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InterRidge News

Initative for international cooperation in ridge-crest studies

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InterRidge Office Updates: Coordinator Update

InterRidge Office Transfer

The 1993-1996 term of InterRidge at Durham has ended, and in January 1997 the office transfered to Paris under the Chair of Mathilde Cannat of CNRS/University of Paris 6. Ruth Williams, who was the acting InterRidge Coordinator during the transistion period, did an excellent job moving the office from Durham to Paris, and maintaining the office until March 1997. The new year also brought six new members to the steering committee. As usual, the current list of steering committee members can be found at the back of this issue.

Membership

InterRidge Membership increased to twenty countries at the start of 1997 with South Africa joining as a corresponding country. Canada and India have announced their intentions to upgrade to Associate Membership in 1997.

Publications

The SWIR Project Plan Report is finished and will be distributed shortly. The cooperative work between InterRidge and IFREMER on the Hydrothermal Vent Fauna Identification Manual, overseen by D. Desbruyères of IFREMER, is finished. This color manual contains descriptions, drawings and photographs of over 100 species. It is currently in press and IFREMER will be selling it later this year. The InterRidge Office will receive copies which we will distribute to selected marine biological institutions and research vessels, particularly those which are frequently involved with submersible and dredging activities.

InterRidge Working Groups

At the InterRidge Steering Committee in September 1996 it was decided to form a new working group to explore the possibility of using existing undersea cables to further ridge research. The chair, Alan Chave, is currently organizing members of the working group. For an overview of all of the InterRidge working groups, see page 8.

Upcoming Workshop

The First International Symposium on Marine Hydrothermal Vent Biology will be held 20-24 October in Madeira, Portugal. Over 100 people have expressed interest in attending. An abstract volume will be produced by the InterRidge Office, and the Proceedings of the Symposium will be published in a separate, citable volume. More details can be found on page 62 or on the InterRidge web page.

WWW

The web pages have been transfered over to the Jussieu server and can be found at: http://www.lgs.jussieu.fr/~intridge. The InterRidge Researcher Electronic Directory and the Ridge Crest Biologist Directory are both accessible on this site.

Mathilde and I would like to thank Roger Searle, Heather Sloan, and Ruth Williams for their work over the last three years and their assistance in making the transition to the Paris office go smoothly. We are both looking forward to working with the InterRidge Community over the next few years.

Cara Wilson
InterRidge Coordinator

The InterRidge Office has Moved!

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InterRidge Office Updates: InterRidge Publications

All of the following InterRidge publications are available from the InterRidge Office upon request at (**intridge@ext.jussieu.fr**).

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
InterRidge News, 1995, 4, 1, pp. 72
InterRidge News, 1995, 4, 2, pp. 52
InterRidge News, 1996, 5, 1, pp. 52
InterRidge News, 1996, 5, 2, pp. 68
InterRidge News, 1997, 6, 1, pp. 72

Meeting and Workshop Reports:

In Preparation

InterRidge Global Working Group Workshop Report: Arctic Ridges: Results and Planning, in prep.

1997

InterRidge Program Plan Addendum 1996, pp. 10, April 1997.
InterRidge SWIR Project Plan, pp. 21, April 1997.

1996

InterRidge Program Plan Addendum 1995, pp.15, 1996.
InterRidge Meso-Scale Workshop Report: Quantification of Fluxes at Mid-Ocean Ridges: Design/Planning for the Segment Scale Box Experiment, pp. 20, March 1996.
InterRidge Active Processes Working Group Workshop Report: Event Detection and Response & A idge Crest Observatory, pp. 61, December 1996.
InterRidge Biological Ad Hoc Committee Workshop Report: Biological Studies at the Mid-Ocean Ridge Crest, pp. 21, August 1996.
InterRidge Steering Committee Meeting Report, Estoril, Portugal, 1996, pp. 17, December 1996.

1995

InterRidge Program Plan Addendum 1994, pp.15, 1995.
InterRidge Meso-Scale Workshop Report: 4-D Architecture of the Oceanic Lithosphere, pp. 15, May 1995.
InterRidge Steering Committee Meeting Report, Kiel, Germany, 1995.

1994

InterRidge Program Plan, pp. 26, 1994.
InterRidge Program Plan Addendum 1993, pp. 9, 1994.
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.

1993

InterRidge Steering Committee Meeting Report, Seattle, USA, 1993.

1992

InterRidge Meeting Report, York, UK, 1992.
InterRidge Meso-Scale Working Group Meeting Report, Cambridge, UK, 1992.

1990

InterRidge Meeting Report, Brest, France, 1990.

InterRidge Working Group Updates

SWIR Working Group Update: SWIR Implementation Group*

Catherine Mével, Chair

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Although super-slow-spreading ridges make up a significant portion of the ridge system, we still know very little about them. For this reason the InterRidge program decided sometime ago to concentrate efforts on the South West Indian Ridge as an example of a super slow-spreading ridge to understand accretionary processes in these settings. A SWIR working group, chaired by Charlie Langmuir, was set up by InterRidge to discuss the primary scientific to address in the forthcoming years. This group generated a Project Plan that will be published shortly (InterRidge, 1997).

The task of the SWIR Implementation Group, created by InterRidge last fall, will be to implement that plan. Its mandate is to promote and coordinate research on the SWIR. Clearly an international effort is needed. The bathymetric and geophysical coverage is uncomplete. We have little constrains on the lithosphere thickness beneath the axis, or on the width of the active zone. Except in a few areas, sampling has been done mostly in fracture zones: a systematic sampling of the axis, at both regional and local scales, is missing. The area has not been surveyed for hydrothermal activity. We expect to fill most of these gaps in knowledge and contribute to a better understanding of the global ridge system. The objective is to collect a critical dataset to compare slow- and fast- spreading ridges, in order to better constrain the influence of spreading rate and mantle temperature on accretionary processes.

Future actions on the SWIR

At this stage, two investigative directions are being pursued :

• meso-scale studies along the SWIR axis and off-axis; these investigations should help select areas for local scale studies, and hopefully locate hydrothermal activity.

• studies around ODP Hole 735B, located on the transverse ridge of the Atlantis II fracture zone, to better constrain the geological setting of this hole and the crustal architecture.

Scheduled cruises:

• EDUL- August 1997, *Marion Dufresne*. PI: Catherine Mével. Sampling of the SWIR axis between the Rodrigues triple junction and 49°E (rock cores, dredges) to look at regional and segment scale variations. Hydrocasts are also planned for an exploratory investigation of anomalies in the water column.

• FUJI - Oct. 1997, *Marion Dufresne*. Co-PIs: Kensaku Tamaki and Catherine Mével. TOBI survey and deployment of OBSs on the SWIR axis between 56 and 66°E.

• ODP leg 176 - 15 Oct. - 10 Dec. 1997, *Joides Resolution*. co-PIs: Henry Dick and Jim Natland. Deepening of ODP Hole 735B, at the Atlantis II fracture zone, into more gabbros and hopefully ultramafics.

• *R/V Sonne*, 1997 or 1998. PI: Chris MacLeod. Geological fine scale mapping and sampling of the platform around 735B using a newly developed drill core.

• 1998, ship? Pis: Henry Dick and Paul Robinson. Geological fine scale observation and mapping of the platform around 735B, using the Canadian ROPOS.

Proposed cruises:

• FRIMAS - 1998, *Marion Dufresne*. Co-PIs: Philippe Patriat and Daniel Sauter. Bathymetric and geophysical mapping of the crust generated at the SWIR from the axis to the triple junction trace around 63°E.

The Japanese also have plans to bring the submersible SHINKAI to the SWIR in 1998-1999.

If you have a funded cruise, plan to submit a proposal, or would like to be involved in research on the SWIR, please contact the SWIR implementation group.

* The SWIR Implementation Group consists of:

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InterRidge Working Group Updates...

Biological Studies Working Group Update: Progress on Recommendations Made by the 1995 InterRidge Biological Studies Workshop

Lauren Mullineaux, Chair

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Last year, Daniel Desbruyères asked me to take the position of Chair of the InterRidge Biological Studies *Ad Hoc* Committee. Daniel has done a wonderful job in this position, coordinating international biology efforts, and I hope to continue in his energetic and sensible tradition. Because the InterRidge Steering Committee met recently (last September), this is a good opportunity to update members of the community on progress on the recommendations from the April 1995 InterRidge workshop at Rutgers University. Many of the following projects have been completed, or are nearing completion; others have been more problematic, with less progress.

Species Identification Manual - This manual, compiled by Daniel Desbruyères, has been completed and is ready for publication. InterRidge and IFREMER are in the process of investigating options for publication and distribution.

International Vent Biology Symposium - This symposium is scheduled for 20th - 24th October 1997. Over a hundred people have already expressed an interest in attending. Information and a registration form are available on the World Wide Web at: http://www.mmf.uma.pt/events/vent_biol_symp.html.

Ridge Crest Biology Directory and International Listing of Seagoing Capabilities - Both of these are available on the World Wide Web via the InterRidge home page which is now up on the the Jussieu server in Paris and can be found at http://www.lgs.jussieu.fr/~intridge. New or updated directory entries are always welcomed by the InterRidge Office.

Data Exchange- Biocean-H- This database continues to be developed by IFREMER.

International Sample Exchange- Copies of a draft international sample exchange agreement were sent out for comments to the National Correspondents of all InterRidge nations. The InterRidge Office did not receive any feedback, possibly because most of the National Correspondents are geologists and were not sure how to evaluate the agreement. The InterRidge Steering Committee has decided to revise the agreement and send it instead to National Corresponding Curators (i.e. those individuals who have agreed to receive and process samples).

Demarcation of Sanctuaries and Definition of Collection Areas- No action has been taken on this issue, but the InterRidge Steering Committee plans to write a letter to EOS (Transactions of the American Geophysical Union) aimed at provoking a response within the community to the issue of experimental seafloor sanctuaries.

If you have any questions or comments, please contact me, Daniel Desbruyères (ddesbruy@ifremer.fr), or the InterRidge Office (intridge@ext.jussieu.fr), now based in Paris for the duration of Mathilde Cannat's (mac@ccr.jussieu.fr) term as InterRidge Chair.

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InterRidge Working Group Updates....

Global Digital Database Update

Ph. Blondel, Chair

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1. Introduction

Knowledge of the Earth and its environment are proving increasingly crucial, and not only for scientific reasons. Information about the Earth's topography is of interest not only to geoscientists, but also to physical oceanographers (to constrain ocean circulation models), marine chemists (to assess the distribution of chemical products, harmful or not, in the deep ocean), governments (extensions of the Exclusive Economic Zones), and industries (e.g. cable or pipe-line companies). However, two thirds of the planet are covered by oceans which prevent a direct access to its topography. It has become a cliché to say that more is known about planets at the other end of the Solar System than about the Earth. It is nonetheless true, for example the whole of Venus has been mapped with a ground resolution of 100 m or less. The Earth is only slightly larger, but the best bathymetric compilations exhibit resolutions of 5 minutes of a degree, or slightly less. The establishing of a Global Ridge Bathymetry Database is therefore primordial, and the present article aims at showing the efforts of InterRidge. This article is not a consensus of all voices inside the InterRidge community. Instead, it shows the problems to address, the achievements from the national programmes that compose InterRidge and the possible way forward. From there it can lead to discussions inside InterRidge and the constituting national programs.

2. InterRidge and the National Initiatives

InterRidge is designed to encourage scientific and logistical coordination, with particular focus on problems that cannot be addressed as efficiently by nations acting alone or in limited partnerships. Its activities range from dissemination of information on existing, single-institution experiments to initiation of fully multinational projects. A particular domain of interest is the acquisition of a balanced set of global-scale data on the entire mid-ocean ridge system. More than 50,000 km of ridges girdle the Earth where lithospheric plates move apart and new crust is formed. They are the most dynamically active places on the Earth's surface, and concentrate most of the world's volcanic activity and a large part of the seismicity in zones only a few kilometres wide. Scientific surveys have been conducted by all member countries of InterRidge, in collaboration or in the framework of their national programmes (such as BRIDGE for the UK, De-Ridge for Germany or Dorsales for France). They have produced huge amounts of bathymetric data (several Terabytes). Each country, or, more appropriately, each institution has different ways of handling and distributing the resulting datasets. It was felt that now was the time to synthesise these processes and regroup bathymetry data into one single dataset available to the whole scientific community.

3. Bathymetry Data Processing

Sonar systems providing bathymetry can be roughly divided into echosounders (one single beam oriented vertically), multibeam (several beams on each side of the ship) and sidescan sonars (one beam on each side) (e.g. deMoustier, 1988; Kleinrock, 1992; Blondel and Murton, 1997). These systems can be hull-mounted, shallow-towed, or deep-towed. Bathymetry data is supplemented by navigation and attitude information. Navigation contains the ship's position, along with its heading, speed and acceleration. Attitude data generally contains roll, pitch and yaw (and, in the case of deep-tow systems, tow-altitude, platform heading and reference net position). Navigation indicates where the sonar is, and attitude indicates where the sonar looks. Both are important, and in this article, the reference to bathymetry implicitly includes navigation and attitude as well. Depending on the origin of the bathymetry (point values for echo-sounders or series of individual measurements for multibeam and sidescan sonars), different operations will need to be performed. Pre-processing prepares the data for processing and includes cleaning the navigation and attitude files, and, if necessary, changing headers and formats. Processing per se is the transformation of raw bathymetry into usable images, or grids, that are topographically and geometrically correct representations of the seafloor. This process usually involves the detection and filtering of spurious values, and the gridding, interpolation and contouring of individual {x; y; z} values. Post-processing includes grid interpolations, mosaicking, cosmetic operations (e.g. contrast enhancement, shading), statistics and detailed image analyses (e.g. feature extraction). All these steps need to be documented as precisely as possible in order to check their accuracy, and, if new algorithms are available, to improve them. The amount of ground resolution of the final dataset depends on the final objectives. Geophysical surveys tend to stay as close as possible to the maximum resolution (generally 100 metres). Other surveys may be more interested in large-scale mapping, or only in the dangers to surface navigation. Quality assessment standards have been set by well-known institutions such as IHO (International Hydro-graphic Office) or GEBCO (GEneral Bathymetric Charts of the Oceans). Although not formally set as standards, stricter rules for checking the accuracy of bathymetric measurements have also been introduced by individual scientists inside the InterRidge community.

4. Archiving and Distributing Bathymetry Products

Archiving of Bathymetry Data

Archiving of processed data is one of the problems. It is often difficult for a scientist to access the bathymetry needed for a particular project, or to even know whereto find it and how to obtain it. For example, bathymetry has been collected in the Northern portions of the Mid-Atlantic Ridge by several institutions, and some portions of the resulting datasets are stored in half a dozen institutions scattered among 4 countries. The project initiated by InterRidge of a "Global Ridge Bathymetry Database" would present the obvious advantage of regrouping the bathymetry available on mid-ocean ridges and back-arc areas in one single dataset, simplifying their access and saving time and energy.

Another problem is the format of the bathymetry data. Following recent meetings (e.g. Stewart, 1990; Blondel and Parson, 1994; 1995), and the growing concern of end-users, some de facto standards have emerged and have been gradually accepted. Text dissemination is more and more achieved through Word-RTF and TeX formats. Graphics files are easily exchanged with PostScript and a set of specific rasterfile formats (e.g. JPEG, GIF, TIFF). Many easily accessible, public domain software exist for translation between these formats. However, the choice of a common format for acoustic data is much more difficult to attain, as often it is specifically adapted to the sonar system in use, and to the processing computer. A new format, called HDF (Hierarchical Data Format), and its offspring NetCDF are architecture-independent and data-independent. They have been used in several successful bathymetry processing software such as MB (e.g. Caress et al., 1996) and GMT (Wessel and Smith, 1991). The main concern for sonar users is that the archived data format be self-describing (Blondel and Parson, 1995). This does not preclude the use of the NetCDF data format, but its use is neither necessary nor sufficient for the data to be self-describing.

Copyrights/Licences

Once an archiving methodology has been defined, the dissemination of the data must be considered. Who can provide data to the central archive? How should the data be distributed? And, concomitantly, to whom? Proprietary rights have always been considered important by scientists. The "gentlemen's agreement" system, along which use of acoustic data is freely granted as far as the proper references and acknowledgements are made, has prevailed for a long time. But the origins and extent of funding for bathymetric surveys have dramatically changed in the last years. In particular, joint ventures with private companies or associations between several countries (e.g. through the European Community) have become quite common. Funding bodies have different copyright rules, allowing different access at different costs. Furthermore, not one person or laboratory can be pinpointed as owner of the data, and new rules have to be established. The same questions arise with licensing. What are the limits in which the data can be used, reproduced, printed, re-distributed, etc.? Is the simple reference of the origin of the map sufficient, or should specific distribution fees be established? Following common business practices, it would be worth introducing formal agreements binding the two parties, somewhat like software agreements.

Physical/Electronic Distribution

The traditional way of distributing bathymetry data was by the large-scale production of maps, which were physically mailed to the end-users. Because of the high amount of data involved, and to better match the customers' requirements, leading institutions now provide bathymetric data on tapes (e.g. United States Geological Survey), on CD-ROMs (e.g. GEBCO) or print tailor-made maps in small quantities (e.g. Geological Survey of Canada). Electronic distribution has accelerated the process, by allowing on-line access to maps or portions of maps through the Internet (ftp or World-Wide Web).

A successful way of blending these different approaches has been demonstrated by a pilot study, the US RIDGE Multibeam Synthesis. Bathymetric data acquired at mid-ocean ridges with funding of the US National Science Foundation is regrouped at the host site (Lamont-Doherty Geological Observatory). Its accuracy is checked, and in some cases the data is reprocessed. The raw and processed data are accessible on-line via the World-Wide Web (http://imager.ldeo.columbia.edu/) and on a series of CD-ROMs. Services for map generation and map printing are also offered on a cost-reimbursable fee structure. The current database covers portions of the Mid-Atlantic, Pacific and Antarctic regions.

5. Toward a Global Ridge Bathymetry Database

InterRidge has taken the formal decision to compile the bathymetric datasets of mid-ocean ridges (and possibly back-arc areas) produced within current national initiatives into one single database. The aim is to make high-resolution bathymetry more accessible to the world's scientific community and maximise the scientific return and to share the burden of distribution and archiving. Another expected return of this project will be the dissemination of bathymetric products to other groups than the mid-ocean ridge community (e.g. physical oceanography, satellite

InterRidge Working Group Updates.... Global Digital Database

altimetry).

The problems to address are numerous, and are being discussed inside the InterRidge community. First, a global inventory of all bathymetric data acquired so far in the whole world needs to be made. Second, consultation of data providers and data users should clear the uncertainties related to copyright and licensing by establishing unambiguous "rules of the road". The actual compilation of the global database is the most difficult part. Where will it be hosted? Could different sites be responsible for different parts of the project? If the choice of one single site proves too unwieldy, it would be possible to have one major site acting as front-end and customer-interface for distributed sites each responsible for a different region. How would the quality control be performed? Data dissemination could easily model the RIDGE Multibeam Synthesis, with on-line access via Internet and physical distribution via CD-ROMs and tailor-made maps. One large question is how this work would be funded: national agencies or international cooperation? The final establishment of a "Global Ridge Bathymetry Database" is still a distant goal. But it is not that far. Important groundwork has been made by several national programmes. This project also benefits from the experience accumulated by other international programmes, such as SCOR, GEBCO or IHO. Bringing together the strength and motivation of scientists everywhere, InterRidge is ideally placed for this task. Scheduled for the end of the millennium, the "Global Ridge Bathymetry Database" will be a perfect summary of the advances in the knowledge of our planet which started only a quarter of a century ago.

Acknowledgements

Some of the ideas expressed in this article were brought forward, discussed and refined during a BRIDGE Workshop about "Sonar Processing in the UK" held at the Institute of Oceanographic Sciences (UK) in June 1994. They were updated through discussions with various colleagues from the InterRidge Community.

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InterRidge Themes and Working Groups:

Global Studies

- SWIR Project- *C. Mével, Chair*
- Global Digital Atlas- *P. Blondel, Chair*
- Actic Ridges- *R. Rihm, Chair*
- Cables- *A. D. Chaves, Chair*

Meso-Scale Studies

- 4-D Architecture of the Oceanic Lithosphere- *L. M. Parson, Chair*
- Quantification of Fluxes- *TBA*
- Back-Arc Basins- *K. Tamaki, Chair*

Active Processes

- Biological Studies- *L. S. Mullineaux, Chair*
- Event Detection and Response- *K. L. Von Damm, Chair*

International Ridge-Crest Research: Biological Studies

Biological Diversity at Deep-Sea Hydrothermal Vents: Preliminary Results from the LUSTRE (LUcky STRike Exploration) '96 Cruise

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Hydrothermal vents and salt marshes are often cited as examples of ecosystems with high productivity but low diversity (e.g. Wright et al., 1993). To our knowledge, however, the only statistical measures of diversity at hydrothermal vents come from the work of Grassle and his colleagues based on a small number of quantitative box core samples in soft-sediment environments (Grassle et al., 1985; Petrecca and Grassle, 1990). Soft-sediment environments are the exception rather than the rule for hydrothermal systems. Measures of diversity or species richness from hard substrate vent communities have usually been restricted to lists of species (e.g. Tunnicliffe, 1988) and comprise datasets that are not comparable from one vent field or geographic region to the next due to differences in sampling methods, effort and presence or absence of specific microhabitats. While it is generally accepted that vent communities are less diverse than deep-sea soft-sediment environments, an appropriate database does not exist to support this statement for hard substrate environments, either in comparison to deep-sea or shallow-water hard substrates. Comparisons among regions require that assemblages and habitats chosen for study should be directly comparable and that sampling techniques (sample size and number of replicates) should be similar (Underwood and Petraitis, 1993). These requirements have so far not been met for any comparison of hydrothermal vent communities with other habitats.

