus these tools on the Arctic Ridges.

Because of the intense interest in the ultra slow-spreading Nansen-Gakkel Ridge, and the complex of large fracture zones in the Fram Strait there was much discussion at the Workshop about access to the ice-covered Arctic Ocean. Station work - coring, dredging, heat flow and deployment of ROVs - on the Nansen-Gakkel Ridge can be carried out from existing ice-capable research vessels such as Germany's F.S. *Polarstern*, Canada's icebreaker the *Louis St. Laurent* or the research icebreaker *Healy* being built by the US Coast Guard. For work in the central Arctic these ships would have to be escorted by a larger, more capable icebreaker such the Swedish *Oden* or the Russian nuclear icebreakers, which would allow work anywhere in the Eurasia Basin. However, surface ships are not ideal for underway geophysics because of the noise, broken ice as well as variable speeds and headings while making progress through ice.

Two platforms deserve special consideration for Arctic exploration aircraft and nuclear powered submarines. There are a number of well equipped aircraft have the range to carry out aeromagnetics and aerogravity surveys over 95% of the deep water regions of the Arctic Ocean. Scientists at the Naval Research Laboratory have been using aircraft in the western Arctic for the past several years. Nuclear submarines are an ideal platform for underway geophysical, cryological and hydrographic measurements because of their complete independence from surface conditions as well as their great range, speed, low noise and stability. A submarine that is dedicated to oceanographic research could carry the full range of geophysical sensors that are now available on modern research ships, and could efficiently chart large areas of the Arctic Ocean in a short period of time.

In some cases the Arctic ice pack can be used to advantage. Remotely recording seismic arrays that navigate by GPS and transmit data via satellite can be frozen into the ice rather than set on the sea floor. Such arrays can be design and placed to carry out seismic refraction imaging of the crust of the axial zone or side-scan mapping of the seafloor.

Some novel approaches to moving over the ice were described at the Workshop. The Arktos, which is carried on the ice breaker *Louis St. Laurent*, is an amphibious vehicle that can travel across ice and through water. It can carry fuel, people and equipment across the ice at a speed of 2-3 knots. Modern hovercraft which can navigate ice ridges up to 5 feet or melt ponds at high speed, that could operate from Arctic ports or from an ice breakers, can greatly extend the range of operations.

In summary, it's time for InterRidge to look northward, to the ridge system in the northernmost Atlantic and Arctic Oceans. The wide variety of responses of the lithosphere to sea floor spreading north of Iceland provides a unique laboratory for study of a broad range of scientific issues relevant to the global mid-ocean ridge system. The ultra-slow spreading in the Arctic Ocean offers an unequalled opportunity to learn more about melt production and migration in the mantle. Comparison of the geochemistry of magmas from the Kolbeinsey Ridge with that of the Reykjanes Ridge may yield insights into large scale mantle movements. We can learn more about hydrothermal circulation and the development high temperature vents in the Arctic ridges where the relatively high strength of the lithosphere near slow spreading centers results in a novel environment in which to study these important phenomena. The isolation of the Norwegian-Greenland Sea from the Atlantic by ridges and the deadend of the mid-ocean ridge in the Arctic Ocean cul de sac should have a profound effect on the distribution and evolution of vent and benthic communities. The response of the Arctic to past climate changes, and its influence on general ocean circulation are critical questions that can be answered by sampling and analysis of sampling of the sediments of the Arctic Ocean and adjacent seas by drilling and coring.

Exploration of the ice Arctic Ocean presents special challenges to would-be investigators. However, these challenges can be met with existing or soon to be built facilities and technology. Large ice breakers capable of operating in multi-year ice, ice capable research vessels such as the *Polarstern* and others being planned, and scientifically outfitted nuclear submarines provide access to the entire Arctic Ocean. Ancillary vehicles such as helicopters, snow mobiles, *Arktos* and possibly hovercraft provide extended mobility and flexibility. Exploration of the Arctic Ocean is expensive, but carefully planned expeditions to the Arctic region using these and conventional assets could increase our base of knowledge of the Arctic Ridges many fold in just a few years, and at the same time greatly increase our understanding of the global ridge system and its many manifestations.

- Mark Langseth

Meso-Scale Studies Workshop:

4-D Architecture of the Oceanic Lithosphere

Boston, MA, USA; 23 & 24 September, 1994

Convenors: Lindsay Parson, Jian Lin, and Catherine Mével

The meeting recommended three designated experiments to take place under Phase 2 of InterRidge. In each, there should be considerable emphasis on the linking of geophysical imaging with outcrop geology.

Fast-spreading experiment: Hess Deep

It was agreed to take advantage of the unique opportunity offered for access to the deep crust in Hess Deep and to designate this area as the site of the InterRidge 4-D Architecture of Fast-spreading Segments Experiment. The experiment would involve carefully co-ordinated surface and near-bottom geophysical and geological observations, sampling, and drilling, in a series of nested targeted boxes of scales ranging from a few meters to 100's kilometers.

Slow-spreading experiment: Mid-Atlantic Ridge

This experiment would also involve co-ordinated studies in a series of nested boxes of similar scales to the fast-spreading experiment, and would include both flow-line transects of shallow drilling and dredging, coupled with deep and offset drilling at two sites characterised by relatively high and low Mantle Bouguer Anomalies. A short-list of four sites was drawn up, and National Correspondents were asked to obtain feedback on these from their national programmes.

Ridge Drilling

In recognition of the importance attached by the Meso-Scale Programme to drilling, it was further agreed to designate drilling studies as a third distinct component of the 4-D Architecture Experiments. This would include and co-ordinate the drilling proposed at Hess Deep and the MAR site, and would in addition promote further drilling at ODP site 735B on the SWIR.

- Roger Searle

Active Processes Workshop:

Event Detection and Response & A Ridge Crest Observatory

Paris, France; 16 - 18 January 1995

Convenor: Joe Cann

The third theme area for InterRidge activities, that of Active Processes at mid-ocean ridges, held its first meeting rather belatedly at the Institut d'Océanographie in Paris early in the year. The Institut, a strange confection of turn of the century spiky ironwork, tall brick towers, marine murals of octopuses and trawlers, and a meeting room resembling a medical school operating theatre, was a suitable venue for some of the more recondite imaginings of the marine community.

This theme centres on the fact that the mid-ocean ridges are one of the most active environments on Earth. Each year about 3 km^3 of lava are erupted onto the sea floor at ridges, and perhaps 5 times as much magma is intruded into the crust. About 10% of the loss of the Earth's internal heat takes place at mid-ocean ridges through hydrothermal circulation and other forms of convection. Hydrothermal systems wax and wane, for reasons yet unclear, generating major sulphide deposits in some places, and strings of little vents in others. New faults are constantly being generated as the crust stretches, and evolve rapidly to maturity. The ridges host biological communities in a constant dynamic flux that must both renew themselves in place and also seek new opportunities for colonisation.

Almost all of this activity takes place at the sea floor or within a few kilometres below the sea floor, in contrast to the situation at subduction zones, where much activity is far deeper in the Earth. This means that the mid-ocean ridges provide a unique opportunity to study active Earth processes and the complex interactions between them.

Understanding the dynamics of processes within a system requires information about the rate of the processes operating and about the episodicity of processes that vary in time. For many geological processes it is difficult to constrain rates or episodicity except indirectly. This is especially true of mid-ocean ridges. It has been difficult in the past to conduct continuous measurements on the ocean floor in the same way as has been possible on land. Our best efforts have often been an irregularly spaced series of snapshots rather than a continuous record. There are many examples of ways in which continuous observation of active processes can lead to new scientific insights.

Tectonics of spreading can be illuminated where spreading centers come above sea level. Events in Iceland have shown that crustal spreading there happens episodically, every 100-200 years in any segment. Studies of mid-ocean ridge seismicity have apparently not yet revealed the clustering of events in time that would be expected if Icelandic-type events were the norm. Events involving major eruptive episodes have been rare in Iceland in historic times, so there may be a longer periodicity, perhaps thousands of years, separating large spreading center eruptions. At the other end of the scale, observation of the ultra-fast portion of the East Pacific Rise suggests that eruptions can be near continuous over substantial periods of time.

Generation of new faults and growth of existing faults is a continuing process at spreading centers, and the process there is much more clearly defined than in, for example, continental rifts, since distance from the spreading axis represents time as well as space. Studies of faulting at the Mid-Atlantic Ridge show that a new major fault must be generated every 100,000 years or so in a given spreading segment, and must grow fast to a length of tens of kilometres. Since there are very many spreading segments, in several there must be active fault growth occurring at any time.

Ocean floor volcanology is still an embryonic science. Pioneering work in subaerially exposed submarine volcanics has contributed much, as have submersible studies, but recent high resolution sidescan images of spreading centers have shown a great variety of morphology at a scale not previously accessible to view. By great good fortune, two seafloor eruptions have recently been studied as they happened, at 9°30'N on the East Pacific Rise and at the Coaxial Segment of the Juan de Fuca Ridge. In both cases it has been possible to define the overall geometry of the erupted unit, which has been done only once before for a single eruption.

In other places, such as further south on the East Pacific Rise and at 25°N on the Mid-Atlantic Ridge, there is evidence for much larger eruptive episodes. Perhaps even at slow-spreading ridges crustal construction periodically takes place in major eruptive events.

Hydrothermal systems present important opportunities, and also a rich variety of dynamics for study. Ocean floor hydrothermal systems have many characteristics that depend on deep water for their operation: the high pressure in deep water suppresses boiling over most of the circulation path, and the presence of the overlying ocean ensures that most of the water passes through the system once only. Understanding of hydrothermal systems requires estimates of the total fluxes of heat and chemicals from vent fields, and also observation of variability at a wide range of time scales, from that of the life time of the vent field down to that of the growth and collapse of individual sulphide chimneys. In between these limits are a rich variety of time variable behaviours, including hydrothermal brecciation events, megaplume generation, and periods of rapidly changing temperatures. The recent Coaxial eruptive event showed that short-lived hydrothermal systems can be generated above dykes intruded laterally beneath the surface.

Associated with hydrothermal systems are biological systems which have their own dynamics. Organisms must have developed a range of strategies to cope with the constantly changing environment in which they live. These will include strategies for reproduction, dispersal and settling within the vent field they now occupy, and also for the colonisation of new vent fields in adjacent parts of the ocean. These strategies will have to take account of the local geological environment and also oceanographic conditions. There have been major changes in vent ecosystems observed on repeated visits to a vent site, and it is not clear whether these are caused by a changing vent environment, by ecological succession or even by human intervention. New eruptions give the opportunity for rapid growth of new colonies, but these may be relatively short lived because of the rapid cooling of the lava and dykes.

The workshop was concerned with all of these scientific areas, and showed, first, the very large extent of the growing effort in the international community on active processes. The US community has developed a major programme centred mostly on the Juan de Fuca Ridge, and there are new programmes starting in Japan, Canada, the UK and France. There are firm links with the ION programme, initiated by seismologists to emplace deep ocean seismic stations, but spreading into the rest of the marine community through a workshop held shortly before this one in Marseilles. The Ocean Drilling Program has also developed research into active processes through the recent drilling of active hydrothermal systems, and the instrumenting of them with long term monitoring packages.

The long term aim of the Active Processes initiative was defined as the development of observatories on the mid-ocean ridges which be emplaced in sites at which events were expected, would be targeted at the types of events expected and at the critical phenomena anticipated, and would make measurements for periods of years. The concept of an observatory that arose was of a collection of instrumental packages, contributed to the observatory from different institutions in, perhaps, different countries, and able to send data to the shore and to receive control from the shore during the course of its life.

The workshop identified a number of types of events of scientific interest:

- Dyke injection, fissuring and minor faulting
- Volcanic eruptions of different types producing different volcanic products
- Magma recharge and related inflation and deflation of the sea floor
- Propagation and growth of major faults
- Slope failure by landsliding and debris flow
- Growth and flow of serpentinite diapirs
- Evolution of hydrothermal vent fields, either natural or induced by drilling
- Megaplume emission from hydrothermal systems
- Reproduction, recruitment and mortality events of vent communities

Three working groups at the workshop discussed different aspects of the problem. The group concerned with the scientific rationale recommended three types of observatory required: a segment scale observatory on slow spreading crust, a segment scale observatory on fast spreading crust, and vent field scale observatories. That on slow spreading crust would require acoustic and seismic monitoring of a wide area initially to identify suitably active segments, followed by detailed site surveys of candidate sites, and eventual deployment of a fully instrumented observatory. The research on fast spreading ridges should build on existing and planned work in the Pacific, but should, it was recommended, include an international effort on the super-fast East Pacific Rise at 17°S. Vent field observatories should target the full range of types of vent fields in different environments.

The working group on event detection, characterisation and response regarded a major initiative in this direction as a necessary prerequisite to an observatory. Crucial to a full characterisation of events would be a properly planned programme of observation and intervention. This requires the immediate establishment of an InterRidge Active Processes Committee, which would undertake wide consultations an co-ordinate an international programme of this type. The working group identified a wide range of activities for this Consulting Group, including co-ordinating the dissemination of information about event detection, increasing awareness of ship schedules, planning the components of a response and proposing baseline surveys of critical areas. The group would consider each event detected on its scientific and technical merits, and recommend the appropriate level of response from the international community.

The third working group was concerned with co-ordination and design of the infrastructure for an observatory. Many of the components necessary for an observatory are already available or are about to be tested, but the integration of these into a single system requires effort of many different kinds. The group recommended that the InterRidge Office should develop a system through Internet that could allow information exchange and facilitate collaboration in instrument development. There should be an attempt to encourage compatibility between the instrumentation developed by various national programmes to allow, as far as possible, instruments to be exchanged between different observatory sites. The InterRidge Active Processes Committee should be charged to follow and facilitate the transfer of new technologies to developers of observatory systems to enhance effort as much as possible.

These recommendations are only given in outline here. A full report of the meeting will be available soon, and has the potential to enhance significantly the research in this important and innovative area of mid-ocean ridge science. And in addition to the writing of the report the meeting brought together individuals with the potential for fruitful collaboration in the future. It was an impressive three days.