Mussel communities, widely-distributed in shallow water, at deep-sea hydrothermal vents, and at cold seeps (e.g. Florida Escarpment and other Gulf of Mexico sites), are an appropriate microhabitat in which to make biodiversity comparisons. In shallow water, mussel beds have high species richness but are typically dominated by a few very abundant species (Seed, 1996). Biodiversity in shallow-water mussel beds has been correlated with age, structural complexity, and mussel patch size (Suchanek, 1985; Tsuchiya and Nishihira, 1985; Tsuchiya and Nishihira, 1986; Peake and Quinn, 1993; Iwasaki, 1995; Svane and Setyobudiandi, 1996).

To assess diversity at deep-sea vents relative to shallow-water communities, we have chosen to measure the diversity of species associated with mussel communities at vents. Mussel beds are typically discrete microhabitats within vent fields. They support a variety of smaller invertebrate fauna, just as shallow-water mussel communities do. These macrofaunal populations include apparent radiations of archaeogastropod limpets and siphonostome copepods. Together with representatives from a

Table 1. Lucky Strike Sampling Budget

JASON Mussel Samples, LUCKY STRIKE, July 1996								
LOCATION	Date	*JASON* #	Rep #	Start Time	End Time	Elapsed Time (min)	Mussel Vol. (L)	No. of Assoc. Macrofaunal Individuals*
Eiffel Tower	07/08/96	176	1	01:38	02:05	27	2.2	2,427
	07/19/96	177	2	05:05	05:30	25	2.6	687
	07/19/96	177	3	05:34	06:02	28	3.0	1,076
	07/19/96	177	4	08:58	09:30	32	2.1	1,680
	07/19/96	177	5	09:30	10:11	41	3.0	1,120
Sintra	07/28/96	181	1	09:56	10:23	27	1.5	2,192
	07/28/96	181	2	08:46	09:37	51		
	07/30/96	183	3	05:06	05:21	15	2.0	623
	07/30/96	183	4	05:21	05:38	17	2.4	660
	07/30/96	183	5	08:14	08:29	15	2.1	4,165
	07/30/96	183	6	08:29	08:45	16	3.0	2,612
						mean = 26.7	mean = 2.4	total = 17,242

*Preliminary values, exclusive of mussels (except post-larvae); preliminary assignment to specific taxa suggests there is a total 20 to 25 invertebrate species associated with mussels at Lucky Strike.

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variety of polychaete families, these taxa dominate species lists from hydrothermal vents. Mussel beds occur at many of the hard-substrate mid-ocean ridge vents which are frequently visited by submersibles, including sites on the northern East Pacific Rise (e.g. Van Dover and Hessler, 1990) and southern East Pacific Rise (e.g. Geistdoerfer et al., 1995), at back-arc basins in the western Pacific (e.g. Jollivet et al., 1989), and at Snake Pit (e.g. Segonzac, 1992), Lucky Strike (Van Dover et al., 1996) and Menez Gwen (Desbruyères et al., 1994) on the Mid-Atlantic Ridge. Mussel beds are thus ideal communities to study for comparative diversity measures.

We have developed a simple method of replicate sampling of vent mussel beds and are using this technique to measure species diversity within mussel beds and its correlation with structural complexity (measured as interstitial volume and mussel size-frequency) at Lucky Strike on the Mid-Atlantic Ridge. Using the manipulator of *JASON*, we collected replicate mussel samples from each of two discrete sulfide edifices within the field (5 samples each from Eiffel Tower and Sintra). Mussel volume was chosen as a measure of sample size rather than the usual area measure because mussel habitats are 3-dimensional and because area is more difficult to measure *in situ* on the seafloor than mussel volumes in the lab. Samples were washed in three changes of seawater and the washings were sieved through a 63 µm mesh sieve. All samples were sorted first on the ship and then a second time in the laboratory to remove all invertebrates. Individuals were sorted as to species and counted. A summary of sampling effort is given in Table 1. Identifications of specimens are being confirmed by taxonomic specialists, thus results presented here are preliminary. We are preparing an SEM catalog of Lucky Strike mussel community invertebrates which we hope to have available for participants in upcoming cruises to the site.

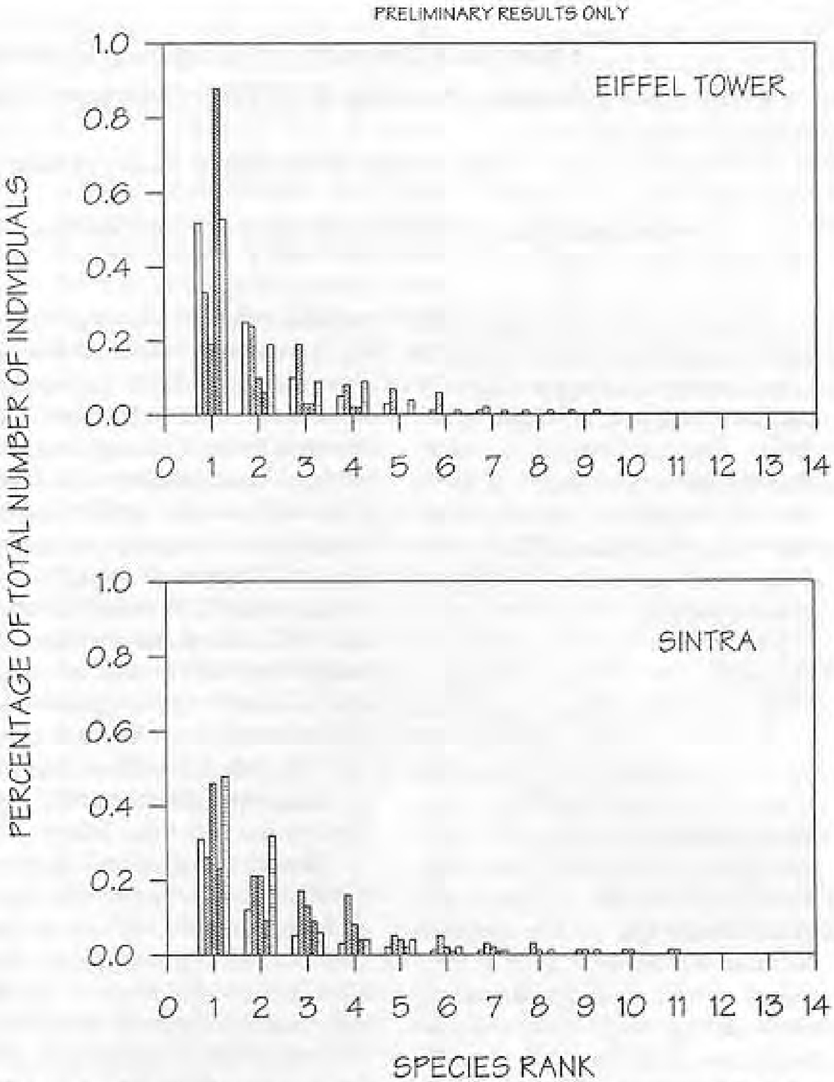

Figure 1. Species dominance in Lucky Strike samples expressed as a percentage of the total number of individuals (see Table 1 for numbers) from a sample. Vertical bars represent each of 5 replicates per site.

The two Lucky Strike sites, separated by approximately 500 m, appear to share much the same fauna, with only 3 rare species found at one site and not at the other. Numerical dominance in all replicates from Lucky Strike (Figure 1) was by three crustacean taxa (ostracod, amphipod and copepod), which combined account for 50-80% of the individuals collected. This composition contrasts with those from deep-sea soft-sediment communities, where typically no single species accounts for more than 8% of the total number of individuals (Gage and Tyler, 1991). The first two replicates sampled captured 75% of the species found at the Eiffel Tower site; 2 replicates at Sintra captured 98% of the species found. Our sampling strategy compares favorably to sample sizes, expressed as areas, used for analysis of mussel bed diversity in shallow water (e.g. 2 replicates of 5 x 10 cm^2 (Iwasaki, 1995)) and, as demonstrated for Lucky Strike, provides us with a representative measure of diversity within mussel clumps.

Using similar methods, we sampled *Mytilus trossulus* from two intertidal sites at Kasitsna Bay, located along the south central Alaskan coast. Preliminary species-volume curves for intertidal and hydrothermal vent mussel communities (Figure 2) provide the first quantitative comparison of vent biodiversity with that of a shallow-water ecosystem and suggest

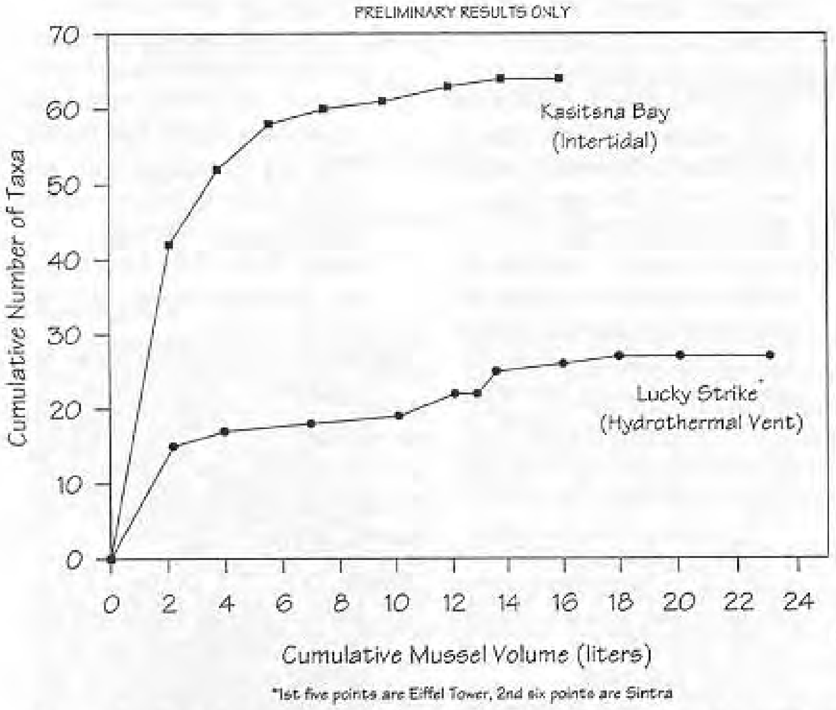

Figure 2. Cumulative species/volume curves for the Lucky Strike hydrothermal site and an interidal site at Kasitsna Bay, southcentral Alaska.

that diversity is greater at the shallow-water site by a factor of 3 for similar sampling efforts. Statistical comparisons within and between sites will be undertaken once final identifications and abundances are obtained. While our data do not allow us to identify subtle statistical differences in diversity between vent sites, we will be able to see large differences or remarkable similarities in diversity among sites that will allow us to generate hypotheses regarding development of community structure and to suggest means of testing mechanisms that might account for any differences observed.

We are also interested in biogeographic comparisons of diversity that might correlate with tectonic histories of ocean basins. Manipulative, experimental approaches would not allow us to address issues on this kind of geographic scale. Local heterogeneity and the scale of differences in diversity along a ridge segment or between ocean basins need to be known before we can propose experimental approaches to study mechanisms controlling diversity in these systems. We intend to continue this method of comparing diversity among vent (and seep) mussel habitats within different ocean basins as part of an effort to identify centers of biogeographic diversity on a global scale.

Acknowledgements.

This work was supported by an NSF RIDGE grant to D. Fornari and S. Humphris, Woods Hole Oceanographic Institution. We are grateful to the entire science party participating in the LUSTRE '96 cruise, especially our Chief Scientists D. Fornari and S. Humphris and the Deep Submergence Operations Group who so capably supported our sampling efforts.

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U.S. Hydrophone Arrays Document Seismicity Patterns and an Earthquake Swarm Along Slow Spreading Centers

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Introduction

Hydrophone arrays designed for nuclear test ban monitoring, missile splashdown detection, and tracking submarines have a supplementary use in long-term, continuous monitoring of seismo-acoustic activity along portions of oceanic spreading centers. The U.S. Navy and U.S. Air Force have recently begun to make these acoustic data available, on a limited basis, for scientific investigation and the initial results are quite promising. Real-time monitoring of volcanic events at two intermediate-rate spreading segments in the northeast Pacific has been achieved based on the recorded T-waves (Fox et al., 1995; Fox et al., 1996). These detections allowed rapid shipboard response for unprecedented collection of oceanographic, biologic, and geologic data during the evolving activity associated with the volcanic event. Additional recording facilities are available to monitor seismicity along slow-spreading ridges. Here we report on recent findings from the southern Mid-Atlantic Ridge, near Ascension Island, and the Mohns Ridge, north of Iceland. The availability of data from these ridge crest observatories provide scientists with a new opportunity to measure long-term variability in ridge behavior.

Seismo-acoustic studies in the Norwegian Sea

Data from SOSUS hydrophone arrays in the Norwegian Basin were archived by the Naval Research Lab in Washington D.C. for the period February 1995 to October 1996. The archive consists of sixteen 'beams' (data processed from groups of individual hydrophones to enhance signals arriving from a certain direction), from multiple arrays, that were selected to focus on the Mohns ridge and the eastern Jan Mayen transform fault. Seismic arrays in Norway also record plate boundary earthquakes in the basin and they detect many more of these regional events than does the global seismic network.

A swarm of earthquakes was reported late November, 1995, in the seismic bulletin generated by the Center for Monitoring Research (CMR) which interprets the land array data for nuclear treaty monitoring purposes. Activity was concentrated in a 2-week period and event magnitudes were listed as 3.5-4.8 mb. During the subsequent year, several isolated events were also reported from the area.

Analysis of SOSUS data for this period shows over 7000 events occurred during the earthquake swarm (Figure 1b). Recorded arrivals include P-waves, water-borne T-waves, PT pairs and P-waves reflected at the seasurface. Activity started before mid-November, 1995, (we cannot document the start precisely due to a recording problem at the time) and continues into January, 1996. The greatest number of events (> 40/hr) occurred over a 3-day period in the middle of the 70-day duration of the activity.

Separation in time of P- and T-waves recorded at the SOSUS arrays are used to determine relative locations of events and their spatial evolution throughout the swarm. For our initial analysis a land-determined epicenter was used as a master event and SOSUS-determined relative shifts were simply projected along the trend of the ridge axis (Figure 1a). More detailed plots show that the locus of activity shifts by 30-40 km during the swarm but no apparent steady migration of activity is seen in contrast, for example, with the migration of seismicity observed in Iceland during an eruption of Krafla. This pattern suggests that surface breaks during dike injection did not occur or, at least, did not generate T-waves, or that the swarm was not associated with a simple dike emplacement along the ridge.

Absolute event locations can be improved by combining land-based information and constraints from P and T waves recorded by SOSUS. The CMR bulletin listed epicenters extending as much as 100 km down the flank of Mohns ridge. Preliminary analysis of SOSUS arrival times indicate that events must have occurred within 50 km of the ridge axis (Figure 1a). More detailed analysis of events recorded at multiple arrays is underway and should constrain locations further.

Ascension Seismicity Study

Ascension Island sits 100 km west of the MAR just south of the Ascension Fracture Zone (Figure 2). A very broadband seismographic station was installed on the island by Project IDA of Scripps Institution of Oceanography as part of the Global Seismographic Network. The station, ASCN, began routine operation in October 1994. Around the island a hydrophone array exists as part of the Missile Impact Locating System (Palmer et al., 1994) which is run by the U.S. Air Force. We have been requesting data from the Air Force on a regular basis since the installation of the seismic station, and recently data have been made available through the International Data Center on a continuous basis. These permanent installations present a unique opportunity to study

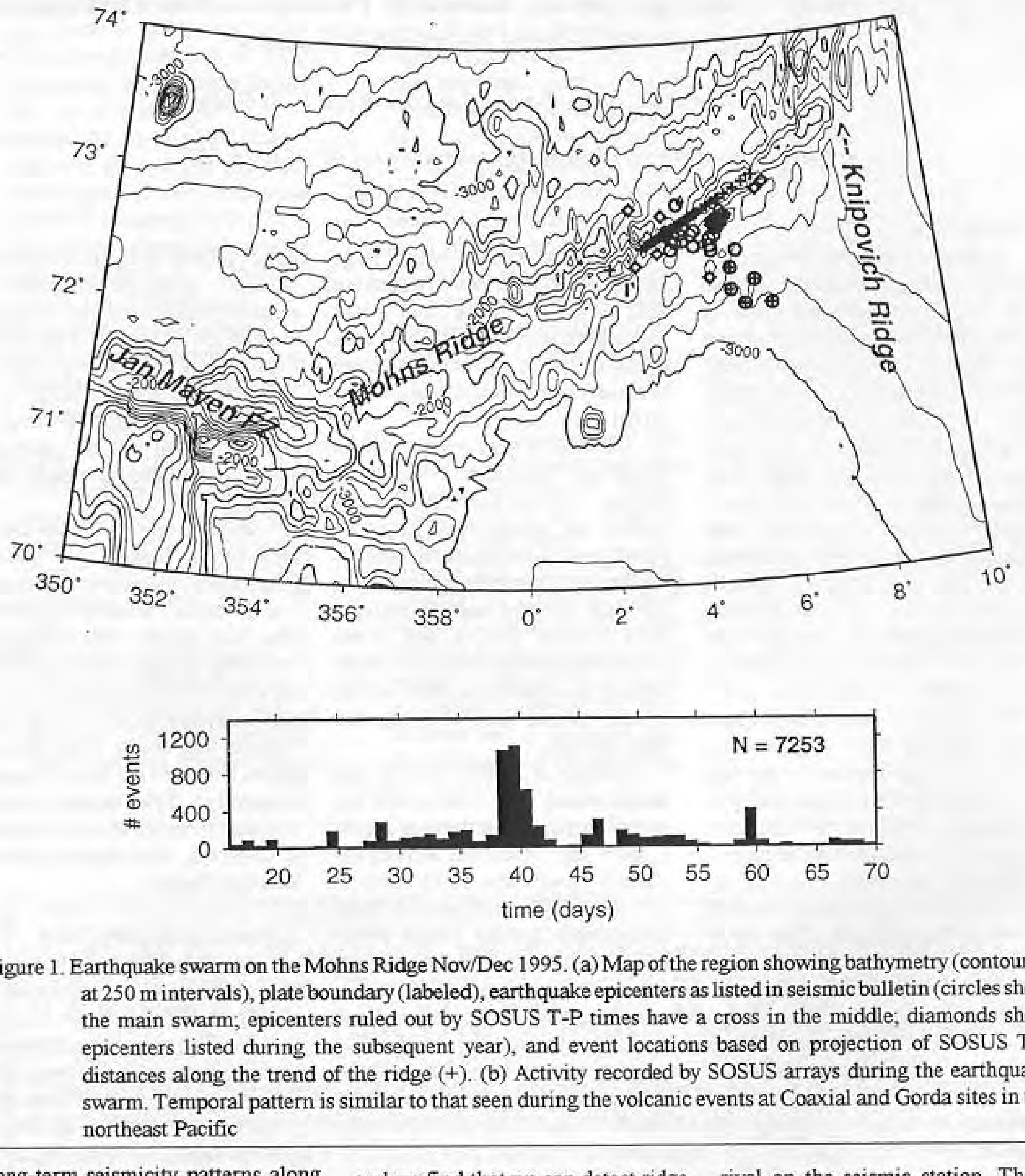

Figure 1. Earthquake swarm on the Mohns Ridge Nov/Dec 1995. (a) Map of the region showing bathymetry (contoured at 250 m intervals), plate boundary (labeled), earthquake epicenters as listed in seismic bulletin (circles show the main swarm; epicenters ruled out by SOSUS T-P times have a cross in the middle; diamonds show epicenters listed during the subsequent year), and event locations based on projection of SOSUS T-P distances along the trend of the ridge (+). (b) Activity recorded by SOSUS arrays during the earthquake swarm. Temporal pattern is similar to that seen during the volcanic events at Coaxial and Gorda sites in the northeast Pacific

long-term seismicity patterns along the mid-ocean ridge in this area (Hanson et al. 1996).

A signal detection algorithm is routinely used on the seismic data to determine when an earthquake has occurred. We then request hydrophone data for time windows surrounding the P- and S-arrivals. Our detection threshold depends on the magnitude of the event, not the size of T-phase produced. A local magnitude scale has been developed and we find that we can detect ridge events to just below ML = 2. In the future it should be possible to detect events using the T-phase since the continuous hydrophone data are now available. Because of the low attenuation of the T- phase this approach should allow detection of many more earthquakes.

Events are located when the arrivals are large enough to pick a P-arrival on the seismic station and at least three hydrophones and a S-arrival on the seismic station. These arrival picks are quite precise, typically within 0.2 seconds. Relative times between T-phase arrivals at the different hydrophones are determined, precise to less than 1 second. Since the instruments are all to one side of the ridge and are 100 km away, they can be viewed as an array where the P- and T- arrivals determine the azimuth to the event and the S-P time determines the distance. The precision of the locations is typically around

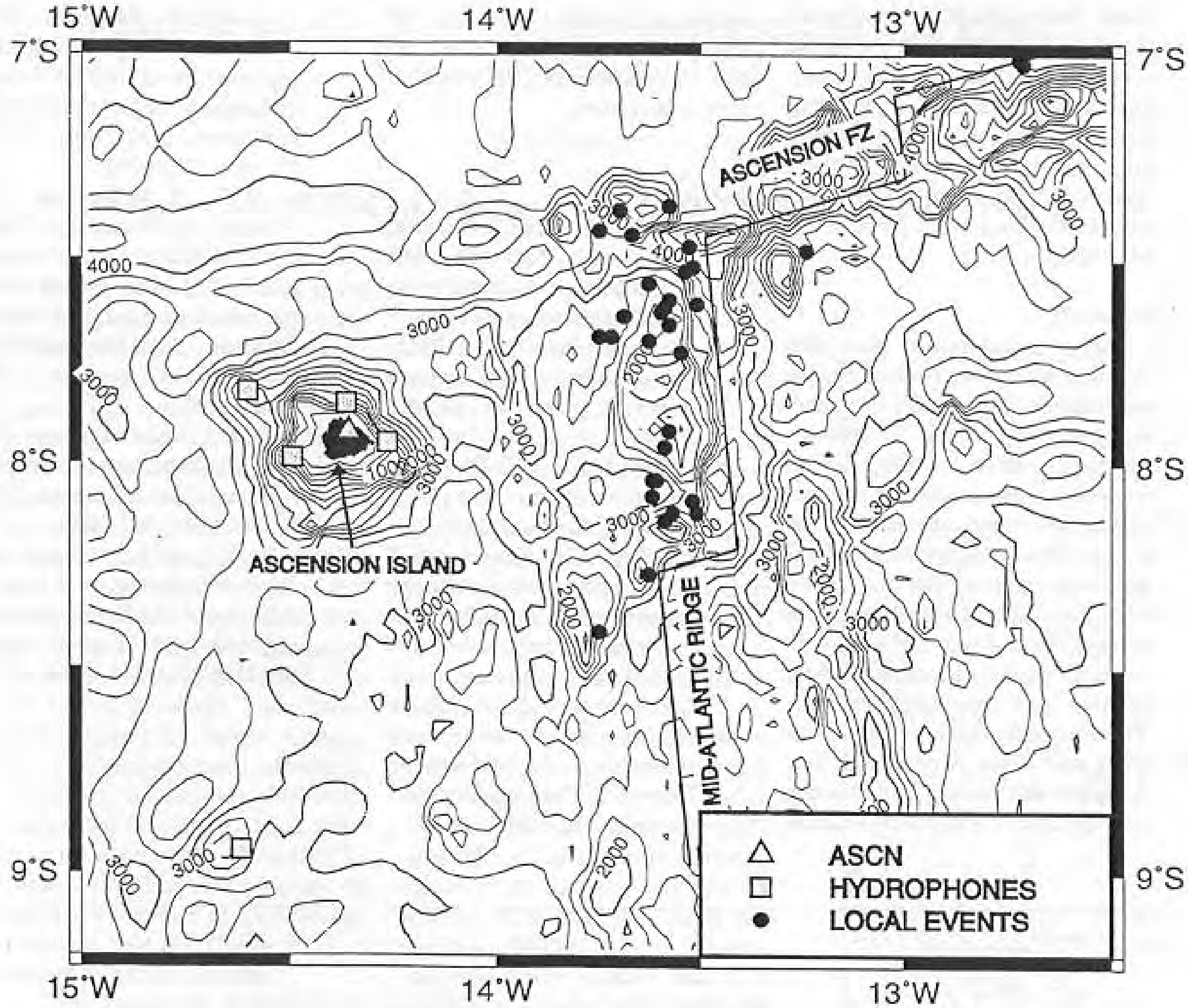

Figure 2. Instrument and event locations for the Ascension seismicity study. Bathymetric contours at 250 m intervals are from the global model derived by Smith and Sandwell (1996). Earthquakes were located using P-arrivals at the island seismic station and at the offshore hydrophones, S minus P times at the seismic station, and T-arrivals on the hydrophones. The epicentral uncertainties are generally less than 10 km (see text). Events during this period are mainly located in the western rift mountains, on the outside corner of the western intersection of Ascension transform fault and the ridge, and on the inside corner of the smaller offset at the southern ridge-transform intersection.

5 km, but because the instruments do not surround the events, systematic errors can be a problem. By including T-phase information in the inversion for epicenters we decrease the possibility of bias introduced by heterogeneity in the P-velocity structure. The biggest contributor to a systematic bias is the assumed Vp/Vs ratio since the distance to the event is almost totally controlled by the S minus P time.

The epicenters shown in Figure 2 were computed using a Vp/Vs of 1.73 which we feel is reasonable since the majority of the travel path is in the upper mantle. Increasing the Vp/Vs ratio would tend to pull the events closer to Ascension while decreasing the ratio would push them away. Unexpectedly, most of the events occur in the western rift mountains. To relocate the event towards the inside corner high at the western intersection of Ascension transform with the ridge would require a Vp/Vs less than 1.6. This problem is discussed in more detail in a publication in preparation (Hanson and Given, 1997). Few of the events we have located have been listed in global seismic catalogs such as the PDE. For those that are, our locations usually agree to within 15 km which is within expected error in PDE locations for this part of the world. Interestingly the PDE locations over a 10 year period show events in between the two main groups of seismicity that we locate. Neither the PDE nor our more recent locations occur at the inside corner high where Ascension transform fault intersects the spreading center, contrary to teleseismic findings (Lin and Bergman, 1990) and model predictions (e.g. Tucholke and Lin, 1994) from other parts of the Mid-Atlantic Ridge.

Summary

These initial results show that existing hydrophone systems provide an important opportunity to characterize seismicity along slow-spreading ridges which, in turn, can increase our understanding of plate accretion and rifting processes. Continuous monitoring can eliminate the possibility of bias that may occur when only short-term observations are possible (2-4 wks has been a typical deployment period in previous seafloor microseismicity studies). Two new considerations of ridge activity arise from these initial data: surface breaks during dike injection may not always accompany volcanic events; earthquake activity may not always concentrate at the inside corners of slow-spreading ridge-transform intersections.

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Pacific Acoustic Monitoring

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The NOAA VENTS Program has extended their acoustic monitoring effort to include the East Pacific Rise between 20°S and 20°N and the Galapagos Ridge. Unlike the effort in the northeast Pacific, which is based on accessing the U.S. Navy's SOSUS arrays, the equatorial monitoring is accomplished using autonomous hydrophone array moorings deployed and maintained by NOAA ships. The hydrophone sensors were developed by Chris Fox and Haru Matsumoto at NOAA's Pacific Marine Environmental Laboratory in Newport, Oregon. Maintenance of the array is possible because the moorings are co-located with surface weather buoys of PMEL's TOGA/TAO program. The data are not currently transmitted in real time but are downloaded every six months. The monitoring began in May, 1996, with an episode of volcanic seismicity discovered in the first month near 3°20'N, 102°14'W. The VENTS Program maintains a web site with epicenter maps and other information for both the northeast and equatorial Pacific monitoring programs at: **http://www.pmel.noaa.gov/vents/oceanseis.html**. Scientists with cruises to the area that are interested in further information for field investigations can contact Chris Fox at fox@pmel.noaa.gov

Joint U.S., Russian and Norwegian research at Knipovich Ridge, Norwegian-Greenland Sea

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An international team consisting of U.S., Russian and Norwegian scientists spent a month last summer on the Russian vessel *Professor Logachev* carrying out geological and geophysical research in the Norwegian-Greenland Sea. Research focused on several sites between 75° and 80° N along the Knipovich Ridge Valley (Figure 1), a segment of the Mid-Oceanic Ridge where the North American plate is moving away from the Eurasian plate. Participants on the cruise included personnel from the Naval Research Laboratory, Washington DC; Hunter College, NY; VNII-oceangeologia institute, St. Petersburg; the Institute of Microbiology of the Russian Academy of Science in Moscow; the Vernadsky Institute ofGeochemistry, Moscow; the Shirshov Institute of Oceanology, Moscow, and the Universities of Bergen and Oslo, Norway.

The Knipovich Ridge is the northern-most extension of the Atlantic Mid-Ocean Ridge and is one of the least known of the oceanic rift valleys. It is characterized by widely spaced clusters of seamount separated by long stretches of sediment-filled valley floor, which is atypical of mid-ocean ridge topography. The rift valley running along the center of the ridge ranges in depth from 3200 to 3400 meters. Near its northern end is the Molloy Deep, which at 5570 meters is the deepest part of the North Atlantic Arctic region.

The major objective within the Kniopvich Ridge area was to search for evidence of hydrothermal activity within the rift valley. The *Professor Logachev*, using sidescan sonar, profiled part of the rift valley from south to north. A CTD was attached to the sidescan to search for temperature anomalies in the water column. Early results indicated a temperature anomaly near the north flank of a submarine volcano at 76°48'N. Coring, dredging and a video sled were deployed to explore the area around the suspected anomaly site. Although the excact site of venting was not located, CTD readings along with evidence from dredging and photographic profiles produced signs of hydrothermal mineralization and recent volcanism in this section of the rift valley.

A failure of the sidescan sonar in the lower rift valley limited the ability to complete the bottom profile. However, enough evidence was gathered during this survey to warrant a future return to expand the investigations. One idea under consideration is to bring the MIR submersible, belonging to the Shirshov Institute of Moscow, to dive in the Knipovich Rift Valley within the next year.

The first follow-up of this collaborative research will be at this year's spring meeting of the American Geophysical Union in Baltimore, where sessions reporting on the scientific accomplishments of the expedition will be given by American, Russian and Norwegian scientists.

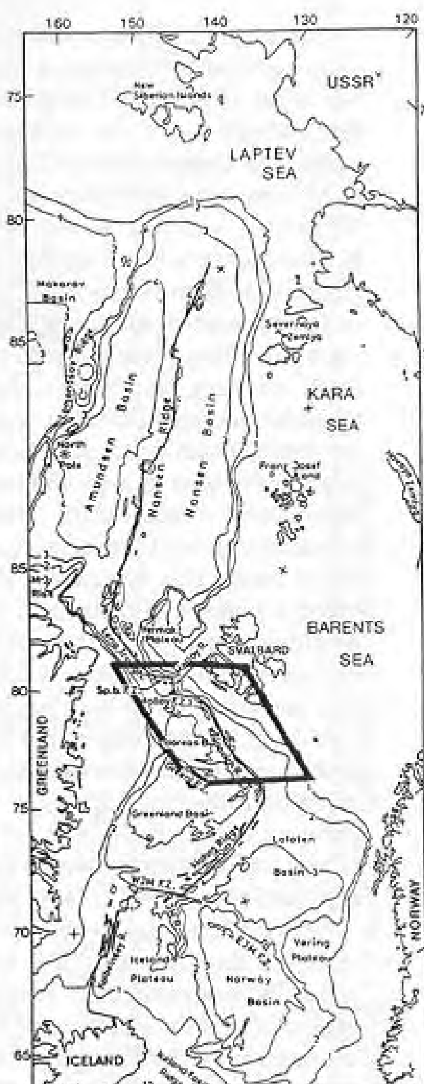

Figure 1: Main physiographic and structural elements in the vicinity of the plate boundary north of Iceland. The region within the trapezoid is the survey site.

International Ridge-Crest Research: 4D Architecture of the Oceanic Lithosphere

RAMESSES Finds a Magma Chamber Beneath a Slow Spreading Ridge

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In October 1993 we conducted a multi-component geophysical survey of the Mid-Atlantic Ridge near the southern tip of the Reykjanes Ridge. The experiment RAMESSES (Reykjanes Axial Melt Experiment: Structural Synthesis from Electromagnetics and Seismics) included wide-angle seismic refraction profiles, controlled source electromagnetic soundings, magnetotelluric (MT) sounding, and some normal incidence seismic reflection profiling, together with the usual underway swath bathymetry, gravity and magnetic measurements. Figure 1 shows a location map and the general layout of our study. This experiment provided a unique and remarkable opportunity to undertake joint geophysical interpretations of these various data sets which, taken together, provide the first compelling evidence of a robust axial magma chamber (AMC) at a slow spreading ridge. The experiment is described in Sinha et al. (1994) and preliminary results have been published in Sinha et al. (1997).

Previous attempts to observe an AMC at a slow-spreading ridge have generally confirmed their absence, suggesting that if they exist at all they are ephemeral features. The only published evidence (Calvert, 1995) for a slow-spreading ridge AMC is based on Mid-Atlantic Ridge seismic data which had previously been used to deny the existence of an AMC at that location (Detrick et al., 1990). Given the global extent of slow-spreading ridges, it is important to find and study whatever AMC's we can. Our understanding of the systematics and dynamics of ridge systems will never be complete until we understand the relationships between spreading rate and the dynamics of crustal accretion.

We chose a study area at 57°45' N on the southern Reykjanes Ridge based on the following criteria:

a) At the southern end of the Reykjanes Ridge the broad bulge of thick crust associated with the Icelandic hot spot gives way to a median valley more typical of the remainder of the Mid-Atlantic Ridge, and so although there are geochemical affinities with the hot spot at this location, it can be argued that morphologically it is representative of normal slow-spreading ridges. This hypothesis was later confirmed by the measurement of normal seismic oceanic crustal thicknesses here.

b) The overall trend of the ridge axis is oblique to the spreading direction, and consequently the Reykjanes Ridge is composed of a series of axial volcanic ridges (AVR) arranged *en echelon* down the ridge. These volcanic highs are clear evidence of magmatic activity at the ridge, and hence an AVR was chosen which appeared to be in the early stages of its constructional cycle. Using available bathymetric and side-scan sonar data we chose the AVR at 57°45' N because it was still quite small, showed bright backscatter on side-scan images indicative of fresh lava flows, and showed no evidence of late-stage tectonic deformation.

c) The rough topography of the Mid-Atlantic Ridge causes significant scattering of seismic energy incident on the seabed, and so the slightly smoother seafloor of the Reykjanes Ridge (due to the influence of the Iceland hot spot) maximized our resolution at mid- and lower-crustal depths and also our ability to establish a reliable measure of crustal thickness.

d) The water depths of 1-2 km at the chosen location were sufficient to isolate the controlled source EM study from atmospheric effects (both contamination from ionospheric sources and a propagated air wave), yet sufficiently shallow that high-frequency ionospheric signals could be detected in the magnetotelluric band.

e) The site was good logistically, as it is relatively close to the U.K. home port of the *R.R.S. Charles Darwin*, the ship used for the study.

We shall now briefly outline the measurements and then describe the resulting model shown in Figure 2.

Seismic Refraction

Eleven ocean-bottom seismometers were deployed in two lines, along the ridge axis and across the axis (parallel to spreading). Each line was shot using a series of 25 and 50 kg explosive charges at 1 and 2 km intervals and re-shot using a large volume airgun array fired at 100 m intervals. A clear characteristic of all the across-axis record sections was a shadow zone of greatly decreased amplitudes associated with the ridge location, and the along-axis records exhibit a pronounced loss of energy at ranges greater than 15 km. The data were quantitatively modelled using Maslov ray-tracing and synthetic seismogram calculations to produce along-axis and across-axis models that fit the travel time picks to within 150 ms for explosive shots and 100 ms for airgun shots, and showed a qualitatively similar pattern of di-

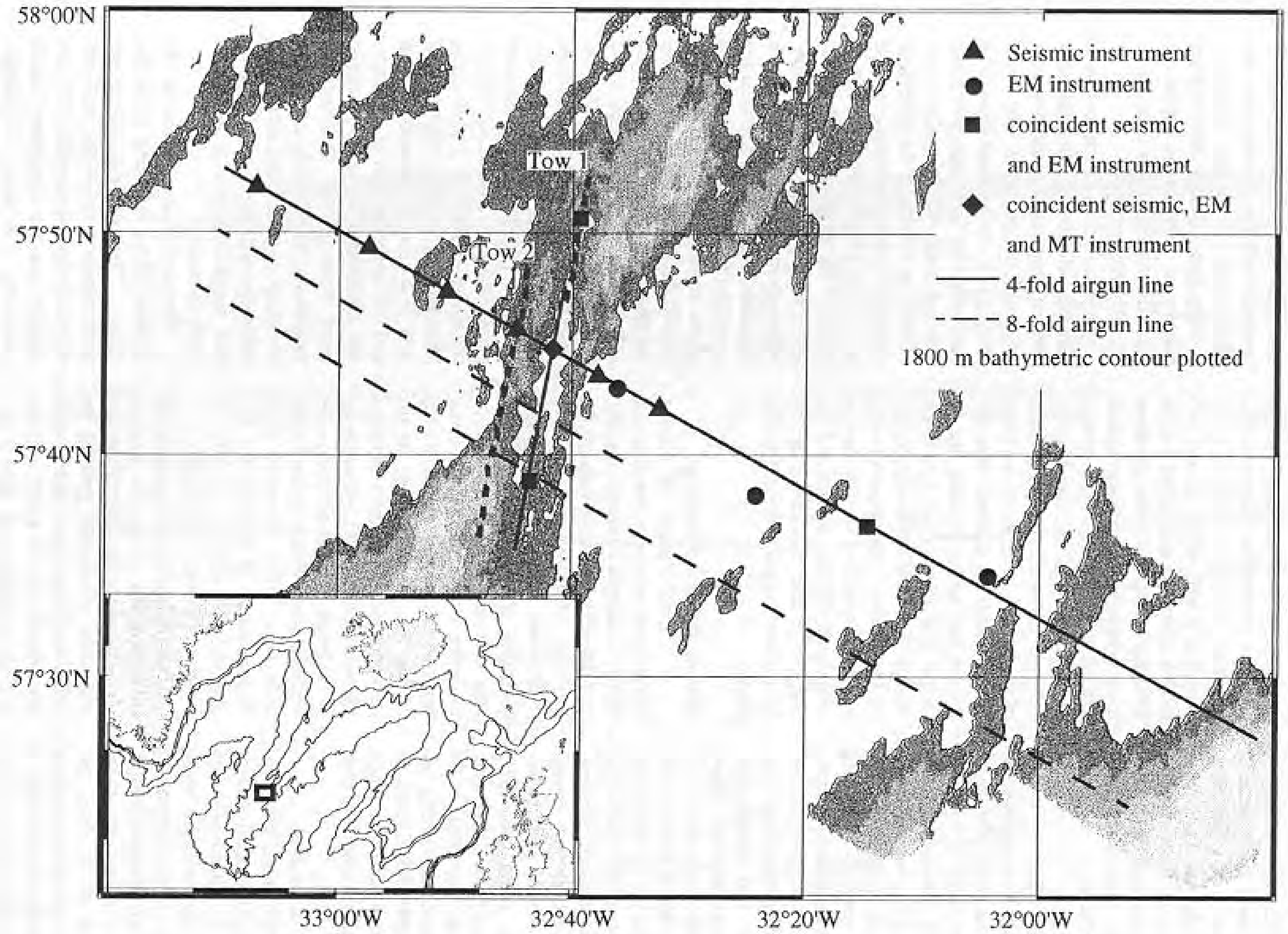

Figure 1. Location map for the experiment (inset) and the distribution of instruments and seismic lines. 'Tow 1' and 'Tow 2' refer to the two controlled source EM tows that were conducted on the north end of the AVR and 5 km to the west of the AVR.

minished amplitudes. The low amplitudes and the associated travel time delays require the existence of a broad axial low velocity zone capped by a much thinner and narrower zone of extremely low velocity, presumably melt. Off-axis, crustal thicknesses (7 km) and velocities are typical of other slow-spreading ridges, and a Moho is observed in zero-age crust immediately under the axis and the associated low-velocity zone using PmP wide-angel reflections.

Controlled Source EM

A total of 14 electrometers were deployed along the same profiles as the seismic experiment. Two transmitter tows were completed, one along the ridge axis and one 5 km west of the ridge, at frequencies of 0.1 to 11 Hz. Short range (1-5 km) data on the ridge have amplitudes characteristic of low resistivities due to seawater in a highly porous top 1 km of oceanic crust, and cannot constrain the existence of an AMC. However, intermediate range data (5-15 km) across the ridge exhibit a splitting of amplitudes for the radial and azimuthal modes characteristic of a buried conductor beneath the axis. Quantitative modelling was carried out using 1D inversion and 2D forward modelling, using geometries partly constrained from the seismic experiment. Long range data (20-50 km) are not considered reliable because the transmitter failed to maintain coherent phase for long enough to stack up signals at these distances.

Magnetotelluric Sounding

Five electrometers and six three-component fluxgate magnetometers were deployed to collect MT data (some of the instruments were controlled-source electrometers collecting data for both experiments). In view of the relatively short deployment time of 20 days, the sample rate of the magnetometers was set to the maximum possible (0.1 Hz). This rate combined with the shallow water depth and active ionospheric source fields during the experiment produced seafloor impedance estimates at frequencies as high 0.04 Hz, an order of magnitude higher than is usually recorded in the deep ocean. Skin-depths at the highest frequencies are less than the crustal thickness, and consequently along-strike measurements were sensitive to crustal resistivities which agree remarkably well with 1-D and 2-D models from the controlled source EM experiment. These data also show a low resistivity zone in the mantle at a depth of 50 to 120 km, presumably associated with decompression melting. However, the upper 40 km of the mantle is resistive, implying that the AMC is isolated from the mantle melt source by a hot, but no longer partially molten, uppermost mantle. This conclusion is supported by the across-strike measurements, which are sensitive to the coast of Greenland 650 km distant and the resistivity and thickness of the lithosphere between the ridge and coast.