- Joe Cann

JOIDES - Ocean Drilling Program News

ODP INTERNATIONAL CONSORTIUM NEWS

On September 29, 1994 the Australian Geological Survey Organization (AGSO) and the Geological Survey of Canada (GSC) signed an MOU that will be in effect until September 30, 1998. Australia will now take over the lead role in the Consortium and the Australian Secretariat will be the location of the consortium Office. A consortium of Taiwanese Universities is expected to join the AUS-CAN Consortium in late 1995 at 1/6 level of contribution. Numerous discussions with several possible candidates for the remaining 1/6 membership, including P.R. China and South Korea, are currently underway.

ODP INTERNATIONALISATION EFFORTS

ODP Director, Dr. David Falvey, met with Dr. Chao-Shing Lee and Prof. Min-Pen Chen in Taiwan on January 12 and 13 to discuss the participation of the National Taiwan University in ODP. Prof. Min-Pen Chen will attend the April PCOM meeting in Japan as an observer. A positive decision regarding the participation of the National Taiwan University in ODP is expected from the Taiwan National Science Council in the spring.

THE 3RD MEETING OF EUROPEAN JOIDES REPRESENTATIVES

will take place during the **EUROPEAN UNION OF GEOSCIENCES** Meeting
at the ESF Offices
STRASBOURG, FRANCE
Tuesday, April 11, 1995

JOIDES Resolution PORT CALLS

Marseilles, France

The **JOIDES Resolution** was in Marseilles, France prior to the two Mediterranean legs, March 8-12, 1995. For the occasion, the "Comité Scientifique ODP France" organized a series of tours of the ship for the media, national and local dignitaries, politicians, scientists, and students. As part of the program, French scientists gave talks on their involvement and contributions to ODP. The mayor of Marseilles also hosted a reception for JOIDES at the Chamber of Commerce and Industry.

The port call was a great success with more than 400 people visiting the ship. Articles about ODP appeared in 8 international, national, and local newspapers, including Le Monde and the International Herald Tribune. Two T.V. stations covered the event. Thanks are due Martine Cheminée, Catherine Mével and Yves Lancelot of ODP France and Aaron Woods of ODP/TAMU for their efforts in organizing the Marseilles port call.

Leith (Edinburgh), Scotland, UK

The **JOIDES Resolution** will be in Leith from the July 4-8, 1995. This port call will coincide with the July EXCOM Meeting. There will be opportunities for geoscientists and members of the public both to visit the ship at Leith docks, and to attend a poster display with a public lecture in the city.

UPDATE ON THE REVISION OF THE ODP LONG RANGE PLAN

The latest draft of the ODP Revised Long Range Plan (LRP) will be discussed and its science objectives finalised at the April PCOM. A previous draft prepared for the PCOM annual meeting by PCOM's LRP subcommittee was the subject of much debate with respect to format and the balance of future ODP science themes. A meeting of the LRP subcommittee, now chaired by PCOM Chair, Rob Kidd, was held in Cardiff earlier this month in order to respond to recommendations from EXCOM'and consider feedback received from the ODP community. One of the successes of the most recent LRP subcommittee meeting was the drafting of an impressive set of ODP scientific accomplishments easily understood by lay readers. We will highlight these by placing them at the front of the final document.

In the current draft version of the revised LRP the scientific goals of ODP are focused under the umbrella, "UNDERSTANDING OUR DYNAMIC EARTH". These goals are further divided into two thematic categories, entitled, DYNAMICS of EARTH'S ENVIRONMENT and DYNAMICS of EARTH'S INTERIOR. The Scientific objectives that are expressed under DYNAMICS of EARTH'S ENVIRONMENT include understanding 1) Earth's changing climate, 2) Causes and effects of sea level change, 3) Fluids, Sediments and Bacteria , and 4) Biological evolution. Scientific objectives included under DYNAMICS of EARTH'S INTERIOR are examining the 1) Transfer of heat and material to and from Earth's interior, 2) Deformation of Earth and earthquake processes, and 3) chemical exchanges between the solid Earth and seawater. New text continues to be written and diagrams modified to convey the science themes in a simple, straightforward and stimulating manner.

Pending PCOM's approval of the draft of the revised LRP presented in April, a version stripped of technical jargon will be presented to EXCOM in July. The version prepared for the April PCOM meeting will be available from April 13 at the JOIDES FTP site (ftp ftp.cardiff.ac.uk in the Pub/JOIDES/LRP). JOIDES panel members, national ODP committees, and participants from global geoscience programs may review this draft and send comments to PCOM members or the JOIDES Office by April 20. Following approval of the final draft of the revised LRP by EXCOM, JOI will refine the LRP with the assistance of a science writer and produce an accompanying glossy version by the end of 1995.

JOIDES Resolution Cruise Schedule 1995-96

Leg	Destination	Cruise Dates	Port of Origin	Days	Transit	On Site
163	S E Greenland VRM	7 September - 26 October '95	Reykjavik, 3-6 September '95	49	7	42
164	Gas Hydrates	30 October - 19 December '95	St.John's, 26-29 October '95	50	8	42
165	Caribbean Ocean History *	24 December '95 - 18 February '96	Miami, 19-23 December '95	56	11	45
166	Bahamas Transect*	23 February - 19 April '96	San Juan, 18-22 February '96	56	8	48
167	California Margin	24 April - 19 June '96	Panama, 19-23 April '96	56	17	39
168	E. Juan de Fuca Hydrothermal	24 June - 19 August '96	San Fransisco, 19-23 June '96	56	4	52
169	Sedimented Ridges II	24 August - 19 October '96	Victoria, 19-23 August '96	56	6	50
170	Costa Rica Accretionary Wedge	24 October - 19 December '96	San Diego, 19-23 October '96	56	11	45
			Panama, 19-23 December '96			

Although five day port calls are generally scheduled, the ship sails when ready.

* These legs may be switched if further study shows that currents in the Santaren Channel are more favourable for the Bahamas project on Leg 165.

News from National Ridge Research Programmes

BRIDGE

Since the last issue of InterRidge News, ODP Leg 158 has successfully drilled the TAG hydrothermal system on the Mid-Atlantic Ridge(MAR), which is located in one of the BRIDGE geographic areas. Following on from the BRAVEX/94 cruise in summer 1994 which deployed instruments to monitor changes induced by drilling, BRIDGE funded two ALVIN dives on Leg 132-02 of the *R/V Atlantis II* (PIs: Adam Schultz, Harry Elderfield - Cambridge; Rachel Mills & Paul Tyler - Southampton). A report from this cruise appears in the April 1995 issue of the BRIDGE Newsletter (No. 8). BRIDGE cruises coming up this summer include the "bath-tub" experiment lead by Bramley Murton, Chris German and others to the Broken Spur segment of the MAR, 29°N, which will form a pilot study under the InterRidge Meso-scale Fluxes theme. This will be followed by the sea trials for the IOSDL's TOBI with its swath bathymetry upgrades that were funded by BRIDGE. The "new, improved" TOBI will be deployed in early 1996 during a cruise also to the Broken Spur (29°N) segment lead by Roger Searle and others to look at faulting dynamics at slow-spreading ridges.