Seismic Reflection Profiling

A limited amount of normal incidence seismic reflection data were collected using an 8 channel streamer and the airgun array, mainly for the purpose of mapping sediment thicknesses. However, with only a minimum of processing the along-axis reflection data show a bright reflection event at exactly the two way travel times predicted for the top of the low velocity zone in the refraction models, further supporting the existence of a melt lens at the top of the larger low velocity zone. The reflector is not visible in the across-axis line, either because it is discontinuous or because the low stack-fold (4) cannot cope with the rougher across-axis bathymetry.

Figure 2 shows the combined interpretation from the various geophysical studies. The pillows and extrusives, dikes, and gabbros are delineated in the seismic model as the usual layers 2A, 2B, and 3, showing a slight thickening of layer 2 in a broad region over the axis accompanied by slightly depressed velocities within 10 km of the axis, suggesting an increased porosity. Low resistivities, on the other hand, are restricted to a narrower zone within about 5 km of the axis, as the controlled source EM method is sensing a region of hot seawater of lowered resistivity directly over the AMC, rather than the increased porosity alone. Resistivities imply a porosity of 30% in the uppermost crust, decreasing to less than 1% in the dikes and gabbros.

There is a broad region on-axis of reduced velocities in the gabbroic section, presumably associated with increased temperatures and some melting in a crystal mush zone. The thin melt lens that caps this zone, required in the velocity model, is too small to be sensed by the controlled source EM method, but the controlled source data help constrain the lateral extent of the mush and its electrical resistivity at around 2.5 Ohmm. Although at too low a frequency to delineate structure, the MT data are sensitive to bulk electrical properties of the crust, and by fixing layer 2 resistivities and mush zone size from the controlled source EM model the MT data constrain the resistivity of the crystal mush to be 2 to 5 Ohmm. From this we can infer a melt fraction between 12 and 30%, or more accurately (since a bigger mush zone could have a proportionately higher resistivity) a total of 2 to 4 cubic kilometers of melt per kilometer of ridge. For a crustal thickness of 7 km and full spreading rate of 20 mm/yr this amounts to 15 to 30 thousand years' worth of melt. It is unlikely that the residency time for an AMC is anywhere near this long, confirming the ephemeral nature of this feature and suggesting that it was quite recently created.

We see a normal Moho in the seismic model extending under the ridge. The low velocities do not extend quite to the Moho, and both the along- and across-strike MT data suggest that the uppermost mantle resistivity is at least 500 Ohmm. Because the AMC has been recently emplaced, upper mantle temperatures must still be close to, but below, the

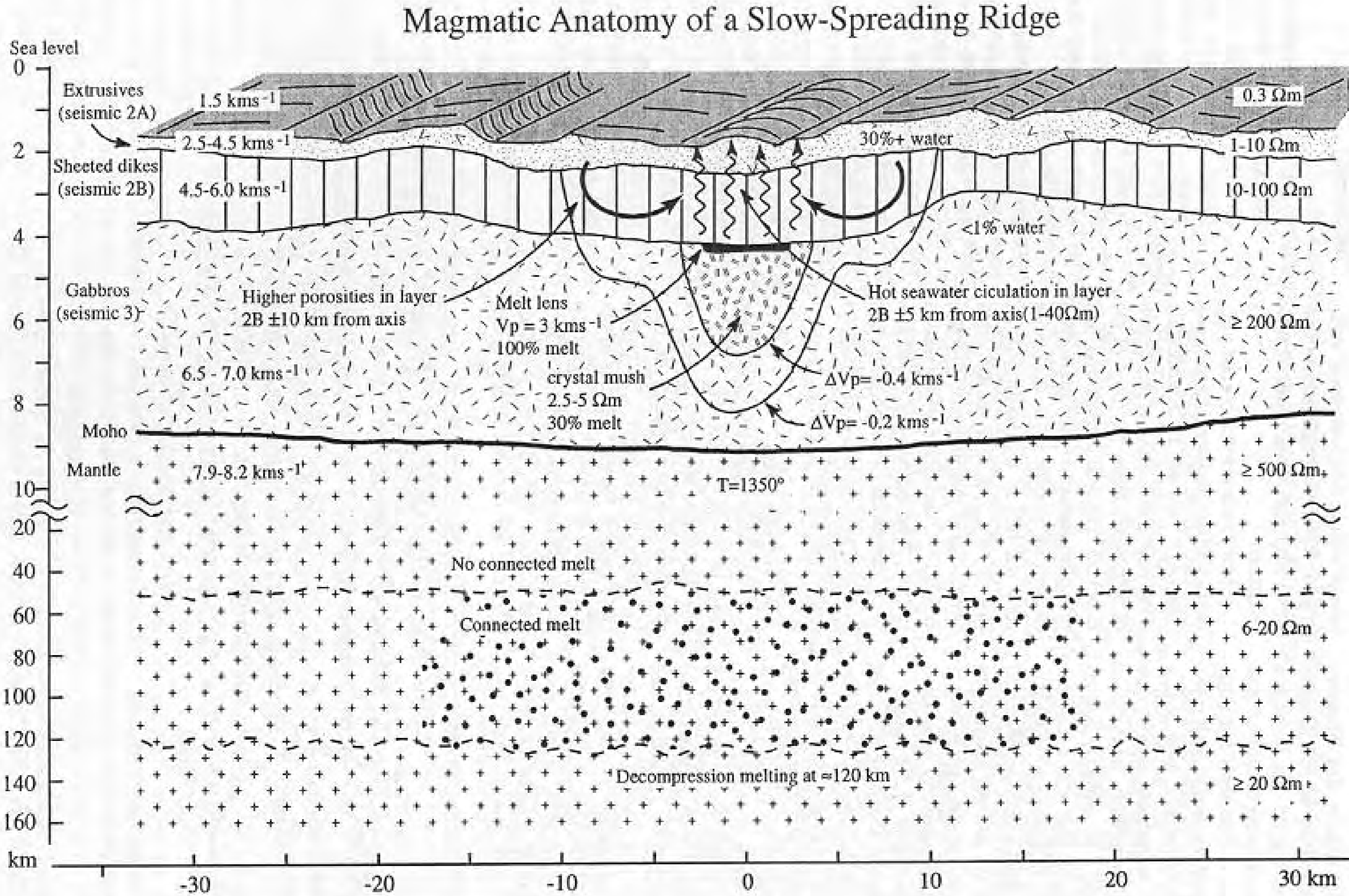

Figure 2. Combined interpretation based on data from seismic, controlled-source electromagnetic, and magnetotelluric experiments. Seafloor bathymetry and seismic layer boundaries are quantitatively accurate based on swath bathymetry measurements and seismic modelling. Similarly, estimates of electrical resistivity, porosity, melt content, and temperature are quantitative estimates based on modelling and interpretation. Note the 10:1 break in scale at 10 km depth.

mantle solidus (1350°C), and laboratory models of olivine conductivity versus temperature (Constable et al., 1992) predict exactly this temperature for a resistivity of 500 Ohmm. The observations do not require a second phase of lower resistivity, and so there is no evidence for a significant fraction of connected melt in the upper 40 km of mantle. Melt in this part of the uppermost mantle has either been completely removed to form the AMC, or it forms disconnected pockets that are either not migrating or migrating only slowly. Finally, at depths between about 50 and 100 km we see low resistivities again in the MT model, suggesting 1-3% melting, presumably associated with decompression of the mantle.

In conclusion, the combination of geophysical techniques has not only demonstrated the existence of an axial magma chamber at a slow-spreading ridge, but placed fairly tight bounds on its size, depth, and melt content. The relatively shallow depth of the AMC combined with normal crustal thickness and slow spreading rate provide strong constraints for geodynamical models of ridge systems. Finally, the lack of connected melt in the uppermost mantle provides an important message about the nature of melt migration. We must think either in terms of efficient, episodic extraction of melt from a substantial volume of mantle, or migration of melt in relatively small veins or pods that do not maintain connectivity after the initial onset of melt migration.

Finally, it is extremely encouraging that all the geophysical techniques that were used are in dramatically good agreement, and that the variety of techniques allow far more of the structure to be well constrained than would be possible with any one method alone. The success of this enterprise rests not just in the co-location of instruments, but also in the close collaboration maintained by the scientific party during the interpretation stages. The outcome fully justifies the combination of many techniques in a single integrated experiment on a carefully selected target.

Acknowledgements

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Off-Axis Crustal Structure of the Mid-Atlantic Ridge

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Introduction

Over the last two decades, much geological and geophysical data has been collected at and near the axes of slow-spreading mid-ocean ridges. These data show that ridges are segmented along-axis on scales of tens of kilometers, and they provide largely a rift-zone perspective on crustal accretion and tectonism. If crustal accretion is episodic, as it is believed it to be, a very large number of along-axis surveys in various segments are necessary to reconstruct all phases of a volcanic-tectonic cycle. Judicious off-axis surveys, however, capture all elements of a number of cycles with the important addition that they show time series of these elements. Off-axis data also provide information on side-to-side asymmetries in accretion and tectonism, on effects imposed by changes in plate motion, and on secondary "aging processes" of the ocean crust.

Until recently very little detailed data has been acquired more than a few m.y. off the Mid-Atlantic Ridge (MAR) axis to investigate crustal structure and potential-field anomalies. The SARA (Sloan and Patriat, 1992; Rommevaux et al., 1994) and ATLANTIS surveys (Pariso et al., 1995; Sempere et al., 1995) reached ~10 m.y. off-axis, collecting multibeam bathymetry, magnetics, and gravity data on both ridge flanks but without high-resolution sidescan sonar imagery. The SEADMA survey (Gente et al., 1995) acquired multibeam and sidescan data out to 10 m.y. on both flanks of the MAR south of the Kane FZ but with wide line spacing (9-18 km) that was not ideal for resolving fine-scale crustal structure using 3-D analysis of magnetic and gravity data.

On *R/V Ewing* cruise 9606 in July-August 1996, we conducted an off-axis geophysical survey out to ~26 Ma crust on the eastern flank of the MAR near 25°-27°N (the MAREAST survey, Figure 1) (Tucholke et al., 1996; Lin et al., 1996). This survey covered crust that is conjugate to a similar, detailed survey that was completed in 1992 on the western flank of the MAR (the MARWEST survey, Figure 1) (Tucholke et al., in press). Data acquired during both the MARWEST and MAREAST surveys include Hydrosweep multibeam bathymetry, HMR1 sidescan sonar and bathymetry, magnetics, gravity, and 3.5-kHz reflection profiles. In addition, three-component magnetic data were collected during the MAREAST cruise using a shipboard magnetometer (Tanaka, et al., 1996). Together, the conjugate surveys provide a uniquely detailed and long-term record of ocean crustal structure which yields fundamental new insights into the origin, structure and evolution of slowly spreading ocean crust.

Survey lines in both the MARWEST and MAREAST surveys were run at about 50°-70° to dominant abyssal-hill fabric of the ocean crust. This approach allowed optimum insonification of primary fault structures associated with abyssal hills, while at the same time allowing acquisition of magnetic and gravity data subparallel to plate flowlines. Line spacing was about 3-5 km near the ridge axis and increased regularly in deeper water off-axis to about 8-9 km at the far limits of the surveys. This variation optimized multibeam bathymetric coverage because swath width is approximately equal to twice water depth. The surveys extended from the MAR axis about 400 km westward to magnetic anomaly 8-10r (26-29 m.y) and 350 km eastward to anomaly 8r (27 m.y.). Along-isochron coverage was 200-230 km, yielding a total study area of ~160,000 square kilometers (Figure 1).

Analysis of the combined MARWEST and MAREAST data will allow us to address a number of fundamental questions about the origin and structure of slowly spreading ocean crust:

- The nature and origin of spreading asymmetry across the rift axis, as well as the nature and origin of asymmetries in crustal structure along isochrons within individual spreading segments;
- The complete structural record and time scales of episodicity in magmatic versus amagmatic extension;
- The detailed record of North Atlantic plate-motion changes over the past ~26 m.y., together with quantitative evaluation of how the plate boundary responded structurally to those changes;
- The processes governing the evolution of non-transform offsets at segment boundaries, including a test of the propagating-rift model in slowly spreading crust; and
- The origin of highly oblique structural discontinuities that strongly disrupt the structural integrity of the crust across spreading ridge segments.

Evolution of Segments and Discontinuities

The MARWEST and MAREAST surveys covered all or part of nine spreading segments bounded by mostly non-transform, right-stepping discontinuities which are subparallel to flowlines but which migrated independently of one another. Some discontinuities alternated between small right- and left-stepping offsets or exhibited zero offset for up to 3-4 m.y. Despite these changes the spreading segments have been long-lived

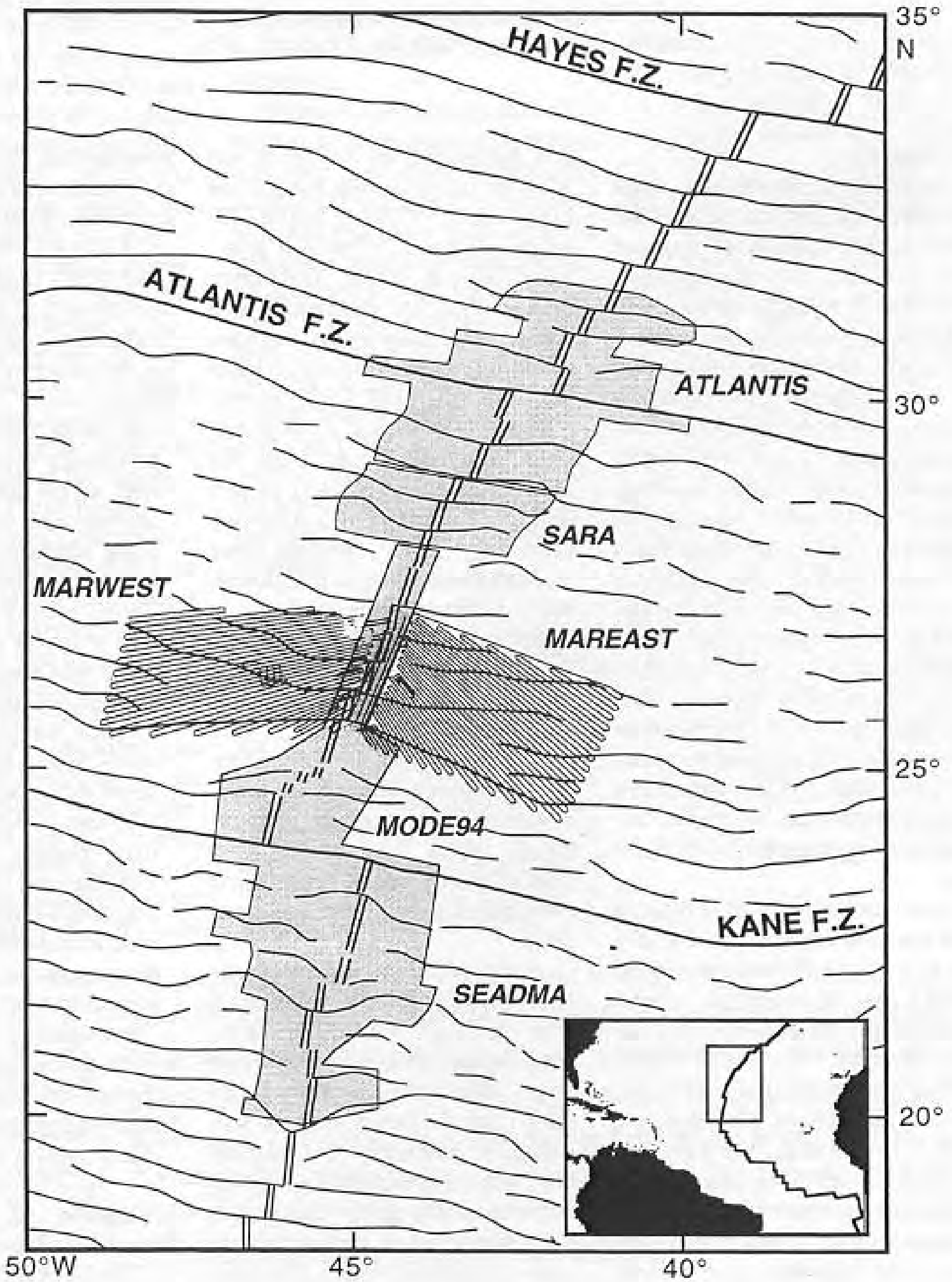

Figure 1. Ship tracks (thin lines) of the MARWEST and MAREAST surveys over zero to 26-29 Ma crust on the flanks of the Mid-Atlantic Ridge. The MAR axis (double line) and off-axis traces of transform faults (labeled) and non-transform discontinuities (light lines) are interpreted from free-air gravity field derived from Geosat and ERS-1 satellite altimetry (Smith and Sandwell, 1995). Other detailed surveys, which extend 3-10 m.y. off-axis, include ATLANTIS (Pariso et al., 1995; Sempere et al., 1995), SARA (Sloan and Patriat, 1992; Rommevaux et al., 1994), MODE94 (Fujimoto et al., 1996), and SEADMA (Gente et al., 1995).

and extend 20 m.y. or more across isochrons. A large shift (~9°) in relative plate motion about 24-22 Ma caused significant changes in segmentation pattern on both flanks. This plate-boundary response, together with the persistence of segments through periods of zero offset at their bounding discontinuities, suggest that the position and longevity of segments are controlled primarily by the subaxial position of buoyant mantle diapirs or focused zones of rising melts.

Morphology and residual mantle Bouguer gravity suggest that crustal structure on the MAR flanks is strongly modified by tectonic extension at the spreading center. Seafloor along the zero-age isochron is systematically elevated and the crust thicker near segment midpoints than at segment ends, suggesting focused magmatic accretion at segment centers (e.g., Lin et al., 1990). In contrast, seafloor older than 2-3 m.y. is usually the shallowest at inside corners, where positive residual gravity anomalies indicate tectonically thinned crust. This thinning is best explained by detachment faulting at the ridge axis.

For most ridge segments, along-isochron variations in bathymetry and residual gravity are larger than across-isochron variations. Thus segmentation exerts first-order control on the structure of slow-spreading crust. However, there is an important second-order effect that is observed across isochrons. Significant temporal variations in residual gravity occur along flowlines, and modeling suggests that this corresponds to 1-3 km variations in crustal thickness at ~2-3 m.y. intervals. Similar variations appear in the gravity field in other surveys along the MAR (ATLANTIS, SARA, SEADMA, Fig. 1). We attribute these variations to cyclic changes in melt input (e.g., magmatic versus relatively amagmatic extension) possibly caused by quasi-periodical release of accumulated melts from mantle reservoirs to the rift-axis crust.

Mullions, Megamullions, and Detachment Faulting

Within ridge segments, there are distinct differences in seafloor depth, morphology, residual gravity, and apparent crustal thickness between inside- and outside-corner crust. These differences demand fundamentally asymmetric crustal accretion and extension across the ridge-axis, which we attribute to detachment faulting near segment ends. Detachment faulting appears to be especially effective in exhuming lower crust to upper mantle at inside corners during relatively amagmatic episodes, creating crustal domes (megamullions) analogous to "turtleback" metamorphic core complexes that are formed by low-angle, detachment faulting in subareal extensional environments.

We have identified several excellent examples of megamullions in the MARWEST and MAREAST survey areas (Tucholke et al., 1996). These features are large elongate to quasi-circular domes, and are associated with strongly positive residual gravity anomalies and thus apparently very thin crust as is confirmed by dredging of gabbros and peridotites. The megamullions exhibit striking extension-parallel corrugations (mullions) (Tucholke et al., 1996; Cann et al., 1997), and they are typically 0.5-1.5 km high and 10-20 km in diameter. Their surface is a low-angle fault that dips gently both toward and away from the MAR axis, much as would be expected from development of a "rolling hinge". The low-amplitude mullions on the fault surface are sinusoidal and have amplitudes of a few tens of meters and wavelengths up to several hundred meters. High-amplitude mullions are up to several hundred meters and several kilometers in wavelength.

The observed sizes and morphology of MAR megamullions and mullions are remarkably similar to those of metamorphic core complexes developed by detachment faulting in continental extensional environments. The occurrence of these features supports the concept of detachment faulting at the ends of segments in slow-spreading crust and their extent in the dip direction indicates that the individual detachment faults are active for periods up to 1-2 m.y.

Propagating Rifts in Slow Spreading Crust

Multibeam and sidescan data also revealed obliquely oriented (~10°-40° to isochrons) structural features in both the MARWEST and MAREAST areas that offset magnetic isochrons and extend the full length of individual ridge segments. These features, which we interpret to be fast-propagating rifts, appear to have formed by tectonic extension migrating along ridge segments as the segments changed from more magmatic to less magmatic crustal accretion.

Non-transform discontinuities also appear to behave as propagating rifts on longer time scales. By combining two paradigms, the inside-versus outside-corner asymmetry and the propagating-rift model, we can predict observed geometric and structural patterns associated with migrating non-transform offsets (Kleinrock et al., 1996). Lithosphere transfer associated with rift propagation causes a significant widening of the zone of anomalously thin inside-corner crust at the inner pseudofault zone and a reduction in the width of thin inside-corner crust within the corresponding outer pseudofault. This prediction is supported by the contrasting morphological, magnetic, and gravity features on the two flanks of the MAR, and the combined paradigm provides an improved view of the four-dimensional (i.e., space and time) architecture of slow-spreading crust.

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Mid-Atlantic Ridge Bull's-Eye Experiment: A Seismic Investigation of Segment-Scale Crustal Heterogeneity at a Slow-Spreading Ridge

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Introduction

Bathymetry and gravity data from the slow spreading Mid-Atlantic Ridge suggest that large variations (ca. >2-4 km) in crustal thickness exist on the scale of an individual spreading ridge segment (e.g. Kuo and Forsyth, 1988; Lin et al., 1990; Rommevaux et al., 1994; Detrick et al., 1995). The circular gravity lows or "bull's-eyes" over many ridge segments on the Mid-Atlantic Ridge are consistent with the presence of thicker crust near the middle of these segments and thinner crust near segment offsets (Tolstoy et al., 1993). The amplitude of the gravity anomaly, and the magnitude of the inferred crustal thickness variations, appear to correlate with variations in both segment length (Lin et al., 1990) and axial morphology (Sempere et al., 1993; Thibaud et al., 1997). Long ridge segments are typically associated with large mantle Bouguer gravity lows, and have shallow, hourglass shaped rift valleys that widen and deepen toward the ends of the segment. Shorter ridge segments, in contrast, are often characterized by smaller gravity lows, and have deeper rift valleys with less variation in rift valley relief along-axis. Near many ridge-axis discontinuities there is a clear asymmetry in sea floor depth and structure across the rift valley. "Inside-corner" crust, adjacent to a transform or non-transform offset (NTO), typically is shallower, and has a more positive mantle Bouguer gravity anomaly than "outside-corner" crust suggesting a significant differences in crustal thickness across the rift valley (Escartin and Lin, 1995; Wolfe et al., 1995).

In an effort to better constrain the three-dimensional crustal heterogeneity at slow spreading ridges, we recently carried out a major seismic refraction experiment along a portion of the Mid-Atlantic Ridge lying between the Hayes and Oceanographer transforms southwest of the Azores (Figure 1). Funded by the U.S. RIDGE Program as part of the FARA project, the Bull's-eye Seismic Experiment is the first major controlled source seismic refraction experiment along this portion of the northern Mid-Atlantic Ridge in over 15 years. A five-day pilot multichannel seismic reflection survey was also conducted in this area as part of our experiment in order to image the velocity structure of the shallowmost crust, and to evaluate the effectiveness of new processing methods for suppressing scattered energy in seismic profiles collected in the rugged topography found at the Mid-Atlantic Ridge.

The Oceanographer-Hayes area was chosen for this experiment because the three ridge segments lying between these two large-offset transforms display contrasting morphologies and gravity signatures (Detrick et al., 1995). The northernmost segment, OH-1, lying immediately south of the Oceanographer transform is ~90 km long and is associated with one of the largest mantle Bouguer anomalies of any segment along the Mid-Atlantic Ridge between 40°N and 15°N. The rift valley is

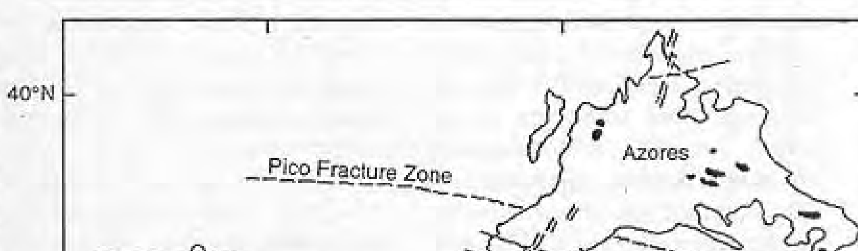

Figure 1. General location of the Hayes-to-Oceanographer section of the Mid-Atlantic Ridge where the Bull's-eye Seismic Experiment was carried out by the *R/V Maurice Ewing* in October/November 1996.

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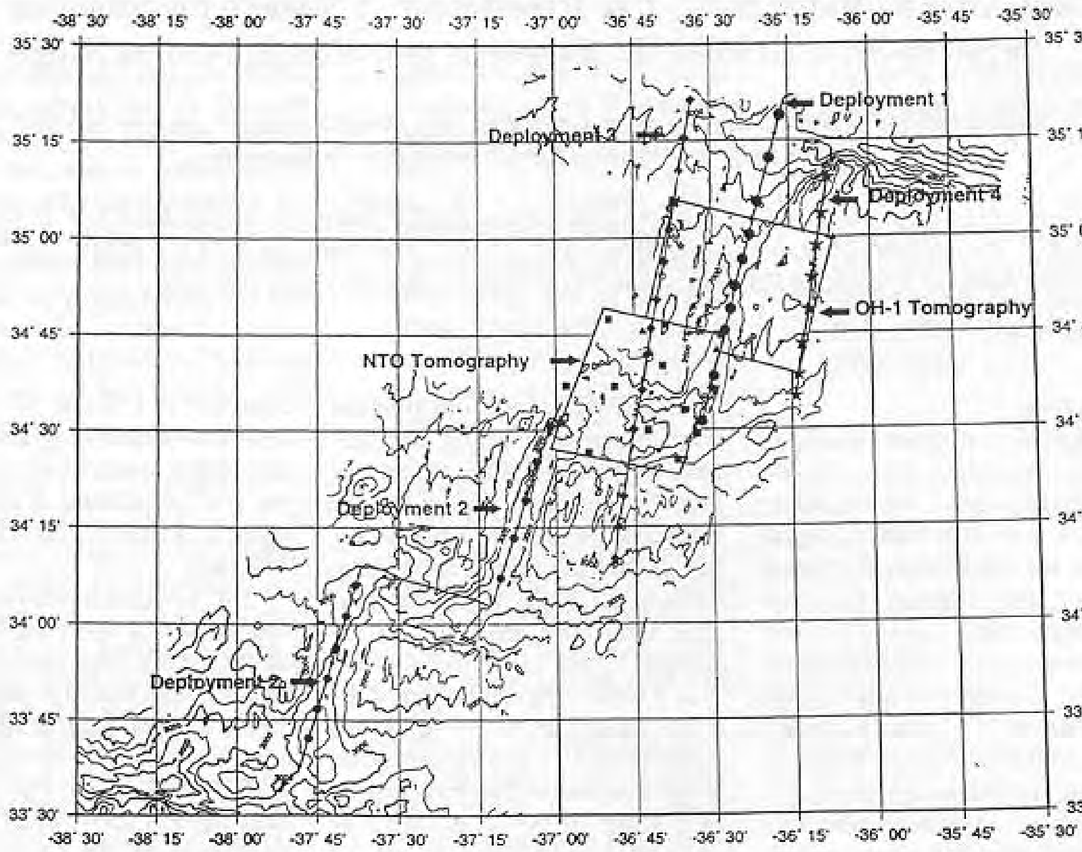

Figure 2. Simplified bathymetry map of the Mid-Atlantic Ridge between the Oceanographer and Hayes transforms showing the location of the seismic refraction experiments carried out as part of the Bull's-eye Experiment. The bathymetry data are from the FARA-SIGMA cruise of the *R/V l'Atalante* (Needham et al., 1991) and are contoured at 500 m.

quite narrow and shallow near the middle of segment OH-1 and widens and deepens significantly toward the Oceanographer transform to the north. An earlier microseismicity experiment in this area found a small, shallow crustal low velocity zone beneath the central portion of the axial valley (Barclay et al., 1996). Segments OH-2 and OH-3, to the south, are shorter, have deep, U-shaped axial valleys, and much smaller associated gravity lows. Extensive exposures of serpentinized peridotites have been mapped within the non-transform offset separating segment OH-2 and OH-3 suggesting the presence of anomalously thin crust (Bideau et al., 1996).

The Experiment

The Bull's-eye Seismic Experiment was carried out on *Maurice Ewing* leg EW96-08 in October/November of 1996. We used the *Ewing's* powerful 20-gun, 139-liter (8495 cu. in.) airgun array as the source for the seismic refraction work. Shots were fired at either a 90 s or 120 s shot interval, yielding a shot spacing of 200-275 m. The seismic refraction data were recorded by 10 Woods Hole Oceanographic Institution ocean bottom hydrophone (OBH) instruments, supplemented by three new hydrophone instruments, currently under development at WHOI. These new instruments, called ORBs (for Ocean Reftek in Ball), use a Reftek 72A-07 data logger mounted in a 17O glass sphere. A total of 74 separate OBH/ORB deployments and recoveries were carried out during the course of the experiment. Data recovery rates were over 97%.

Six seismic refraction and tomography experiments were completed using between 8 and 13 instruments on each deployment (Figure 2). The first four experiments were conventional refraction lines. On the first two deployments refraction lines were shot along the rift valleys of segments OH-1, OH-2 and OH-3. The purpose of these profiles was to determine how variations in crustal thickness and velocity structure are related to the contrasting morphologies and gravity anomalies of these segments. Deployment 3 was a ~140 km long axis-parallel line shot in the western rift mountains of segment OH-1, across the non-transform offset separating segments OH-1 and OH-2, and along the eastern rift mountains of segment OH-2 (Figure 2). On deployment 4 a shorter refraction line was shot in the eastern rift mountains of segment OH-1. The main goal of these lines was to determine how the structure of crust formed within the rift valleys of segments is

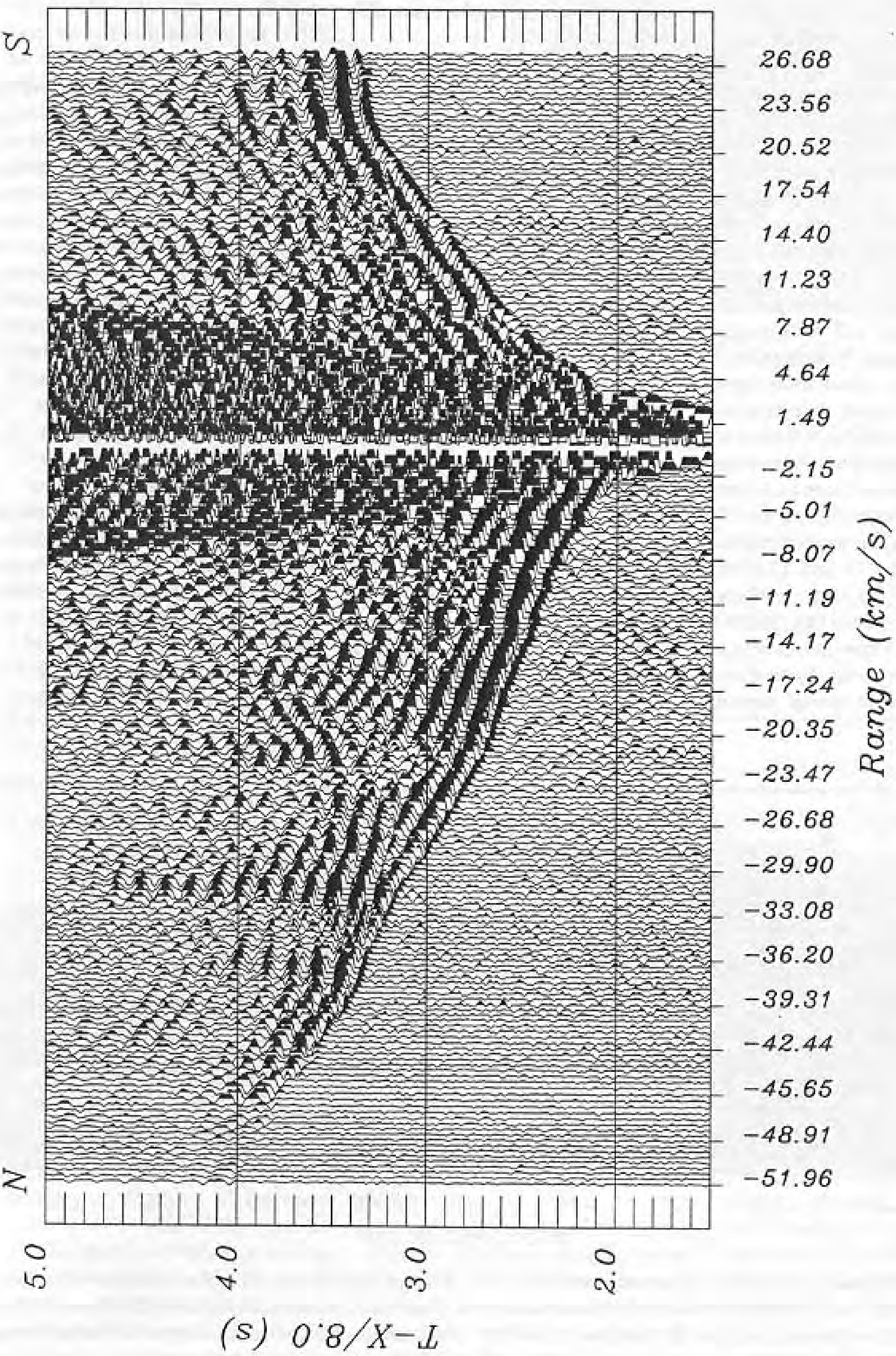

Figure 3. Record section for OBH 25 from deployment 1 along the rift valley of segment OH-1 south of the Oceanographer transform. This instrument was located about 10 km south of the midpoint of the segment. The record section is plotted with a reduction velocity of 8 km/s; negative ranges are for shots north of the receiver. Clear crustal refracted arrivals are observed out to ~45 km range.

modified by tectonic processes as it is uplifted out of the rift valley. In particular, we wished to contrast the structure of "outside-corner" crust with "inside-corner" crust in the rift mountains flanking segment OH-1. For both deployments 3 and 4 shots were also fired along parallel lines in the opposing rift mountains of segment OH-1 in order to record Pn arrivals that undershoot the ridge axis. These Pn arrivals will be used to constrain anisotropy in the uppermost mantle beneath the rift valley.

The final two deployments of the Bull's-eye Experiment were designed specifically for 3-D tomographic imaging of crustal heterogeneity in the axial region. One of these experiments was centered near the midpoint of segment OH-1, the other was located over the inside-corner high and NTO at the southern end of segment OH-1 (Figure 2). Over 2000 shots were fired for each experiment and recorded by 11 and 13 instruments, respectively. Instrument spacing in each 40x40 km area was 5-15 km. These two experiments will provide a picture of the three-dimensional variation in crustal structure over the middle and southern portion of segment OH-1, beneath the inside-corner high at the southern end of segment OH-1, and along the NTO separating segments OH-1 and OH-2.

Midway through the seismic refraction and tomography work, a pilot multichannel seismic (MCS) reflection experiment was undertaken to test the effectiveness of a dip-moveout (DMO) based scheme for removal of 3-D scattering of seismic energy from the rugged Mid-Atlantic Ridge topography (Kent et al., 1996). A second goal of this pilot study was to use the 4-km aperture (160 groups, 25-m spacing) of the *Ewing's* MCS streamer to constrain the thickness and velocity structure of seismic layer 2A in several different locations including the rift mountains of segment OH-1 and in the rift valley near the center of this segment. The MCS data were acquired using a 10-gun, 49-liter (3005 cu. in.) array. The guns were floated at ~10 m depth to permit very slow towing speeds (3.5-4 kts) which allowed a dense shot spacing of ~25 m. MCS profiles were shot along the rift valleys of segments OH-1, OH-2 and OH-3, in the rift mountains of segments OH-1 and OH-2, and on a profile across the rift valley near the midpoint of segment OH-1.

Preliminary Results

A record section from the refraction line (deployment 1) shot along the rift valley of segment OH-1 is shown in Figure 3. This instrument was located about 10 km south of the midpoint of segment OH-1. Crustal arrivals are recorded from shots along the entire length of the segment, and out to ~45 km range along the northern rift valley toward the Oceanographer transform. Clear Pn arrivals are not observed on this record section, but a possible PmP phase may be present as a second arrival between 17 and 40 km range.

Travel-times of first arrivals on this instrument, and nine others deployed on this line, were picked at sea using an automatic picking algorithm which uses an autoregressive method to identify the onset of arrivals on a single trace (Toomey et al., 1994). A total of 1,622 Pg travel times from 547 shots were used to construct a

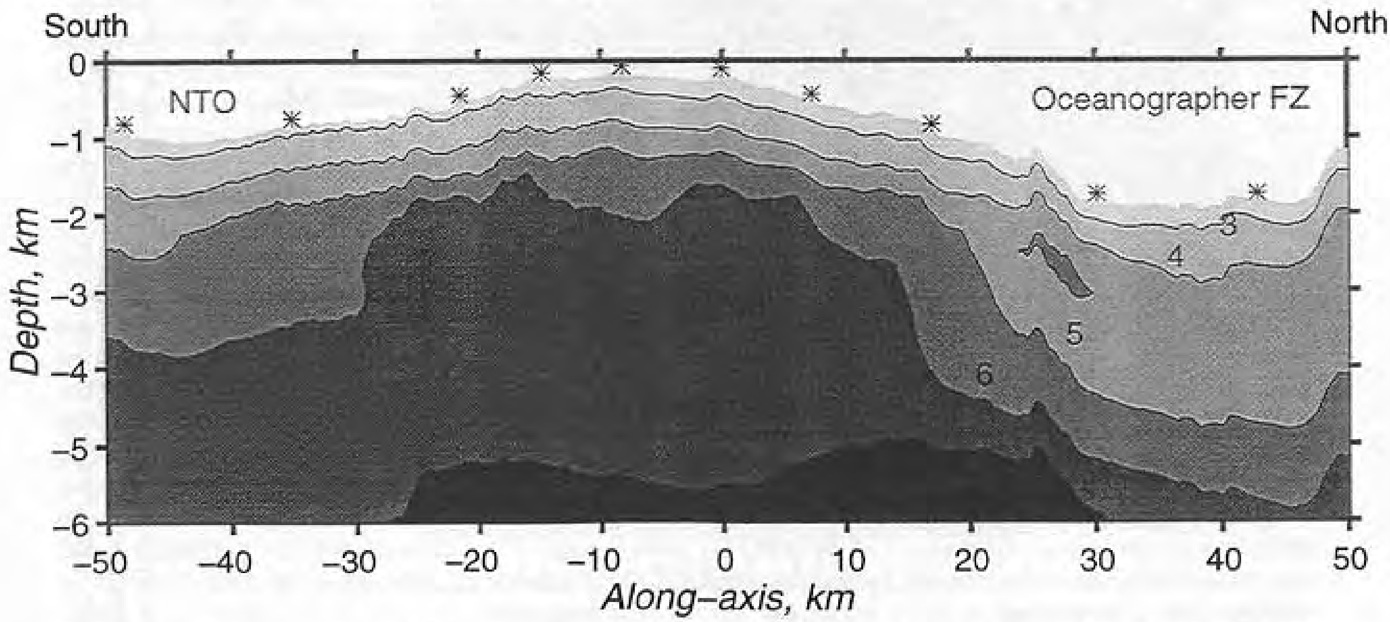

Figure 4. Preliminary tomographic image, constructed at sea, of the crustal velocity structure along the rift valley of segment OH-1. P-wave velocity is contoured at 1 km/s. Position of the 10 ocean bottom hydrophone receivers is shown by the asterisks. This segment is offset on the north (right) by the Oceanographer transform and on the south (left) by a smaller, non-transform offset (NTO). Note that at 2-3 km depth p-wave velocities are significantly lower near the ends of segment OH-1 than near the segment mid-point.

preliminary 2-D tomographic model of the OH-1 rift valley using the method of Toomey et al. (1994). The starting velocity model for this inversion was the one-dimensional velocity model of Purdy and Detrick (1986) derived for the MARK area on the Mid-Atlantic Ridge. This one-dimensional velocity model was hung from the sea floor, producing a two-dimensional model with isovelocity contours conformable to the bathymetry along this line. The velocity model had nodes spaced at 200 m in the along-axis and depth directions. Sea floor topography, which varies by nearly 2 km along the length of the rift valley, was explicitly included in the model parameterization. For the inverse problem, perturbational nodes were spaced at intervals of 2 km along-axis and 200 m in depth.