By the time this issue reaches your desks, BRIDGE will have jointly convened another international conference at the Geological Society of London during April on the theme of segmentation at mid-ocean ridges. Abstracts from this meeting will appear in the April 1995 issue of the BRIDGE Newsletter.

At its last meeting, the BRIDGE Steering Committee decided to extend the BRIDGE Science Plan to include a fifth geographic area in the programme. Proposals to carry out research in the region between the Azores and 36°N on the MAR will now be eligible for BRIDGE funding.

By the time the next issue of InterRidge News goes to press, the way in which the BRIDGE programme is administered will have changed significantly in response to internal changes within NERC (the programme's funding agency). We already have a new Chairman, Dr. Alistair Robertson (University of Edinburgh) and a reshaped Steering Committee. Prof. Joe Cann continues his role as BRIDGE Chief Scientist, but the Science Co-ordinator's role will cease to exist as we have known it. A new role will be introduced in the form of a Programme Manager based somewhere outside of the NERC HQ. However, the details of these changes are not yet finalised. In the meantime, if you want information about BRIDGE, continue to contact:

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Tel: +(0)113 233 5241; Fax: +(0)113 2335259; e-mail: C.L.Walker@earth.leeds.ac.uk

CanRidge

The summer of 1995 will see three cruises on Canadian vessels to vent sites in the northeast Pacific. Participating Canadian agencies and institutions include the University of Toronto, the Université du Québec à Montréal, the University of Victoria, the Geological Survey of Canada and the Institute of Ocean Sciences. In addition, US and UK scientists will be joining CanRidge cruises this summer (see below) and Canadian scientists will be participating in several US led cruises to the Juan de Fuca Ridge. Focal points for Canadian ridge crest research include hydrothermal deposits, vent community ecology and hydrothermal plume processes. Seafloor work will use the ROPOS remote vehicle for sampling, mapping and deployment of experiments. The *CSS John P. Tulley* will be used as a support vessel for ROPOS again this year.

1. BioROPOS 95

Cruise dates: July 3-17, 1995
Vessel: *CSS John P. Tulley* & ROPOS
Study region: Endeavour Segment, Juan de Fuca Ridge

Principal Investigators	
Kim Juniper: Chief Scientist	(Université du Québec à Montréal)
Chuck Fisher: Co-chief Scientist	(Penn State University)
Ted Williams	(Penn State University)
Ian MacDonald	(Texas A&M University)
Eve Southward	(Plymouth Marine Laboratory)
Alan Galley	(Geological Survey of Canada)
Jon Grant	(Dalhousie University)
Garry Massoth	(NOAA PMEL)
Verina Tunnicliffe	(University of Victoria)

This collaborative cruise is co-funded by NSERC Canada, the Geological Survey of Canada and the NOAA West Coast National Underwater Research Centre. The main objective of the cruise is the development of a biological observatory in the main vent field at Endeavour Segment on the Juan de Fuca Ridge. The observatory work has two principal thrusts: 1) Quantification of faunal growth and colonization processes in relation to the dynamics of the physico-chemical environmental; and 2) quantitative modelling of biological production and carbon flow within different vent communities and at the vent field scale. This program involves a considerable amount of methodological tool development and collaborative work with geologists. Observatory studies began in 1994 with the BioROPOS '94 cruise where we deployed two time-lapse imaging systems with recording thermistors at diffuse flow vents colonized by tube worms and associated organisms. Tube worms at the time-lapse sites were stained with a vital chitin stain for growth increment determinations. Temporal variability studies are also being carried out on a hydrothermal chimney complex known as S&M. The focus here is on links between organism distribution and geological evolution of the sulfide structure. Video mosaicing combined with limited quantitative sampling are being used to document organism distribution on S&M, which was first thoroughly imaged by the Jason ROV in 1991.

Plans for the BioRopos 95 cruise include:

1. Repeating temperature and imaging surveys of time-lapse sites and recovery of cameras and thermistor arrays.
2. Collection of stained worms from time-lapse sites, staining of new groups of worms and re-deployment of HOBO recording thermistors among stained worms.
3. Making quantitative collections of tube worm communities from time lapse sites.
4. Quantification of free-living bacterial biomass and chemosynthetic activity on animal and mineral surfaces at diffuse flow sites (for carbon flow model).
5. Quantification of suspended particulates at diffuse flow vents (for carbon flow model).
6. Repeat video mosaics of S&M chimney and collection of additional quantitative samples.
7. Completion of study of structural controls of venting at S&M and throughout the main vent field by grid mapping of seafloor features.
8. Complete geo-rectification of digitized bathymetry map of the main vent field and incorporation into a GIS.

2. GeoCanRidge IV

Cruise dates: July 17-28, 1995
Vessel: *CSS John P. Tulley* & ROPOS
Study region: Southern Explorer Ridge

Principal Investigators

Nigel Edwards: Chief Scientist	(University of Toronto)
Steve Scott: Co-chief Scientist	(University of Toronto)

GeoCanRidge IV will use the ROPOS remotely operated vehicle deployed from *CSS Tully* for geophysical and geological research at Explorer Ridge in the NE Pacific off Canada's west coast. Here there are many fascinating, large and small, active and inactive, hydrothermal vents and metallic sulphide-sulphate-oxide deposits. The Explorer Ridge is centred at 49°45'N, 130°17'W. We plan to work in the axial valley at water depths between 2000 and 1800 m, and in the valleys to either side at depths up to 2500 m. The science will be the continuation of projects started during GeoCanRidge III, described recently in InterRidge News (vol. 3, no. 2).

Steve Scott will use ROPOS to:

1. Map in detail the area around selected active and inactive hydrothermal vents for the purpose of fully understanding the subtle structural and volcanological controls on their distribution;
2. Sample basalts in cliff faces to establish volcanic stratigraphy; to sample sulfide mounds and chimneys from well located sites to establish age (by radio-isotopic methods and perhaps C-14 using our IsoTrace AMS), mineralogy, geochemistry and growth history of selected deposits;
3. Sample particulates in hydrothermal plumes in the near-vent field as a complement to far-field sampling done from surface ships for the purpose of understanding geochemical dispersion patterns;
4. Sample vent fluids with existing titanium samplers for the purpose of relating vent fluid chemistry to mineralization processes. The latter data is also of great interest to the biologists and will be shared with them.