A preliminary tomographic image for segment OH-1, obtained at sea, is shown in Figure 4. It reveals considerable crustal heterogeneity along the rift valley. Near the segment center velocities at depths of 2-3 km below the sea floor are higher (6-6.75 km/s) than at similar depths near the ends of the segment (4-5 km/s). The crustal velocities near the center of segment OH-1 are, on average, higher than reported for the MARK area by Purdy and Detrick. The anomalously low, upper crustal velocities are not confined to the ends of segment OH-1, but extend up to 20 km along the rift valley from each segment offset. The magnitude of this velocity anomaly is larger near the large-offset Oceanographer transform at the northern end of segment OH-1 than at the small NTO at the southern end of the segment. This segment-scale variation in upper crustal structure may be the result of enhanced intrusive activity near the center of the segment and greater faulting or alteration of the upper crust near the ends of the segment. The along-axis variation in average crustal density implied by these variations in crustal velocity will result in an underestimation of the total variation in crustal thickness using conventional mantle Bouguer anomaly

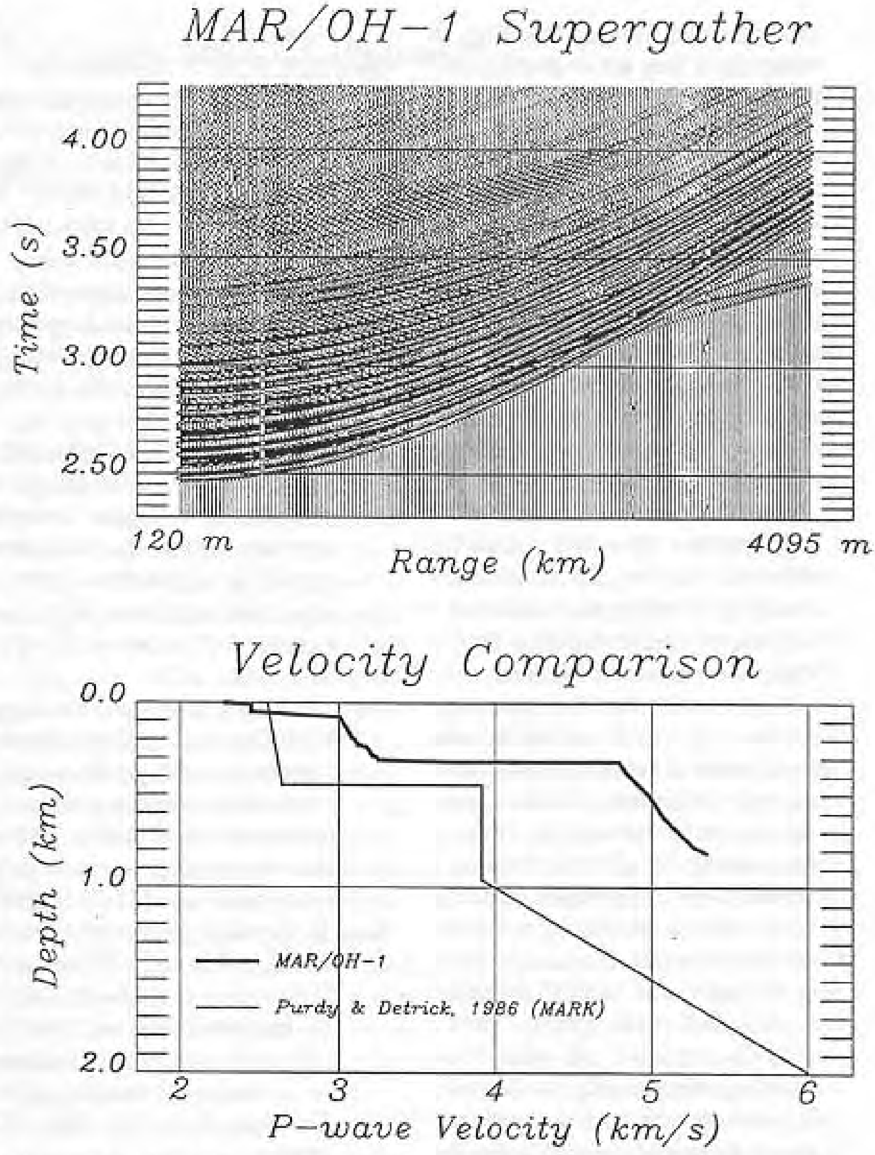

Figure 5. (Top) Stacked CMP gather from the western rift mountains of segment OH-1 on ~2 Ma old crust. A layer 2B refraction can be observed emerging from the sea floor reflection at ~2.9 km range. (Bottom) A preliminary upper crustal velocity model for the OH-1 western rift mountains based on a genetic algorithm waveform inversion (Hussenoeder et al., 1996). Shown for comparison is an upper crustal velocity model for the MARK rift valley (Purdy and Detrick, 1986).

interpretations which assume a constant density crust. A similar observation was made by Tolstoy et al. (1993) on the southern Mid-Atlantic Ridge.

A notable feature of the multichannel reflection data collected during the Bull's-eye Experiment is the lack of a continuous Moho reflection. Even on lines shot along the crest of the rift mountains where topography and scattering is minimal (even in comparison with the East Pacific Rise), the Moho is not a continuous feature but is patchy in appearance. A few high-amplitude mid-crustal "reflectors" with a lateral extent of only a few kilometers were observed on the rift valley reflection profiles. Many fault-like dipping reflectors were also imaged in the reflection data. These events are being carefully examined using both a DMO-based noise suppression technique and forward modeling to determine if they are scattering artifacts or are real.

Refractions from the layer 2A/2B boundary were observed in common midpoint (CMP) gathers on multichannel reflection profiles located in the rift mountains and in the central portion of the rift valley of segment OH-1 where the sea floor shoals to ~2200 m. An example of a CMP "supergather", constructed by stacking several adjacent gathers to enhance signal-to-noise, is shown in Figure 5. This profile is from ~2 Ma crust in the rift mountains west of the segment OH-1 rift valley. A layer 2B refraction can be clearly observed emerging from the water wave at 3 km range. Unlike the East Pacific Rise, where the layer 2A refractions exhibit a "reflection-like" character, the layer 2A refraction can be seen both behind and in front of the waterwave. A preliminary velocity inversion for this supergather (Fig. 5; Hussenoeder et al., 1996) shows a thinner layer 2 and higher velocities in the uppermost crust at this 2 Ma old rift mountain site than on "zero-age" crust in the MARK rift valley (Purdy and Detrick, 1986).

Taken together, the seismic refraction, tomography, and multichannel seismic reflection data collected as part of the Bull's-eye Experiment will be well-suited to address a number of fundamental questions regarding the crustal structure and tectonics of the Mid-Atlantic Ridge.

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Update on the MELT Experiment

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The MELT (Mantle ELectromagnetics and Tomography) Experiment is designed to provide direct observational constraints on the distribution of melt and the pattern of upwelling beneath a mid-ocean ridge spreading center. Phase I of the experiment began in October and November of 1995, when the *R/V Melville* deployed 51 ocean-bottom seismometers (OBSs) in an array south of the Garrett Fracture Zone on the southern East Pacific Rise. 37 of the OBSs were deployed in an 800 km long line crossing the ridge at about 17° 15' S, approximately the center of a long, straight section of the ridge. Ten additional instruments were placed in a parallel line about 150 km to the north, crossing the ridge near a small offset in the axis where upwelling and melt production may be less active. Five other instruments were deployed along the ridge axis to detect changes in structure along the strike of the ridge. The OBSs were each equipped with seismometers and hydrophones to record seismic signals from distant earthquakes.

Phase I was completed and Phase II begun during the cruise of the *R/V Thompson* in May and June, 1996. 48 of the 51 seismometers were successfully recovered and 47 seafloor magnetometers and electrometers were deployed to begin the recording of natural variations in the geoelectric and geomagnetic fields. Two additional seismometers were recovered in September, 1996 using a deep-towed vehicle. The electromagnetic instruments will be recovered in July, 1997. This data will be used to compute the magnetotelluric response tensor as a function of location and frequency, which can then be interpreted in terms of the electrical conductivity structure to depths of a few hundred km and to distances comparable to the extent of the EM array (200-300 km). Electrical conductivity is an extremely sensitive indicator of the extent and connectivity of partial melt, among other physical variables. The combination of EM and seismic data is expected to prove much more powerful than either type taken alone for studies of the ridge magma source region.

Preliminary results of the seismic component experiment were reported in a special session at the Fall AGU Meeting in San Francisco in December. There was an excellent set of large, globally-distributed earthquakes that occured during the recording period from November to the end of May and acted as teleseismic sources to probe beneath the ridge. In addition to three shallow earthquakes with moment magnitude of 7.8 or larger, there were two large events that were located directly in line with the array: to the east, a magnitude 7.3 earthquake off the coast of Peru; and, to the west, a magnitude 7.1, intermediate-depth event in the southern Tonga subduction zone. These events were well-recorded by many of the instruments. Preliminary analysis indicates that seismic anisotropy associated with mantle flow may dominate the seismic anomalies generated beneath the ridge. Shear-wave splitting of up to two seconds is observed, there are azimuthal variations in Rayleigh wave phase velocities of several percent, and the pattern of body wave residuals seems to be best explained by alignment of olivine crystals in the upwelling flow beneath the axis. A set of papers reporting the initial results is planned for publication in Science in summer 1997.

Geological and Geophysical Exploration along Carlsberg Ridge

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The Carlsberg Ridg is a slow-spreading ridge, similar to the Mid Atlantic Ridge, which forms the northern part of the Indian Ridge system. In June-July 1996 it was surveyed for the first time with a state-of-the-art multibeam bathymetric system and the topographic features of this slow-spreading ridge segment were obtained. We used the oceanographic ship *ORV Sagar Kanya* fitted with Hydrosweep, a multibeam bathymetric system (MBS) along with other geophysical equipment such as a magnetometer and a gravimeter.

We surveyed a small area of about 15,000 km² out to the 2A magnetic anomaly with closely gridded survey lines to get one hundred percent coverage by the multibeam system. A total of seventeen survey lines with a spacing of 5.5 km were made during the survey. The multibeam data shows a ridge axial discontinuity (RAD) or a non-transform discontinuity (NTD). The general observation of the data shows a broad axial valley with depth varying from 4500 to 2200 m. The sections across ridge axis shows a uniform spreading along this section of the Carlsberg ridge. Figure 1 shows the location and generalized depth contour map of the survey area. The back scatter amplitude data from MBS was processed to generate pseudo side-scan images, from which it was determined that the rift valley is sedimented.

Rock sampling brought up altered ultramafic rocks such as serpentinites, lherzolites and gabbros. The lherzolites have large phenocrysts (4-5 mm) of clinopyroxenes and bastite, indicating the rocks have undergone hydration alteration. The bastites display a typical bronze-like luster, even macroscopically. Short spade cores for sediments were also collected from the axial valley and from the flanks of the ridge from a depth of about 4500 m.

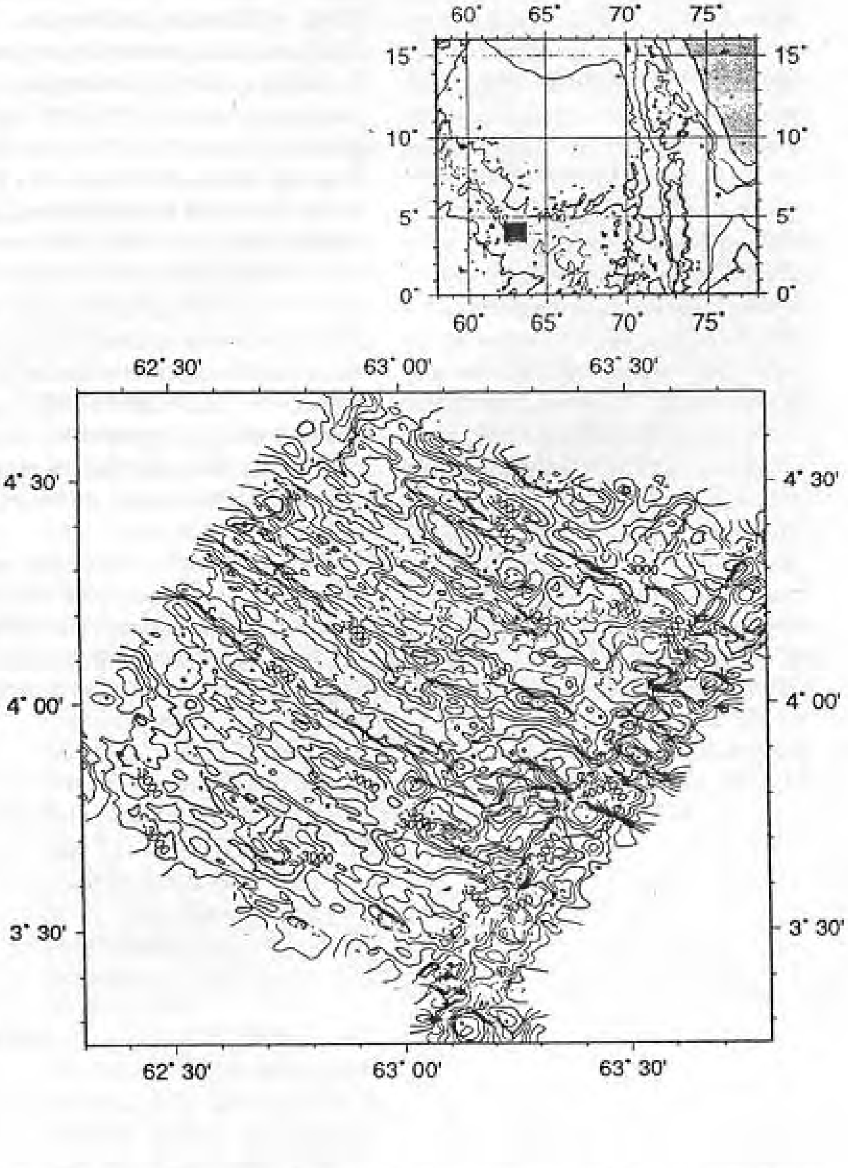

Figure 1. (top) The general location of the survey area, indicated by the black box, and (bottom) a generalized depth contour map (contour interval is 200 m) of the region surveyed by the *ORV Sagar Kanya*.

Hydrothermal Activity and Rift-induced Tracers at Axial (Juan de Fuca Ridge): Results of Cruise SO-109 of *R/V SONNE* -ROPOS

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Introduction

Axial Volcano is the dominant volcanic feature on the Juan de Fuca Ridge and host to several important active hydrothermal fields (CASM and ASHES areas). The volcano is located 250 nm from the Oregon coast (Fig. 1), at a water depth of 1500 m, and is easily accessible to manned and remotely-operated submersibles. The summit and the caldera of Axial Seamount (Fig. 2) have been the focus of intensive US-Canadian research following a series of undersea volcanic eruptions creating megaplumes between 1986 and 1993. Continuous monitoring of earthquakes suggests that Axial Seamount is still active. Recent eruptions north of Axial, as well as ongoing high-temperature hydrothermal venting, have made this site an important long-term observatory for investigations of volcanic-hydrothermal processes, boiling hydrothermal systems, and metal inputs into the oceans. Because of its well-characterized biological communities, Axial Volcano is also considered to be unique for the study and long-term monitoring of faunal successions and their response to changing hydrothermal activity.

Cruise SO-109 of *R/V SONNE* (May 24-July 8, 1996) was designed to characterize the detailed relationships between recent volcanic and tectonic events and hydrothermal fluxes in the vicinity of Axial Volcano for comparison with other sources of trace elements within the Juan de Fuca Plate (e.g. Cascadia Margin). This collaborative German-Canadian-US project led to the first deployment and testing of Canada's deep submergence vehicle ROPOS (Remotely Operated Platform for Ocean Sciences) from *R/V SONNE* (Fig. 3).

Results

A mapping program using *SONNE's* Hydrosweep system and Differential GPS (DGPS) was carried out to survey the area of Axial Volcano including the North and South Rift Zones. A total of 53 Hydrosweep profiles was compiled to generate a bathymetric map encompassing the CASM and ASHES Fields, the South Rift Zone (5 m contour interval), and the North Rift Zone (5 m contour interval). The new bathymetric data provide an important baseline for ongoing monitoring of volcanic and tecontic activity at Axial and complement existing Sea Beam bathymetric maps of the neovolcanic zone completed by NOAA in 1991. The Hydrosweep maps were published jointly by the principal investigators as an Open File Report of the Geological Survey of Canada in August 1996.

Sediment sampling by box cores in the bathymetric basins NW and SE of Axial Seamount, as well as in the Helium Basin to the NE, was carried out in order to determine the extent of hydrothermal signatures recorded in distal sediments. The box cores in the Helium Basin recovered two distinct layers of volcanic ash (about 2-3 cm and > 90 cm thick), separated by a thin layer of pelagic sediment and topped by 5 cm of pelagic ooze. Radiometric dating of those layers will help to unravel the depositional history at this site.

A CTD with 12 Niskin water samplers (10 l) was used to map the hydrothermal plume above Axial Volcano in three dimensions. A total of 18 CTD stations was carried out both inside and outside the caldera. Two CTD stations close to the ASHES Vent Field were transponder-navigated and sampled the near-field fluids. Shipboard methane analyses have shown values up to 680 nl/l CH_4, potential temperature anomalies up to 0.4°C, and distinct anomalies in light transmission, all about 10 to 20 m above bottom.

Thermophile (>55°C) and hyperthermophile (>90°C) micro-organisms were cultivated onboard from vent plume samples collected with the CTD/rosette system, marking the first time that the presence of thermophile and hyperthermophile bacteria has been demonstrated in a hydrothermal plume. Similar bacteria were also cultured from samples of sphalerite and barite and in samples of gut from Paralvinellid worms collected with the TV-grab from active chimneys in the caldera. DNA analyses and epifluoreszence microscopy will further characterize these bacteria which are of potential interest to industry.

North Rift Zone

The North Rift Zone of Axial Seamount was investigated with the EXPLOS TV/camera sled system using the transponder net deployed for ROPOS diving. A zig-zag tow indicated abundant fissure- and fracture-controlled diffuse hydrothermal activity, marked by the presence of bacterial mats and hydrothermal fauna. Deployments of the TV-controlled grab sampled a young lava flow observed during the camera runs and recovered a large pillow, partly covered with fresh glass. In an attempt to measure horizontal extensions of the seafloor related to dike intrusions, five acoustic extensometer instruments were deployed in a line across the North Rift Zone at 100-200 m spacings. These instruments are calibrated to measure baseline distances up to about 1 km with an accuracy of about 1 mm. The battery powered instruments can make one measurement per day for a year. The data are stored in a data unit which will be recovered together with the instruments in summer 1997.

South Rift Zone

Deployments of the EXPLOS system in the South Rift Zone mapped additional areas of hydrothermal activity. NOAA's chemical scanner SUAVE (Submersible System Used to Assess Vented Emissions) was fitted at sea for use on the EXPLOS frame and has measured temporally coherent anomalies in temperature, light scattering, dissolved Mn, and H_2S. For each parameter measured, isolated anomalies were found. The scanner was run in an unattended monitoring mode at low sensitivity with detection limits of 20 nmol/l Mn, 35 nmol/l Fe and 40 nmol/l H_2S. The thermochemical anomalies (Mn/heat(=Q), Fe/Q and H_2S/Q) at the South Rift Zone are characteristic of diffuse fluid venting.

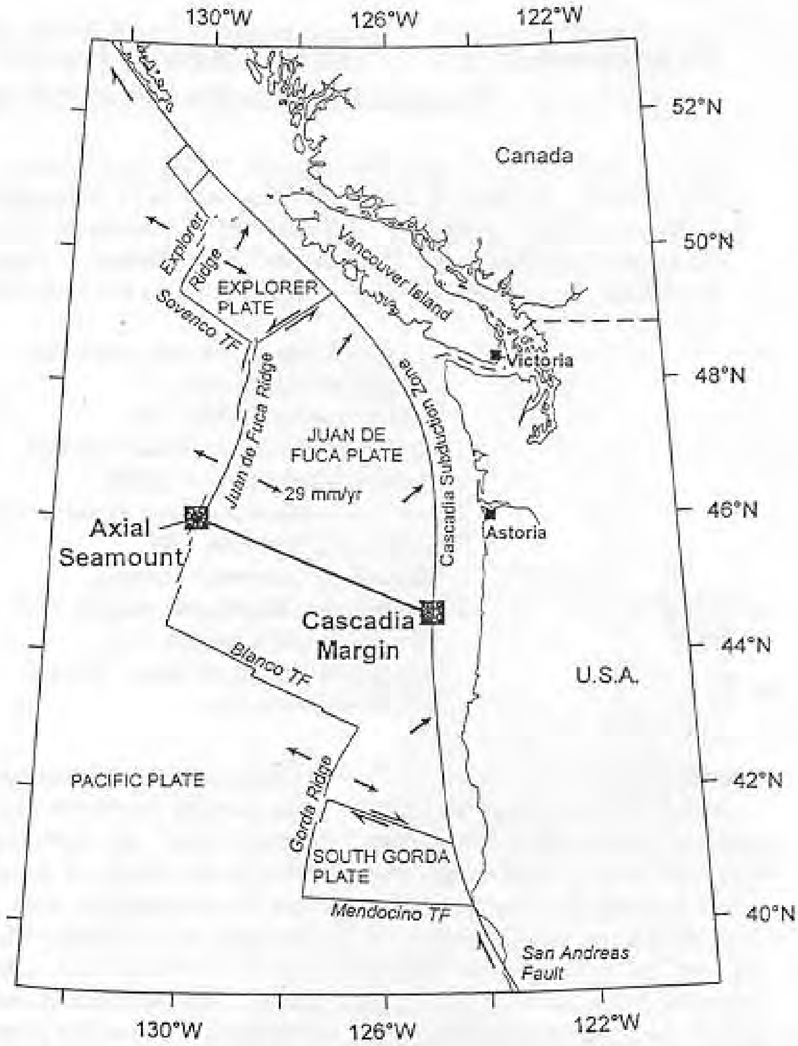

Figure. 1: Location of Axial seamount at the Juan de Fuca Ridge and the Cascadia Margin off the Oregon coast. The study of cold seeps at the Cascadia Margin and the investigation of the tracer distribution along a transect between Axial Seamount (hot vent source) and the Cascadia Margin (cold vent source) were an important part of the scientific objectives of cruise SO-109 and followed up in detail during cruise SO-110 (Principal Investigator: Erwin Suess, GEOMAR Kiel).

CASM Hydrothermal Field

The CASM Hydrothermal Field in the northern part of the Axial Seamount caldera was sampled extensively with the TV-grab. These deployments recovered basaltic material with some Fe-staining and pyrite as well as pyrrhotite occurring in vesicles as well as basaltic sheet flows with distinct sulfide mineralization, anhydrite in cavities, and abundant vent fauna. The occurrence of sphalerite and chalcopyrite on the underside of broken sheet flows, and the fact that tube worms observed during sampling were growing from the surface down into lava cavities and collapse pits, indicates hydrothermal fluid flow beneath the lava surface. The presence of chalcopyrite in the mineral assemblage points to fluid temperatures of more than 300°C. Fluid inclusion analyses of coexisting anhydrite will constrain the fluid temperatures. Compared to earlier observations by PISCES IV and ALVIN, the main eruptive fissure at CASM appears to have been hydrothermally reactivated after a period of relative quiescence. Further deployments of the TV-grab at CASM recovered massive barite with some associated sulfides, abundant vent fauna, and weakly altered basalt. The barite is part of the CASM chimneys which were located with the TV-grab during several crossings of the main fissure zone.

ASHES Vent Field

Reactivation of hydrothermal activity was also observed in the ASHES Vent Field. In 1986, ALVIN temperature measurements indicated that the Inferno chimneys were venting at about 330°C. Repeat measurements in 1995 showed that the fluid temperatures had increased by about 20° to 348°C. At a water depth of about 1500 m (equal to 150 bars or 15MPa), these fluids cross the two-phase boundary of seawater and start to boil, as observed at Inferno during ALVIN diving. Sampling with *SONNE's* TV-grab in the vicinity of Virgin Mound recovered massive sulfides consisting of pyrite, marcasite, sphalerite and chalcopyrite, together with abundant tube worms, sulfide worms and other vent fauna. Some of the samples represent small sulfide mounds of about 50 cm in diameter and 30 cm in height showing distinct high-temperature fluid channels lined with chalcopyrite. This hydrothermal area was not known previously and probably represents a new vent that has grown during the recent thermal intensification of the field. A camera tow just east of the chimney field revealed new areas of venting, extensively covered by white bacterial mats with abundant tube worms and spider crabs indicative of diffuse hydrothermal flow. Several small active vents were photographed.

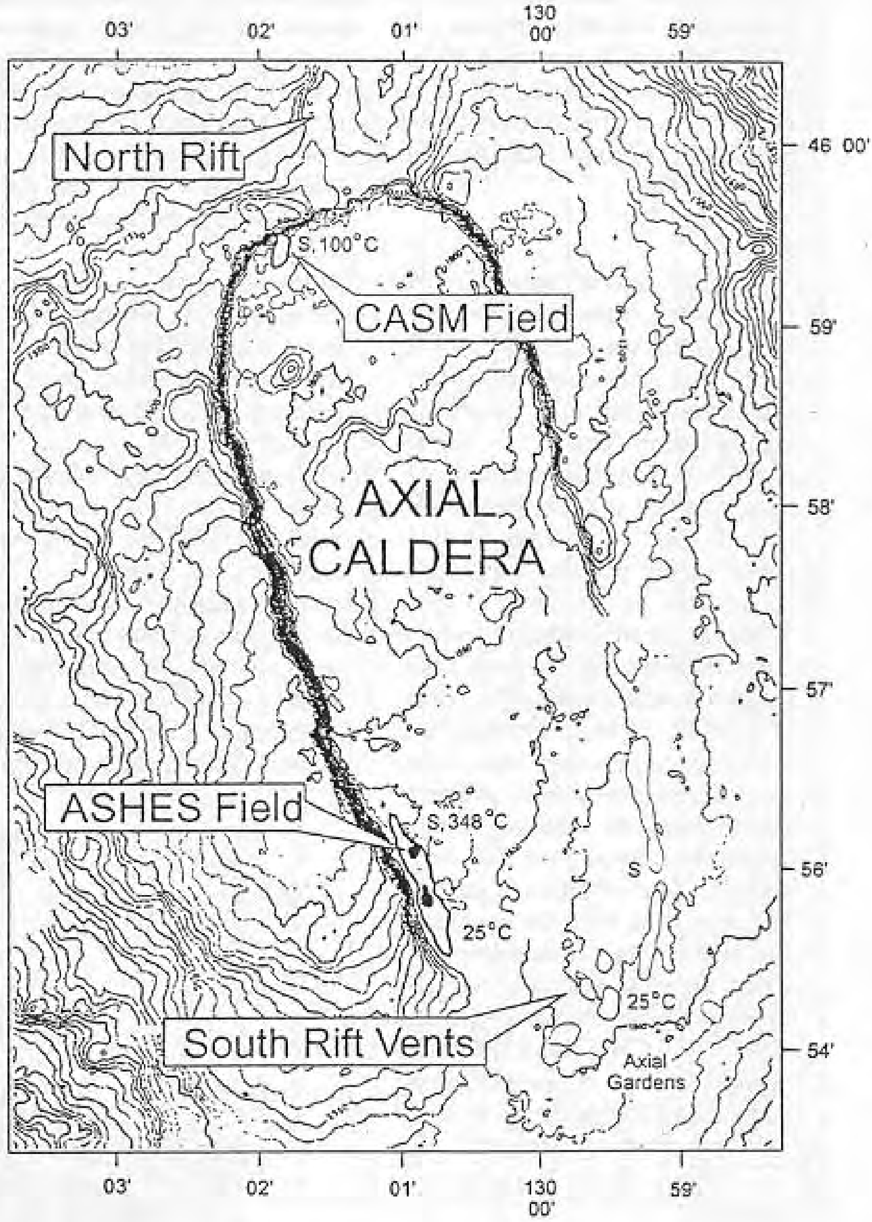

Figure. 2: Bathymetric map of Axial Caldera showing the location of the main vent fields.

CoAxial Segment

The CoAxial Segment, which was the site of a major eruption just north of Axial in 1993, was surveyed using EXPLOS and SUAVE. A traverse along the main eruptive fissure up to the HDV (High Diffuse Venting) site indicated several areas of diffuse hydrothermal fluid flow and associated biological activity. Both vent specific fauna and bacterial mats were found, but their extent appears to have diminished dramatically since 1993, owing to the cooling of the lava flows and the collapse of low-temperature circulation. During one survey, the SUAVE system detected 6-8 distinct thermal and chemical anomalies, although no visible indications of active venting were observed during this tow. The H_2S/Q value determined by SUAVE for CoAxial (5.3 nmol/J) is similar to the value measured in 1995 (3.8 nmol/J) but much lower than the pulse of high H_2S/Q (32 nmol/J) that immediately followed the dike intrusion associated with the 1993 eruption.

ROPOS

During Leg 3 of cruise SO-109, the Canadian remotely operated vehicle ROPOS was successfully used to collect a unique suite of sulfide-sulfate precipitates from the actively boiling Inferno Vent in the ASHES Vent Field of Axial Seamount. Although boiling of hydrothermal fluids is an important metal-depositioning process, it is poorly documented, and is known to occur at only a few sites along the world-ocean ridge system. Using the high-resolution camera system (BetaCam) of ROPOS, the boiling process and the sampling procedure were documented in particular detail. A clearly visible flame-like halo surrounding the top of Inferno Vent was interpreted as light reflection of gas bubbles separating from the liquid during boiling. This centimeter-scale observation and sampling can only be achieved with a remotely-operated system and ROPOS remarkably demonstrated that it is one of the best deep-diving ROVs currently available for deep-ocean research.*

Summary

Axial Volcano is a complex magmatic system which also affects ridge-crest tectonism and hydrothermal activity north and south of the volcanic center, and these areas were targeted for additional investigation. In addition to mapping and sampling in the caldera, the near and far field element dispersion from high- and low-temperature sources was examined in order to document the temporal and spatial variations in the physical and chemical characteristics of the water column above the volcano. Monitoring of the state of the volcano and the present hydrothermal fluxes was accomplished by

(i) detailed mapping and sampling of the ASHES and CASM hydrothermal vent fields in the caldera,
(ii) recovery of samples from the actively boiling Inferno Vent using ROPOS,
(iii) investigations of several sites of recent eruptions and ongoing seismic activity in the North and South Rift Zones (including areas with events recorded between April and June of 1996),
(iv) detailed sampling of flows from recent volcanic eruptions in the caldera (CASM) and in the North and South Rift Zones,
(v) monitoring of hydrothermal activity associated with volcanic eruptions and dike intrusions recorded in 1993 on the CoAxial Segment,
(vi) extensive (total of 18) hydrocast surveys of the caldera and adjacent rift zones, including navigated-CTDs over the active vent sites,
(vii) sediment sampling in nearby basins, and
(viii) placement of a long-term monitoring device (NOAA extensometer array) to measure ongoing extension in the North Rift Zone.

Acknowledgements

Principal funding for this research was provided by the German Federal Ministry for Education, Science, Research and Technology (BMBF Grant 03G0109A). Additional support was provided by the Geological Survey of Canada, Ottawa, and the Institute of Ocean Sciences, Sidney/Vancouver Island, Canada. We thank Master H. Papenhagen, the officers and crew of the *R/V SONNE*, and the ROPOS pilot team for their enthusiasm and expert technical assistance during cruise SO-109.

Figure 3. First deployment of the Canadian remotely-operated vehicle ROPOS from *R/V SONNE* in the port of Victoria/Vancouver Island the summer of 1996.

*Editor's Note: ROPOS was lost during a recovery in rough weather in Oct. 1996. However, construction has begun on ROPOS II which will have all the capabilities of the original ROPOS. For more details, see page 45.

World Ridge Cruise Schedule 1996-1998* *(1996 in white, 1997 and 1998 in gray)*

Country	PI	Institution	Name/Location	Research Objectives	Ship	Dates
Australia/ Canada	Binns/ Scott	CSIRO Australia/ Univ. of Toronto	PACMANUS-III: Eastern Manus Basin, Yuam Ridge Hydrothermal Field	Hydrothermal field study: CTD-transmissometer, dredge, corer, video	Franklin FR09/96	Nov-Dec '96
Australia/ Canada	Binns/Davis/ Scott	CSIRO Australia/ Geol. Survey Can./ Univ. of Toronto	PACMANUS IV: Eastern Manus Basin, Bismark Sea, Papua New Guinea	Core drilling to 100m at PACMANUS hydrothermal field with PROD seafloor drill	Franklin FR09/97	Oct-Nov '97
Canada/ USA	Thomson/ Cowen/ Lavelle	Inst. Ocean Sci./ Univ. of Hawaii/ PMEL/NOAA	ER96: Juan de Fuca Ridge: Endeavour Segment, CoAxial Ridge, Cascadia Basin	Recovery of two strings of current meters, conventional and inverted sed. traps, bio-acoustic net tows, camera, video, CTD, water chemistry.	J. P. Tully	June '96
Canada/ USA	Tunnicliffe	U. Victoria, GSC/ NOAA/ Penn State Univ.	Juan de Fuca Ridge, Axial Seamount ASHES Vent Field	Biological and geological aspects of ASHES Vent Field	J. P. Tully/ ROPOS II	June 30 - July 14, '97
Canada/ USA	Juniper/ Fisher/	Univ. du Québec/ Penn State Univ./ U. Washington	BioROPOS 96: Juan de Fuca Ridge: Endeavour Segment, Middle Valley	Return visit to biological observatory, survey of massive sulfide	Thompson/ ROPOS	Aug '96
France	Géli	IFREMER	PACANTARTIC: Antarctic-Pacific Ridge	Geophysics, geochemistry	Atalante	Jan/Feb '96
France/ USA	Gaill	IFREMER/ Univ. Oregon	HOT 96: 9°N and 13°N, East Pacific Rise	Hydrothermal activity and thermaphilic organisms, biology	Nadir/Nautile Wecoma	Feb-Mar '96
France	Gente	Univ. Bretagne Occidentale	TAMMAR: 22°N, Mid-Atlantic Ridge	Submersible study of mid-ocean ridge segmentation	Nadir/Nautile	Apr-May '96
France	Maia	Univ. Bretagne Occidentale	FOUNDATION HOTLINE: Foundation Seamounts, Pacific-Antarctic Ridge	Geophysics, mapping	Atalante	Nov-Dec '96
France	Sibuet	IFREMER	SARRidge: 33°-39°N, Mid-Atlantic Ridge	Mapping	Nadir/SAR	'97
France	Mével	Univ. Paris 6	EDUL: Southwest Indian Ridge	Dredge sampling of an ultra-slow spreading ridge	Marion Dusfrene	Aug '97

*Archives of the 'World Ridge Cruise Schedule' as published in *InterRidge News* from 1992 onwards are accessible on the World Wide Web via the InterRidge Home Page (http://www.lgs.jussieu.fr/~intridge).

Country	PI	Institution	Name/Location	Research Objectives	Ship	Dates
France	Fouquet	Univ. Bretagne Occidentale	FLORES: Azores, Mid-Atlantic Ridge	Study of hydrothermal vent fields and their volcanic and tectonic context	Atalante/ Nautile	June-July '97
France	Desbruyères/ Alayse	IFREMER	MARVEL: Azores Sea, Mid-Atlantic Ridge	Study of deep-sea hydrothermal vent communities; influence of depth, chemical, physical and biological factors	Atalante/ Nautile	June-July '97
Germany	Devey	University of Kiel	Poseiden: Kolbeinsey Ridge, 68.5° - 70°N, Eggvin Bank, S. Mohn Ridge	Bathymetry, rock sampling, geochem. Small-scale variation in MORB composition relation between geochemically defined mantle domains & ridge offsets.	Poseidon	July-Aug '96
Germany	von Huene	GEOMAR Kiel	ORWELL: Northeast Pacific	Exploration of the lithosphere: a geophysical experiment	Sonne	Apr-May '96
Germany/ Canada	Herzig/ Suess/ Embley	TU Freiberg/ GEOMAR Kiel/ Univ. Victoria/GSC NOAA	HYDROTRACE (SO-109): Juan de Fuca Ridge: Cascadia Margin, Axial Seamount	Remote vehicle investigation. Tracer distribution and chemical fluxes at hot vents and cold seeps. Biology.	Sonne/ ROPOS	May-July '96 (3 Legs)
Germany	Villinger	UHB	HYDROCELL: Northeast Pacific	Hydrothermal circulation in the oceanic crust	Sonne	Aug-Sept '96
Germany	Devey	Geolog. Inst./ Univ. of Kiel	Azoren: Azores Platform, Eurasia/ Africa Plate Boundary	examine hot-spot origin of the Azores Platform, look at magma generation	Poseidon	Aug. 97
India	not available	National Inst. of Oceano./DOD	Central Indian Ridge, 15°-20°S	Mapping regional tectonic fabric, evolution of seamounts	not known	1995/6
India	not available	National Inst. of Oceanography	Central Indian Ridge	Tectonic & petrologic implications of FZs on crustal generation	not known	1995/6
India	Mudholkar	National Inst. of Oceanography	Carlsberg Ridge	Geophysical mapping and dredging	Sagar Kanya	Jun/Jul '96
Japan	Fujikura	JAMSTEC	Y96-13 Mariana Cruise: Mariana Trough	Biology, geochemistry and geophysics of the Mariana Back-Arc Basin	Yokosuka/ Shinkai 6500	Nov-Dec '96
Japan	Hashimoto/ Ohta	JAMSTEC/ ORI-Univ. of Tokyo	BIOACCESS: Manus Basin 2 Legs	Submersible study of hydrothermal vent community distribution, biological and geological characterisation.	Natsushima/ Shinkai 2000/ ROV Dolphin	Oct-Nov '96 Nov '96
Japan	Urabe/ Fujioka	JAMSTEC	MODE '97: Southern EPR 13°-19°S 2 Legs	15 dives each leg	Yokosuka/ Shinkai 6500	Jul/Aug '97 Aug/sep '97
Japan/UK/ France			FUJI Cruise: Eastern part of SWIR	TOBI deep towing, earthquake monitoring with OBS's	Marion Dufresne	Oct-Nov '97

Korea	Suk/ Lee	Korea Ocean Resh. & Dev. Inst.	East Sea: 37°-37.5°N and 131°-132°E	Geophysical survey SeaBeam 2000, SBP, gravity	Onnuri	Mar '96
Korea	Suk/ Kim	Korea Ocean Resh. & Dev. Inst.	East Sea: 37°-38°N and 130.5°-131.5°E	Geophysical survey SeaBeam 2000, mag., grav., multi-channel seismics.	Onnuri	Sept '96
Korea	Han	Korea Ocean Resh. & Dev. Inst.	BASAPES-96: East Sea: Ulleung Basin 37°-38°N and 130°-132°E	Basin structure and past changes in the East Sea. SeaBeam 2000, mag., grav., multi-channel seismics, sed. sampling	Onnuri	Sept-Oct '96 (3rd year)
Korea	Han	Korea Ocean Resh. & Dev. Inst.	MECBES: East Sea: 35°-37°10'N and 129.5°-132°E	Basin structure and past changes in the East Sea. SeaBeam 2000, mag., grav., multi-channel seismics, sed. sampling	Onnuri	Mar 22 - Apr. 25 '97
Korea		Korea Institute of Geology, Mining and Minerals	Study on data acquisition techniques East Sea	Development of 3-D seismic survey techniques, multi-channel seismics	Tamhae II	May '97 (30 days)
Korea		Korea Institute of Geology, Mining and Minerals	Geological Mapping Project: East Sea	Geophysical study of the Korean continental margin; mult-beam bathy., grav., mag. and mult-channel seismics	Tamhae II	Jun/Jul '97 (60 days)
Korea		Korea Institute of Geology, Mining and Minerals	Korea Petroleum Development Company project	Petroleum exploration around the Korean continental margin: multi-channel seismics	Tamhae II	Aug./Sep. '97 (60 days)
Mexico/ USA	Knox	Scripps Inst. of Oceanography	Middle Americas Trench	Origin and evolution of the Cocos Plate. Multi-beam bathymetry.	R. Revelle	July '96
Russia	Krasnov	Polar Mar. Geo.Exp. Sevmorgeologiya/ VNIIOkeangeol.	Logatchev - 12: Mid-Atlantic Ridge, TAG Hydrothermal Field, 24.5°N, 15.8°N	Geological mapping, quantative evaluation of massive sulfide deposits, prospecting for new deposits.	Prof. Logatchev	Fall '96 110 days
Russia	Batuev/ Cherkashev	Polar Mar. Geo.Exp. Sevmorgeologiya/ VNIIOkeangeol.	Logatchev - 13: Mid-Atlantic Ridge, 24°N- 26°N	Investigation of relic and active hydrothermal vents. Electric field profiling, CTD, dredging, coring, TV grab, submersible.	Prof. Logatchev	Apr, May, June '97
Spain	Canals	University of Barcelona	GEBRA-2: Bransfield Basin Antarctica: Western Antarctica, Pacific Trinity Peninsula, South Scotia Sea	Continuing investigation of the Bransfield Basin Swath bathymetry, seismic reflection, gravity magnetics, bottom parametric source	Hesperides	Dec '96- Feb '97
Spain	Dañobeitia/ Córdoba	Inst. de Ciencias de la Tierra, CSIC	CORTES-96: Gulf of California, Middle Americas Trench	Tectonic evolution of Mexican Cont. Margin and Gulf of California	not available	1996/7

Country	PI	Institution	Name/Location	Research Objectives	Ship	Dates
Spain	Dañobeitia	Inst. de Ciencias de la Tierra, CSIC	Galápagos Swell	Geophysical reconnaissance along a segment of the Galápagos Swell	Hesperides	Spring '96
United Kingdom	Searle/ Mitchell/ Cowie	Universities of Durham and Edinburgh	CD99: Mid-Atlantic Ridge, 29°N axial segment	Quantification of total strain in a single spreading segment. Deep-towed side-scan and multi-beam sonar, 3-component magnetics.	Charles Darwin/ TOBI	Mar-Apr '96
United Kingdom	Cann/ Blackman	Univ. of Leeds	CD100: Mid-Atlantic Ridge, Segment south of Atlantis FZ	Determine strain from strain indicators near ridge-transform intersection. Test low-angle serpentinite landslide zone vs. fault scarp model. New TOBI inst. package, dredge.	Charles Darwin/ TOBI	Apr-May '96
United Kingdom	Murton/ Palmer	SOC/ Univ. Bristol	FLUXES II CD102: MAR, 26°N and 29°N	Hydrothermal sediment processes at TAG and recovery of FLUXES I instruments	Charles Darwin/ BRIDGET	Sept '96
United Kingdom/ Greece	Varnavas/ Dando	U. of Patras/ U. of Wales - Bangor	Milos, Hellenic Arc	Recovery and re-deployment of video and flux landers, current meters and sed. traps, sampling of: vent fluid bacteria, fauna and sediment.	Vasilos G/ ROV	June '96
United Kingdom	Larter	BAS	JR18 SLICE-Sandwich Lithospheric and Crustal Exp.: South Sandwich arc and East Scotia Sea	Crustal structure and geodynamics of the South Sandwich Arc and back arc. Multi channel seismic reflection, wide angle OBS and land stations, geodetic mapping, sampling on land and at sea - dredge, coring	James Clark	Jan-Mar '97
United Kingdom	German	SOC/BRIDGE	FLAME Fluxes at AMAR Exp.: Rainbow, Lucky Strike, Famous, 36°-37°N, Mid-Atlantic Ridge	Study of hydrothermal discharge at 3 sites phys. oceano., plume geochem., marine biology	Discovery/ BRIDGET	May-June '97
United Kingdom/ USA	Kent/Harding/ Orcutt/Sinha/ Singh/White	WHOI/ U. of Cambridge/ BIRPS	ARAD 3-D East Pacific Rise, 9°03'N	3-D seismic reflection imaging, 3-D wide angle/ocean bottom seismometer survey of the axial magma chamber(s) beneath OSC	Ewing	Sep./Oct. '97
United Kingdom	MacLeod/ Allerton	U. of Wales, Cardiff	SWIR, Atlantis II Fracture Zone, 32°40'S, 57°15'E	meso-scale arch. of lower oceanic crust, constrain melt transport processes	Sonne	1998
USA (RIDGE)	Spiess	Scripps Inst. of Oceanography	Juan de Fuca Ridge	Seafloor strain measurements	not available	94/95/96
USA	Cande	Scripps Inst. of Oceanography	South Tasman Sea	Geophysics	Ewing	Jan-Feb '96