Nigel Edwards is developing submersible-deployed dipole arrays for mapping resistivity of seafloor polymetallic sulfide mounds. The TEM method is based on the measurements of the time of travel of an electrical pulse from a transmitter carried by ROPOS to remote receivers deployed near the target. The experimental procedure was tested successfully on the TAG mound using ALVIN to transport the transmitter and again last year during GeoCanRidge III. The resulting information can be used to interpret physical properties and shape of the mounds and the character of the seafloor immediately beneath them. Interpretation is based on the sensitivity of electrical conductivity to the presence of both seawater and basaltic melt. The electrical conductivity of rock containing these fluids can be several orders of magnitude higher than that of dry crustal rock. Metalliferous sulfide deposits, which consist largely of iron sulfides, are also good conductors and can thus be probed using this technology. Most of what we presently know about seafloor sulfide deposits is derived from reconnaissance mapping and surficial sampling. This severely limits our understanding of the size and physical properties these deposits and of the nature of the hydrothermal circulation system that feeds them. Electromagnetic techniques are a promising means of addressing the problems. The experimental project is supported by the theoretical research. The group has written software for the computation of the electromagnetic responses of 2D and 3D structures likely to be found in the vicinity of mid-ocean ridges. Working with colleagues at Univ. of Waterloo, we have also developed a numerical finite element model for convective flow in porous anisotropic and discretely fractured media. Temperatures and fluid velocities predicted by the model may be compared with observations, and may be used with porosity estimates to predict electrical properties.

3. Carbon and Mineral Fluxes from Hydrothermal Plumes: Biogeochemical Linkages with the Upper Water Column.

Cruise date: July 10-31, 1995
Vessel: *CFAV Endeavour*
Study region: Endeavour & Coaxial Segments (Juan de Fuca Ridge); Cascadia Basin

Principal Investigators

Richard Thomson: Chief Scientist	(IOS)
James Cowen	(University of Hawaii)
Brenda Burd	(IOS/University of BC)
William Lavelle	(NOAA, PMEL)

Co-Investigators

Steve Calvert	(University of British Columbia)
Edward Baker	(NOAA, PMEL)
Ian Whyte	(Pacific Biological Station)
Lou Hobson	(University of Victoria)
Stuart Wakeham	(Skideway Institute)

The primary goal of this project is to link descending and ascending carbon/mineral fluxes at Endeavour Segment with biogeochemical processes within the overlying water column. Focus is on the role of bacteria in the alteration of plume chemistry, the distribution and composition of "marine snow", and the contribution of macrozooplankton to vertical fluxes between the plume and the upper ocean. The 1995 field season marks the second year of this program.

In July 1994, three sediment trap moorings were deployed from the *CFAV Endeavour* in the vicinity of the main vent field on the Endeavour segment of Juan de Fuca Ridge. Each of the moorings consisted of hourly-recording Aanderaa-type RCM5 current meters and two pairs of conventional and inverted Baker-type sediment traps positioned at depths of 1700 and 2100 m depth. Each trap has 10 sequencing cups and the integration period is one month per cup. The deeper combination of traps will measure vertical fluxes near the core of the main effluent layer while the shallower pair of traps will measure vertical fluxes well above the direct influence of the plume. The central moorings was deployed within 100 m of the main vent field; additional moorings were set 10 km to the east and west of the central ridge. All three moorings will be recovered, serviced and redeployed at the same sites for a second year during our survey in July 1995. The ship will leave Esquimalt sometime after July 10 and return to port by July 31.

In addition to the mooring work, we will repeat the water sampling program, bioacoustical net tows, and camera/video profiles conducted in July 1994. Specific observations planned include:

1. Water column chemistry (using a 10 litre Niskin rosette sampler) for manganese, iron, 3He, methane, bacterial biomass, stable carbon and nitrogen isotopes, nutrients (silicate, phosphate and nitrate) and other constituents;
2. Bioacoustical net tows for sampling zooplankton abundance and species composition using a combined 150 kHz acoustic Doppler current profiler (ADCP), CTD/transmissometer package, and six discrete Tucker trawl nets;
3. Imaging of the plume and vent environment through profiles and tows of a camera/video system.

Mooring sites	Water Depth (m)	Location
CB01	2610	48°07.489'N, 128°21.106'W
ERA2	2140	47°56.971'N, 129°05.704'W
CA01	2404	47°56.372'N, 129°09.666'W

Dorsales

- As translated from *La Lettre Dorsales* by Roger Searle -

"The Dorsales programme is now well underway. The Dorsales Committee met on 23 June and 21 October 1994, and proposed various actions:

- A call for ideas and proposals on modelling mantle processes at ridge axes;
- A review of the initial import of satellite altimetry to the understanding of oceanic accretion processes;
- A call for proposals on methods for dating recent basalts;
- A workshop on biogeographic evolution of hydrothermal fauna.

Other initiatives are in preparation:

- Use of high resolution magnetometry;
- Design of chemical samplers adapted to the detection of hydrothermal fluids in the water column.

The co-founding organisations of Dorsales (IFREMER, CNRS, ORSTOM and BRGM) have just renewed their support of the Dorsales Programme, with a substantial increase in funding for 1995, and expressed the wish to maintain the status of France as a principal member of the international InterRidge Program.

The value of any programme can only be measured by the dynamism of its participants. The French community is very active, not only in its cruise programmes but also in publications. Nevertheless, an effort should be made to co-ordination and develop new approaches and innovative tools. The basic idea of the Dorsales programme is precisely to promote this effort by bringing together collaborative teams for common study programmes on the mechanisms of oceanic accretion, and in assisting the development of new directions and methods of research."

Prof. Jean Francheteau, président du Comité Dorsales
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DeRidge

On 1 March 1995 the fifth DeRidge Meeting was held at Kiel. It was the first meeting held since Germany's official entry into InterRidge as an Associate Member in late 1994. Germany will attempt to make the step to Principal Membership this year or, at the latest, in 1996.

The major topics of the 1995 annual DeRidge Meeting which is usually held in tandem with the annual ODP Colloquium, were 1) presentation and discussion of recent and future DeRidge projects, and 2) reports on recent InterRidge activities.

DeRidge Projects

A project carried out aboard the *R/V Sonne* earlier this year (cruise 99, PI: P. Halbach, TU Berlin) aimed at studies of hydrothermal vents and , in co-operation with biologists on board, hydrothermal communities in the North Fiji Basin. A new hydrothermal field (SO 99 Field) was detected in the depression located at the triple junction in the North Fiji Basin, and the known hydrothermal sites LOHS and White Lady, located south of the triple junction, were further studied. The intensity and chemistry of the hydrothermal fluids was found to be very highly variable and to be closely accompanied by variations of the distribution of vent organisms. Occurrence of individual species was found to be indicative of vent fluid temperature; the time span between the end of hydrothermal activity of an individual vent and disappearance of living organisms at this site appears to be on the order of 2 years. Skeletons and shells dissolve after about ten years.

Analysis of dredged basalt samples indicate large variations of crustal composition over short distances. On the southern segment of the North Fiji spreading ridge N-MORB compositions of the basalts were found, while in the area of the SO 99 field OIB-compositions are interpreted as a reflection of the influence of a hot spot located to the north.

Further studies on hydrothermal activity at the ridge crest (project HYDROCK, PI: P. Halbach, TU Berlin) are planned with *R/V Meteor* at the Rodriguez Triple Junction (RTJ) in the Indian Ocean. They will be aimed at following up the detection of hydrothermal activity at the Sonne field originally made during the GEMINO program in the 80's and then confirmed and located during the SONNE cruise 92 in early 1994. It was during this cruise that Green Rock Hill was discovered and sampled (lherzolithic serpentinite diapir) near the RTJ . Analysis of Green Rock Hill samples have shown 750,000 years old basaltic crust.

An *R/V Sonne* project (PI: R. Muehe, Kiel) is proposed for the slow-spreading, strongly tectonised and segmented Chile Ridge. During SO40 (1986) altered brecciated basalts were dredged from the Chile Ridge, showing a unique enrichment (>1000 ppm) of lead with an isotopic MORB signature. The proposed project aims at mapping and quantifying the occurrence of this formerly unknown type of MORB and at sampling rocks from the gabbro zone at tectonically exposed locations in transform of fracture zone.

The first phase of the EXCO (EXchange Crust-Ocean) project at the EPR (13°-15°S) with the *R/V Sonne* (PI: W. Weigel, Hamburg) is planned for fall 1995. The project aims at studying the variation and possible episodicity of geophysical and petrological parameters of the crust in correlation with hydrothermal circulation in crust aged 0-8 Ma. Methods to be applied are OBS seismology, high resolution reflection seismology, gravity and heat flow measurements. Petrological, geochemical and sedimentological studies of the hydrothermal convection system are planned for a second stage during the following years. Close co-ordination with the US MELT program at 17°N was strongly recommended during discussion of this project.

The two cruises of the HYDROCELL project (PIs: E. Davis, Canada; H Villinger, Bremen) aim at detailed mapping (50 m grid) of heat flow distribution in the area of the scheduled ODP drilling leg 168 at the Juan de Fuca Ridge (JFR). The first cruise, scheduled for summer 1995 with the Canadian *R/V Tully* will cover an area of smooth basement topography where estimated size of the hydrothermal cells are on the order of 500 m. A second cruise is planned using the *R/V Sonne* which will survey an area with rugged basement topography in which the highs obviously focus the positive heat flow anomalies, i.e. the regions of hydrothermal upflow.

Since Germany joined the InterRidge Program, a DeRidge Newsletter, to be published in English, has been in preparation. The first issue is planned for publication in the Fall of 1995 and will contain a summary of the past and recent ridge-related research of German scientists and research groups. The summary shall cover the areas of the DeRidge working groups (chaired by):

North Atlantic	H.-J. Wallrabe, Kiel
Red Sea	R. Rihm, Kiel
East Pacific	G.A. Dehghani, Hamburg
Back-Arc Basins	P. Herzig, Freiberg
Indian Ocean	P. Halbach, Berlin
Technical Development	H. Villinger, Bremen

DeRidge - InterRidge

The second major topic of the DeRidge meeting included reports on the InterRidge workshops in Boston in September 1994 (4-D Architecture of the Oceanic Lithosphere) and Kiel in November 1994 (Arctic Ridges: Results and Planning), which are reported elsewhere in this issue. A report on the ION workshop in Marseilles in January 1995, was given within the main ODP Colloquium.

Further recommendations for DeRidge activities in the near future include development and installation of a German data bank for swath bathymetry data, presently being followed up by BEO Warnemunde, and the implementation of a DeRidge World Wide Web home page on the Kiel 'pangaea' server.

- March, 1995

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InterRidge/Japan

InterRidge/Japan is composed of two sub-groups which correspond to the funding agencies associated with two types of institutions. Research activities of universities in Japan, including ODP, are funded by "Monbusho" (Ministry of Education, Science, and Culture) and those of governmental research institutes are funded by STA (Science and Technology Agency). The two groups have, however, a joint working group to co-ordinate the research programmes. The working group has a few meetings and a symposium every year. A symposium on deep-sea researches held every year by JAMSTEC (Japan Marine Science and Technology Center) is also concerned with ridge crest research. The group is now publishing a domestic newsletter printed in Japanese as well as news bulletins sent by e-mail.

University group is currently carrying out ridge research in two ways. The first is a research cruise of the *R/V Hakuho-maru* of ORI (Ocean Research Institute, University of Tokyo). A cruise planning meeting for this ship is held every three years; usually one research cruise is devoted to surveys of a spreading system. The most recent cruise was carried out in 1993 around the Rodriguez Triple Junction in the Indian Ocean (see report in InterRidge News, vol. 3, no. 1). The next cruise will be in 1998 in the western Pacific. A smaller research vessel, the *R/V Tansei-maru*, will also visit Mariana area this year.

The second is a ridge crest research program supported by "Monbusho International Scientific Research Program". Prof. H. Shimamura will lead a group in carrying out a number of extensive seismic experiments in the northern Mid-Atlantic involving tens of ocean bottom seismometers.

Drs. H. Fujimoto and K. Tamaki are co-ordinating a program to support InterRidge planning activities and to exchange scientists for ridge research cruises. We are also proposing to carry out a major research cruise by hiring a foreign research vessel.

Most of the scientists of the STA group are from GSJ (Geological Survey of Japan), JAMSTEC, and JHD (Japan Hydrographic Department). Principal members are Drs. T. Urabe (GSJ), H. Hotta & K. Fujioka (JAMSTEC), and A. Nishizawa (JHD). They launched a major research program "Ridge Flux" in 1993, which aims to observe and monitor the energy and mass flux from the mid-ocean ridge systems. The first sea-going work was a geochemical cruise with extensive tow-yo surveys in 1993 using the *R/V Melville* in the area of super-fast spreading center of the East Pacific Rise.

Diving surveys were carried out last year on the Mid-Atlantic Ridge as well as on the Southern East Pacific Rise. An extensive morphological survey is scheduled this year using the side-scan sonar system, TAMU2. Please see the reports on these research activities which have appeared in this newsletter.

Because the Japanese islands are located in active subduction zones, and because any mid-ocean ridge is quite far away, ridge-related research activities in Japan were once limited to a few petrologists. InterRidge program has given us a chance to change this situation. Research cruises on mid-ocean ridges were carried out by Japanese scientists for the first time in 1993. We held a special session on ridge researches during the Japan Earth and Planetary Sciences Joint Meeting in March 1994, which was like a small version of AGU general meeting. This year we will also have a similar special session during the joint meeting on 27-30 March. The convenors are Drs. K. Fujioka, K. Tamaki and H. Shimamura. The ridge research session has become to be one of major sessions.

The office work of InterRidge/Japan is shared by two InterRidge correspondents:
Hiromi Fujimoto, ORI, email: fujimoto@ori.u-tokyo.ac.jp
Tetsuro Urabe, GSJ, email: urabe@gsj.go.jp

RIDGE

The Crustal Accretion Variables (CAV) theme within the RIDGE Initiative is focused on identification of the key variables (e.g. spreading rate, magma supply, mantle temperature, etc.) that affect the crustal accretion process at mid-ocean ridges. Over the past few years, efforts have been concentrated on understanding the interplay between spreading rate and magma supply, and so collection of comprehensive, comparable datasets on sections of slow-spreading and fast-spreading ridges have been a priority. Work is now well underway on the Mid-Atlantic Ridge between 15° and 40°N (which is also the site of the French-American, FARA co-operative program), the East Pacific Rise south of the Garrett Fracture Zone, and the East Pacific Rise between 9° and 16°N. Consequently, it is timely to start defining the direction of the CAV theme of the RIDGE program for the next 5 years.

Considerable progress towards that goal has been made in the last twelve months through two RIDGE Workshops. The RIDGE Design Workshop for Experimental Approaches to RIdge SEgment Structure and Dynamics (RISES) was held in September immediately following the InterRidge 4-D Architecture Workshop. It was convened by J. Lin, J. Karson and J. Sinton, and more than 50 scientists from 20 U.S. institutions participated. The principal objective was to design a set of co-ordinated, hypothesis-driven experiments for CAV studies over the next 3-5 years. Three major scientific problems were identified: (1) The origin of gravity "bull's eyes" (i.e. gravity lows centered on segment mid-points) and the spatial distribution and relative roles of magmatism and tectonism with respect to ridge segmentation at slow-spreading ridges; (2) The nature of the melt delivery and crustal magma plumbing systems at fast-spreading ridges; and (3) The interplay of active magmatic, tectonic and hydrothermal processes at the segment scale.

A two-pronged investigative strategy for addressing the above problems was suggested that involves (1) initiation of a new set of co-ordinated INTRA-segment experiments/surveys to investigate the linkages between magmatic and tectonic processes and other crustal accretion variables (CAVs) at one or more segments; and (2) continuation of INTER-segment studies to define systematic variations in segment characteristics and to understand their dependence on CAVs. In addition, the Ocean Drilling Program (ODP) was identified as an integral component of the intra-segment experiments to directly constrain the structure and composition of the lower crust and upper mantle.

Specific sites were selected for the intra-segment studies. For the "bull's eye" experiments, there was a strong consensus for the 35°N area on the Mid-Atlantic Ridge because it contains two adjacent segments with large contrasts in both axial morphology and mantle Bouguer anomaly. Three areas on fast-spreading ridges were identified as sites for focused studies of the magma plumbing system: Hess Deep Rift, the East Pacific Rise (EPR) between 9°-11°30'N, and the EPR between 17°-17°30'S (MELT area). Additional drilling at Hess Deep was recommended, and the other two areas were selected because of the planned MELT experiment in the 17°-17°30'S area, and the apparent contrast in axial morphology and magma supply between the segments immediately north and south of Clipperton near 9°-11°30'N. The target areas for studying active processes (magmatic, tectonic, hydrothermal) at the segment-scale would include, but would not necessarily be limited to, 9°N and 17°S on the EPR and 35°N on the MAR.

Comparative inter-segment studies of ridge-crest processes in the last decade have produced very valuable scientific results that became the driving force behind other co-ordinated RIDGE programs such as MELT and ROBE. The full range of known magmatic and tectonic features cannot be addressed at any single location. Thus, to ensure continuous significant progress within the CAV element of the RIDGE Program, it was recommended that an active component of the inter-segment studies be maintained within the CAV program in the next 3-5 years.

The Workshop also emphasized the need for a shore-based component of theoretical and laboratory studies for data integration and further model development and comparative studies with ophiolites. The workshop addressed the importance of accelerated theoretical and laboratory work on three broadly defined, overarching theoretical issues on ridge segment dynamics: (1) further modelling and laboratory studies of mantle-driven versus lithosphere-controlled mechanisms for ridge segmentation and segment evolution; (2) modelling studies of the physics, rheology, and emplacement mechanisms of crustal magma plumbing systems; and (3) theoretical studies of the segment-scale interactions of hydrothermal and crustal magma plumbing systems.

The other Workshop focused on a biological question that falls within segment-scale studies, and was motivated by the recognition that questions of larval dispersal, and gene flow and their influences on biogeography would be best solved by an integrated , multidisciplinary approach. Convened by L. Mullineaux and D. Manahan in May 1994, and attended by about 25 scientists, the general objectives of the workshop were to develop approaches for investigating dispersal and gene flow in vent environments, and evaluate the potential role of these processes in generating and maintaining biogeographic patterns along mid-ocean ridges and across ocean basins.

The Workshop recommended that a multi-year study (named the LARVE Project, Larvae at Ridge Vents:

Experiments) of recruitment in vent communities be undertaken, with emphasis on the processes that affect larval dispersal and gene flow between vent sites. The four primary objectives which are organized by the stage in the organism's life history are: (1) to determine reproductive periodicity (if any), gamete production, spawning, and fertilization success in vent organisms; (2) to develop high-pressure culture chambers to produce sufficient material for studies of larval biology (e.g. behavior, physiology); (3) to measure factors that control recruitment success (e.g. biological and physical constraints on larval dispersal, success of settlement and metamorphosis); and (4) to measure gene flow between vent sites and identify the source of new recruits. The main site selected for this work was 9°-10°N on the EPR because it is an area where much research on the initial work on the distributions of organisms has already occurred. However, the option was left open for work in other areas since some of the questions may be better answered at other sites. Another meeting is scheduled for later this spring to prioritize and sequence the research, and to put together a description of the experimental design and guidelines for proposals for general distribution to the community.

For copies of the Reports resulting from this Workshop, or for any other additional information, please contact:

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InterRidge Publications

InterRidge News:

InterRidge News, 1992, 1, 1, pp. 26.
InterRidge News, 1993, 2, 1, pp. 32.
InterRidge News, 1993, 2, 2, pp. 4 (bulletin)
InterRidge News, 1994, 3, 1, pp. 28
InterRidge News, 1994, 3, 2, pp. 44

Meeting and Workshop Reports:

InterRidge Program Plan, pp. 26, 1994.
InterRidge Program Plan Addendum 1993, pp. 9, 1994.
InterRidge Program Plan Addendum 1994, pp.15, 1995
InterRidge Meeting Report, Brest, France, 1990.
InterRidge Meeting Report, York, UK, 1992.
InterRidge Meso-Scale Working Group Meeting Report, Cambridge, UK, 1992.
InterRidge Steering Committee Meeting Report, Seattle, USA, 1993.
InterRidge Meso-Scale Project Symposium and Workshops Reports, 1994:
    Segmentation and Fluxes at Mid-Ocean Ridges: A Symposium and Workshops &
    Back-Arc Basin Studies: A Workshop, pp. 67, June 1994.
InterRidge Global Working Group Report 1993:
    Investigation of the Global System of Mid-Ocean Ridges, pp. 40, July 1994.
InterRidge Steering Committee Meeting Report, Tokyo, Japan, 1994.
InterRidge Global Working Group Report 1994: Indian Ocean Planning Meeting Report, 1994.
InterRidge Meso-Scale Workshop Report: 4-D Architecture of the Oceanic Lithosphere, in prep.
InterRidge Global Working Group Report: Arctic Ridges: Relults and Planning, in prep.
InterRidge Active Processes Report: Event Detection and Response & A ridge Crest Observatory, in prep.

These publications are available from the InterRidge Office upon request.

Announcements and Notices

Revised Announcement

R-RIDGE

Revised Announcement

(Russian RIDGE)
Workshop Announcement:

MID-OCEAN RIDGES: GEOLOGY, GEOPHYSICS AND ORE FORMATION

23-25 May, 1995
St. Petersburg, Russia

The workshop is open to all Russian and foreign researchers interested in studies of spreading centers and processes of oceanic ore formation.

OBJECTIVES:

The aim of the workshop is to present and discuss the recent works of Russian and foreign scientists on the investigation of diverging plate boundaries and processes of oceanic hydrothermal ore formation. We would like to invite you, and your colleagues dealing with the geology and geophysics of the mid-ocean ridges to participate in this Workshop.

If you are interested in the workshop, please provide the following information:

(1) Your name, Institution, Address, Phone, Fax, E-mail address.
(2) Please submit title(s) of your presentation(s).

Applications must be received by 1 March, 1995, and should be sent to the appropriate convenors (fax or e-mail are preferable). Participants are responsible for payment for registration ($200), travel and accommodation.

CONVENORS:

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BRIDGE Meeting

Tectonic, Magmatic, Hydrothermal & Biological Segmentation at Mid-Ocean Ridges

at

The Geological Societey of London, Burlington House, Piccadilly, London, UK

19 & 20 April, 1995

This two-day joint meeting between BRIDGE, The Geological Society of London and the Challenger Society for Marine Sciences will report on the latest research on mid-ocean ridges associated with segmentation. The multi-disciplinary nature of the meeting will bring together geologists, geophysicists, oceanographers, biologists and geochemists, all with the common goal of understanding how segmentation affects the dynamic environment of our planet and to determine a way forward for future efforts in this field. In addition to 20 minute oral presentations, there will be an informal poster session accompanied by refreshments, and there will be adequate time allocated for group discussion. A book of abstracts will be available at the meeting.

Keynote Speakers:
Keynote speakers will provide a 30 minute overview for each of the four subject areas

•	Tectonism	Dr. J.-C. Sempéré (University of Washington, USA)
•	Magnetism	Dr. R. Batiza (University of Hawaii, USA)
•	Hydrothermalism	Dr. R.M. Haymon (University of California, Santa Barbara, USA)
•	Biology	Dr. D.R. Dixon (Plymouth Marine Labs, UK)

Presentations:
If you wish to give a paper, please submit your title to Dr. Cherry Walker (address below) as soon as possible, and a 100-word abstract no later than 17 March, indicating clearly whether it is being submitted as an oral or poster presentation. It is hoped that papers from the meeting will form a Special Publication of the Geological Society, and the deadline for submission of papers will be the first day of the meeting. Additionally, programme and abstracts for the meeting will be published in the April issue of the BRIDGE Newsletter, now circulated to over six hundred mid-ocean ridge scientists.

Registration:
Registration forms can be obtained from Dr. Cherry Walker. The registration deadline is Monday 10 April - fees are £10 to students, £20 to members of the Geological Society of London or the Challenger Society for Marine Sciences; and £30 to nonmember. Speakers will be expected to register and pay for the meeting at the same tome as submitting their abstract.

Convenors:
Dr. C.L. Walker (first point of contact) Department of Earth Sciences, University of Leeds, Leeds, LS2 9JT, UK. Tel: 44 0532 335241, Fax: 44 0532 335259, e-mail: cherry@earth.leeds.ac.uk;
Dr. L.M. Parson Institute of Oceanographic Sciences, Decon Laboratory, Brook Road, Wormley, Godalming, Surrey, GU8 5UB, UK. Tel: 44 0428 684141, Fax: 44 0428 683066, e-mail: lmp@ua.nwo.ac.uk;
Prof. P. Taylor Department of Oceanography, University of Southampton, Southampton, SO9 5NH, UK. Tel: 44 0703 592557, Fax:44 0703 593059, e-mail: pat8@soton.ac.uk

InterRidge Biological Studies Ad Hoc Committee Announcement:

Biological Studies at the Mid-Ocean Ridge Crest

24-25 April, 1995

Rutgers University in New Brunswick; New Jersey, USA

Convenors: Daniel Desbruyères and Richard Lutz

The Steering Committee of InterRidge has recommended that "biological studies" aspect of InterRidge remain interwoven with the three principal scientific themes of InterRidge ("Global", "Meso-scale", and "Active Processes"). To date, however, the ridge biological community has been very poorly represented at workshops focusing on these themes. The Biological Studies Ad Hoc Committee is charged with addressing issues which are specific to ecosystems at the mid-ocean ridges with the aim of integrating them in interdisciplinary aspects of the InterRidge Program. The InterRidge Steering Committee has also requested that biological studies objectives and an "implementation plan" be developed. This implementation plan will be integrated into the InterRidge Program.

Objectives:

- Development of an Implementation Plan for the integration of biological studies into the three principal InterRidge themes.
- Draft a formal international agreement endorsed by InterRidge to provide for exchanges of samples and data in order to avoid duplication of effort and to broaden effective distribution of data and samples.
- Maximisation of the effectiveness of biological sampling and observations during "geological" cruises.

Participation: In order to maintain an effective working group size, attendance will be limited to 30 people. Participation in this workshop implies agreement to contribute substantially to a workshop report. A registration fee of US$20 will be asked of each participant This fee will help to defray the cost of refreshments during the meeting and a small reception.

Funding: The InterRidge budget does not include travel and accommodation funding for meeting participants. Travel funding should be requested from national funding agencies or other sources.

Applications: Those interested in participating in this workshop should notify the InterRidge Office no later than **25 March, 1995**. Limited housing will be available at the university. Please indicate in your application whether you will require accommodation. Further details will be made available upon application receipt.

Contact: Heather Sloan, InterRidge Co-Ordinator
InterRidge Office, Department of Geological Sciences, South Road, Durham, DH1 3LE, UK.
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MARINE STUDIES GROUP, GEOLOGICAL SOCIETY, LONDON
AND THE CHALLENGER SOCIETY

THE GEOLOGICAL EVOLUTION OF OCEAN BASINS: RESULTS FROM THE OCEAN DRILLING PROGRAM

A Conference to be held at Burlington House
18/19 October, 1995

Call for papers/expressions of interest

Convenors:
Drs. Adrian Cramp and Chris MacLeod
Dept. of Earth Sciences, University of Wales, Cardiff, UK.
Dr. John Jones
Dept. of Geological Sciences, University College London, UK.

For the last ten years the Ocean Drilling Program (ODP) has provided geoscientists with a unique opportunity to probe the composition and the structure of the ocean basin. Knowledge of the geological processes of basin evolution and climate fluctuation as preserved in the sedimentary sequences has advanced significantly.

This meeting jointly organised by the Marine Studies Group and the Challenger Society, is designed to bring together a wide range of geoscientists who have current/recent research interests in the geological evolution of ocean basins and climate fluctuation.

We are hoping to attract an international audience and would like paper/posters from individual disciplines as well as synoptic/overview contributions. We are considering publishing the proceedings in a Special Publication of the Geological Society of London.

The two day meeting will be arranged into thematic sessions each of which will be introduced by keynote speakers.

Expressions of interest, and/or contribution abstracts (talk/poster) should be sent to:

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Marine Geosciences Research Group
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Deadline for the submission of abstracts will be June 30th, 1995.

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