USA (RIDGE)	Grindlay/ Madsen et al.	Univ. Puerto Rico/ Univ. of Delaware	Southwest Indian Ridge, 15°E to 35°E	Geophysics	Knorr	Mar '96
USA	Taylor	SOEST, Univ. of Hawaii	MW9603: Lau Basin: 17°-18.6°S, 174.3°-178°W Central Lau Spreading Center ETZ - Peggy Ridge	HMR1 & MGG Survey of back-arc basin rifting and spreading.	Moana Wave	Feb-Mar '96
USA	Johnson/ Scheirer/ Graham/ Forsyth	Bishop Museum/ Brown Univ./ Oregon State U.	Boomerang - Leg 6: SEIR 77°-90°E, St. Paul/Amsterdam Hotspot	SeaBeam, dredging, wax coring, gravity, magnetics.	Melville	Feb-Apr '96
USA	Chave/Stein/ Van Dover/Cary/ Cavanaugh/ Ravizza	WHOI/ Univ. Alaska/ Univ. Delaware/ Harvard Univ.	AII/Alvin: East Pacific Rise, 9°-10°N, 13°N	Hydrothermal vent biology. 14 dives, light measurements, biological and water sampling	Atlantis II/ Alvin	Apr '96
USA	Michael/ Hanan	Univ. of Tulsa/ San Diego State U.	SMARTS: Southern Mid-Atlantic Ridge, Temporal variation Study: 32.5°-33.5°S, axis to 7 Ma.	Determine temporal variation of mantle composition and extent of melting. Rock dredging, seabeam	Knorr	Apr-May '96
USA	Cannon	PMEL/NOAA	Kodiak-Seattle Transit: Juan de Fuca Ridge: Cleft Segment	Current meter mooring recovery	Discoverer	May '96
USA	Chave/ Dorman	WHOI/ Scripps	MELT II: East Pacific Rise at 17°S	Deploy magnetotelluric array of 47 instruments Recovery of MELT I instruments	T. Thompson	May-June '96
USA	Baker/Cannon/ Freely/Lupton/ Massoth	PMEL/NOAA	VENTS 1996 Leg 1: Juan de Fuca	Plume survey and water sampling for hydro-thermal activity; mooring deployment and recovery	Discoverer	June '96
USA	Fornari/ Humphris/	WHOI/ LDEO	LUSTRE '96 Lucky Strike: Mid-Atlantic Ridge, 37°18'N	Mapping and sampling of the Lucky Strike Hydrothermal Field.	Knorr-Jason/ ARGO II/ 120 kHz Sonar	June-Aug '96
USA	Tucholke/ Kleinrock/ Lin	WHOI/ Vanderbilt Univ.	Eastern Mid-Atlantic Ridge Flank Survey: 26°N	Mapping of 400 x 200 km box centered near 26°N. Segment history, spreading asymmetry, episodicity	Ewing	July-Aug '96
USA	Speiss/ Hildebrand/ Chadwell/ Zumberge	Scripps Inst. of Oceanography	GEO 3: Juan de Fuca Ridge: Cleft Segment, 48°10'N, 127°10'W	Seafloor geodesy, revisit precision benchmark transponders & absolute gravity reference points, testing installation of fiber optic strain meter. Seafloor strain measurements, plate motion.	New Horizon	Sept '96

Country	PI	Institution	Name/Location	Research Objectives	Ship	Dates
USA	Rona/ Jackson	Rutgers Univ./ U. of Washington	Northern Cleft Segments, Juan de Fuca Ridge	Acoustic imaging of hydrothermal plumes and diffuse flow.	Laney Chouest/ Sea Cliff	Sept '96
USA	Macdonald/ Scheirer/ Cormier	UCSB/ Brown Univ./ LDEO	Sojourn-1: Southern East Pacific Rise Flanks, 16°-20°S. (MELT area and south)	SeaBeam 2000 mapping gravity, magnetics	Melville	Sept-Oct '96
USA	Haymon/ Macdonald	UCSB	East Pacific Rise: Axis 17°-18°S	JASON/ARGO II, AMS 120, hydrothermal/ tectonic studies	Melville	Oct-Nov '96
USA (RIDGE)	Detrick	WHOI	Mid-Atlantic Ridge, 34°-37	Seismic experiment	Ewing	Oct-Nov '96
USA	Webb	Scripps Inst. of Oceanography	DINS II: Escanaba Trough, Gorda Ridge, JdF-Middle Valley	Recovering OBS's deployed to observe seismicity associated w/ hydrothermal venting	Wecoma	Apr/May '97
USA	Collins	WHOI	Mid-Atlantic Ridge: MARK 15°20' N	on-bottom seismic refraction experiments (NOBEL)	Ewing	Jun 1 - Jul 5 '97
USA	Delaney	U. Washington	Juan de Fuca Ridge		Thompson/ Jason	Aug 5-26 '97
USA	Becker	U. Miami	JdF: Endeavor Ridge and Middle Valley, 48° N, 128° W	Long-term monitoring of temp. and pressure in hydrothermal system with CORKs	Thompson/ Jason	Aug 29- Sep 6 '97
USA	Johnson/ Cowen	U. Washington/ U. Hawaii	Juan de Fuca Ridge and Gorda Ridge	study temporal changes in young ocean crust; test bare rock heat flow instruments/ develop proxies of microbial activity in ocean crust	Thompson/ Jason	Sep 7-14 '97
USA	Chadwick/ Stakes	OSU/ MBARI	JdF: south Cleft segment	install acoustic extensometer instruments/ DSL120 Survey	Thompson/ Jason	Sep 15-27 '97
USA	Lutz	Rutgers Univ.	EPR, 9°50' N	Documenting temporal changes in biological community	Atlantis/ Alvin	Oct/Nov '97
USA	Toomey/ Wilcock/ Detrick	U. Oregon/ U. Washington/ WHOI	EPR Undershoot, 9°-10°N	image lower crust/upper mantle structure along the EPR between 9°-10°N	Ewing	Nov 1- Dec 1 '97

If you have a ridge-related scheduled or proposed cruise that is not listed here, please inform the InterRidge Office at intridge@ext.jussieu.fr.

Canada: CanRidge

The CanRidge program was seriously perturbed by the loss of the ROPOS ROV in October 1996. The vehicle was lost during recovery in a severe storm. The Canadian Scientific Submersible Facility, which operates ROPOS in partnership with the Canadian Department of Fisheries and Oceans (DFO) was able to obtain permission from DFO to construct a new vehicle from insurance proceeds. This decision was significantly influenced by a deluge of letters of support from the international community. Thanks again.

Construction of ROPOS II began in early February 1997 and pool and sea trials will be completed in time for a cruise to the Juan de Fuca Ridge this summer. The new vehicle will be essentially the same as the original ROPOS, except for updated vehicle and science telemetry systems and extra hydraulic functions for scientific tools.

Axial Seamount Cruise

Chief Scientist - Dr. Verena Tunnicliffe (University of Victoria), Cruise Dates - June 30 - July 14, 1997
This cruise will be a collaborative effort involving two Canadian universities, the Geological Survey of Canada, the NOAA Vents program, the Chicago Field Museum and Penn State University. ROPOS II will sail on the Canadian vessel *John P. Tully* to Axial Seamount, on the Juan de Fuca Ridge. There will be a very full science program, focussing primarily on geological and biological aspects of the ASHES vent field.

For further information about CanRidge contact:

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National News....

France: Dorsales

The Comité Dorsales has been renewed and new members nominated by the funding agencies CNRS/INSU, CNRS/SDV, IFREMER and BRGM. The new Comité Dorsales stands as follows (as of March 97):

President: Jean Francheteau, UBO
Members: Jacques Boulegue, Paris 6/CNRS
Bernard Bourdon, IPG
Mathilde Cannat, Paris 6/CNRS
Olivier Dauteuil, Rennes
Daniel Desbruyères, IFREMER
Alain Dinet, Banyuls
Françoise Gaill, Paris 6/CNRS
Philippe Gros, IFREMER
Louis Géli, IFREMER
Pierre Nehlig, BRGM

In 1997 the Dorsales program will be reviewed on the basis of past achievements and future prospects. International expertise will be used. A National Dorsales Symposium in the fall of 1997 will present the Dorsales results to the French scientific community and to the review board.

In 1997 the Dorsales program will:

- launch two calls for proposals:
  one in biology on "Life cycle and recruitment processes for hydrothermal species" and one in earth-sciences on "Time-scales for magmatic and hydrothermal fluxes"
- sponsor a biology workshop in Roscoff on 6-8 October '97
- finance participation to the Funchal (Madeira) InterRidge Biology Symposium on 20-24 Oct '97
- organize the National Dorsales Colloquium in Paris on 24-25 November '97
- give support to the following 1997 cruises:
  FOUNDATION (Maia), SARRIDGE (Sibuet), EDUL (Mével), FUJI (Tamaki/Mével), FLORES (Fouquet) and MARVEL (Desbruyères)

In 1996 the Dorsales program has:

- launched four calls for proposals:
  one in biology on " Metabolite outward fluxes and recycling" within the theme "Adaptation of hydrothermal organisms (physiology,biochemistry)" and three in earth-sciences on " Dating recent oceanic basalts", "Oceanic lithosphere" and "Input of magnetism to the knowledge of ridge processes".
- sponsored and financed the Iceland FARA Symposium in June '96
- financed participation to the electromagnetic segment of the MELT experiment
- sponsored a bathymetric synthesis of the Mid-Atlantic Ridge
- financed a hydrothermal community biological data-base(BIOCEAN-H project)
- given support to the following 1996 cruises:
  PACANTARCTIC (Géli), HOT96 (Gaill), TAMMAR(Gente)

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Germany: DeRidge

Focus Themes

During the last year two workshops were held to discuss the future strategy of the DeRidge initiative. In Kiel (Oct. 17-18, 1996) the decision was made to circulate a questionnaire within the German geoscience community asking for their view of the program. The replies to this questionnaire were evaluated and taken to facilitate defining focus themes and areas at a workshop in Berlin (Jan 16-17 1997). The annual DeRidge plenum in Kiel (Mar 5-7, 1997) approved the decision to focus on two major themes: (1) Evolution of oceanic crust and (2) Back Arc Basins. Both themes have some tradition in Germany, with 'Evolution of oceanic crust' aiming at expanding the scope of the EXCO I project, that had started with SONNE cruise 105 in Nov. / Dec 1995 at the EPR and 'Back Arc Basins' aiming to continue the series of German surveys of back arc basins in the West Pacific. For both focus themes a workshop will be held in the summer to define a strategy and evaluate a program plan: 'Evolution of oceanic crust' will be organized by H. Villinger in Bremen, organization of 'Back Arc Basins' will be discussed by J. Erzinger, P. Herzig, P. Stoffers, D. Stueben, P. Halbach and others and decided during the spring.

DeRidge Office

No funds could be mobilized to formally establish a DeRidge office. Low budget operation (basically e-mail communication) will continue in Kiel in cooperation between GPI (C. Devey) and Geomar (R. Rihm). Contacts are given below.

The next full DeRidge meeting will be held together with next year's German ODP meeting (probably early March in Freiburg).

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National News....

Korea

In August 1996 the Ministry of Maritime Affairs and Fisheries was created in Korea, signifying Korea's increasing commitment to marine research. As a result, various marine research institutions and departments that were previously scattered among different ministries, including Korea Ocean Research and Development Institute (KORDI), which was attached to the Ministry of Science and Technology, have been reorganized under the Ministry of Maritime Affairs and Fisheries. However, not all marine research groups have moved to the new ministry. One notable exception is the Petroleum and Marine Resources Division of the Korea Institute of Geology, Mining and Materials (KIGAM), which will still be overseen by the Ministry of Science and Technology.

Basin structures and past changes in the East Sea

The investigation of the East Sea, a back-arc basin formed behind the circum-Pacific volcanic and seismic belt, is the focus of several recent geological and geophysical surveys. Last year, KORDI successfully completed the third phase of an 8-year program entitled "Basin structures and past changes in the East Sea" (PI: Sang-Joon Han), which included multibeam bathymetric (Sea Beam 2000), gravity, magnetic and multichannel seismic reflection surveys of an area around Ulleung Island onboard *R/V Onnuri*. Some of the results of their first and second years' studies are presented in Ocean Research (Volume 18, Number 2, 1996) published by KORDI.

Bransfield Strait

Another important area that KORDI scientists have been investigating is the Antarctica seas around Bransfield Strait, which is also a back-arc region. To understand the tectonic structures and sedimentary processes of this region, multichannel seismic reflection profiles (1093 km in total length) and gravity cores were collected in December 1996 and January 1997 (PI: Sang-Heon Nam).

Cruises

The latest vessel to join the Korean research fleet is *R/V Tamhae II*, which arrived in the port of Pohang in February 1997. *Tamhae II*, operated by Petroleum and Marine Resources Division of KIGAM, is built as a 3-D seismic research vessel and is equipped with a Simrad EM12/950 multibeam bathymetric system, a Lacoste & Romberg S-118 shipboard gravimeter and a Geometrics G-811/811G gradiometer. At present, three major cruises are planned this year, all in the East Sea. In May, the ship will be testing her 3-D seismic capability and other geophysical instruments. In June and July, a multidisciplinary survey as part of KIGAM's ongoing geological mapping project will be performed over a 8000 km^2 area of the Korean continental margin, and in September the vessel will carry out a petroleum exploration reconnaissance survey around the continental shelf.

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South Africa

Few scientists in South Africa are directly involved in research into ridge processes. This fact is due to the unavailibity of an appropriate research vessel to the general science community, the relatively low level of available funding , and, of recent, a major swing in government policy emphasising funding of research more directly relevant to the South African population. At present, the only ridge related research being undertaken is confined to a very small group in the Department of Geological Sciences at the University of Cape Town (Anton le Roex, Phil Janney and Petrus le Roux), whose interests are primarily igneous geochemistry of MORB and their underlying source regions. Although now retired from the University of the Witwatersrand, Hugh Bergh is still involved to a limited extent in collaborative projects (concerning bathymetry and magnetics of the Southern Ocean) with colleagues at Scripps (John Sclater) and IPGP, Paris (Philipe Patriat).

The University of Cape Town group is currently involved with two main projects:

Southern Mid-Atlantic Ridge: Anton le Roex (in collaboration with Jean-Guy Schilling, URI) is studying the bulk rock major and trace element geochemistry of lavas recovered by dredging between 40° and 54° S (cruise 93/09 of *R/V Maurice Ewing*) to examine the impact of two important mantle plumes found in this region on the regional MORB mantle source. In a companion study, Petrus le Roux is investigating detailed trace element variations in quench glasses and phenocrysts of the lavas, as part of a PhD study investigating local melting and crystallisation conditions giving rise to the range of magma compositions found along the southern Mid-Atlantic Ridge axis.

Southern Ocean Ridge System: Phil Janney is undertaking an integrated regional study of the isotope and trace element geochemistry of basalts recovered from the Southern Ocean spreading centres (America-Antarctica Ridge and Southwest Indian Ridge) to better constrain the location and origin of the different mantle components that can be identified in the basalt source regions. The study is based on sample collections recovered during the 1980's.

In view of the lack of access to their own research vessel, future work by South African scientists on ridge related matters will rely heavily on collaborative projects with their international colleagues, offering in return excellent facilities for geochemical analysis of MORB samples. Currently there is no hydrothermal, biological research being undertaken in South Africa.

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National News....

Sweden

Work on ridge related problems in Sweden has been carried out at the Department of Geology and Geochemistry, of Stockholm University. In November 1996 Nils Holm and Jón Örn Bjarnason of the Icelandic Energy Authority sampled wells of the Reykjanes Peninsula for the analysis of organic compounds. Two wells of the Svartsengi field (240°C) and one of the Reykjanes field (290°C) at the tip of the peninsula were sampled by concentrating the organic constituents of the water onto C18 Sorbent Extraction units. The Svartsengi aquifer consists of 2/3 seawater and 1/3 meteoric water, whereas the Reykjanes field hydrothermal water consists of undiluted seawater. Preliminary data indicate the presence of C8 to C16 straight chain organic acids in both hydrothermal systems. However, the concentrations of the acids are orders of magnitudes lower in the 290°C system compared to the 240°C wells. Shorter acids as well as alkanes were probably expelled with the steam during the phase separation at the pressure release during sampling.

During June-August 1996 Eva Andersson participated in ODP Leg 168 to the Juan de Fuca Ridge. Eva is currently working with preparation and chemical analysis of hydrothermally altered sediments. The goal is to reveal the distribution and stereochemistry of dissolved amino acids in sediments of hydrothermal systems of mid-ocean spreading-ridges.

Hakam Al-Hanbali has analysed ODP Leg 158 material (Fe oxides, clay, anhydrite and pyrite) from the TAG hydrothermal field by means of ICP, XRD and neutron activation. Phosphorus in the form of apatite and other phosphorus-bearing compounds comprise up to 0.80% P_2O_5 in some Fe oxide samples. Similar enrichment was found in clay enriched samples. The barium content is relatively higher in Fe oxides compared to the other hydrothermal components and links positively to P. Enrichment of P, Ba and other trace elements is likely to be attributed to scavenging from sea water, probably with the involvement of microorganisms in the overall oxidation process.

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UK: BRIDGE

THE BRITISH MID-OCEAN RIDGE INITIATIVE

The new year started well for BRIDGE with the television repeat of the 1995 documentary detailing BRIDGE's 1994 British-Russian Atlantic Vents Expedition aboard the *R/V Akademik Mstislav Kheldysh* (BRAVEX/94).

Before that broadcast BRIDGE held its Annual Science Meeting at Southampton Oceanography Centre (6-7 January 1997), enhanced by the presence of *RRS Charles Darwin* at the quayside. The meeting included the following talks, and abstracts will be published in the next BRIDGE Newsletter.

This is not the Pacific: Tectonic Controls of Venting on the Mid-Atlantic Ridge
Chris German and Lindsay Parson (SOC)

Metalliferous Sediments Ancient and Modern: Evidence from TAG and Oman
Helen Goulding (SOC) et al.

Lipid Profiles of Hydrothermal Vent Shrimp from the Mid-Atlantic Ridge
Cathy Allen Copley (SOC)

Tectonic Strain and Recent Evolution of the Broken Spur Segment, MAR 29°N
Roger Searle (University of Durham) et al.

Detailed Investigation of Crustal Magnetization of the Reykjanes Ridge Between 57°30'N and 62°30'N.
Sang-Mook Lee and Roger Searle (University of Durham)

Epidotised Faults Link Hydrothermally Altered Dykes to Stockwork Zones -Troodos Ophiolite, Cyprus.
Graeme Penwright and Joe Cann (University of Leeds)

How Much of the Mid-Atlantic Ridge is Affected by the Icelandic Plume?
Rex Taylor (SOC) et al.

The Interaction of Microbial Activity and Diagenesis in Hydrothermal Sediments at the Mid-Atlantic Ridge at 26°N: Preliminary Results of Cruise CD102.
Martin Palmer (University of Bristol) et al.

Mid-Atlantic Ridge Magma Eruption Rates and Pressures from Direct Measurement of Vesicle Internal Pressures.
Pete Burnard (University of Manchester)

ODP Leg 169: An Investigation of Hydrothermal Circulation and Genesis of Massive Sulphide Deposits at Sediment-Covered Spreading Centres (Middle Valley and Escanaba Trough)
Rachael James (University of Bristol) et al.

Models of Structural Processes at Oblique Spreading Centres
George Tuckwell (SOC) et al.

Self-Organisation of Submarine Hydrothermal Siliceous Deposits: Evidence from the TAG Hydrothermal Mound, 26°N Mid-Atlantic Ridge.
Laurence Hopkinson (SOC) et al.

Hydrothermal Vent Barnacles at the Indian Ocean Ridge
Alan Southward (Marine Biological Association) et al.

Detailed Structure of the Top of the Melt Body Beneath the East Pacific Rise at 9°N from Waveform Inversion of Seismic Reflection Data.
Jenny Collier and Satish Singh (University of Cambridge)

On the Nature and Implications of Non-Transform Discontinuities Along Medium Spreading Ridges
Bram Murton (SOC) et al.

Corrugated Slip Surfaces Formed at North Atlantic Ridge-Transform Intersections
Joe Cann (University of Leeds) et al.

National News....UK continued

The next BRIDGE-related meeting will be a joint meeting of BRIDGE, the Marine Studies Group of the Geological Society, and the Challenger Society for Marine Science. This meeting, 'Modern Ocean Floor Processes and the Geological Record', will be held on 20-21 May 1997 at the Geological Society in London, with the poster session at the Royal Institution of Great Britain. A programme and registration details can be found on page 57.

In the summer BRIDGE will be a partner in a US submersible cruise to the Mid-Atlantic Ridge. This cruise - PIs Bob Vrijenhoek and Richard Lutz of Rutgers University - will be the first science cruise of the new Atlantis-Alvin combination. The BBC will also be aboard filming for a new series on the Earth and how we have come to our current understanding of it. Hopefully there will be good publicity for all science projects and for the operators' new vessel. The BRIDGE science will focus on feeding and behaviour of vent shrimp, and lipid profiling of vent animals.

These proposals were funded as part of the final BRIDGE funding round in 1996. From the earlier rounds, approximately a quarter of BRIDGE's 43 research projects have now concluded and results are being assessed with increasing intensity. The first project began in April 1993 and the last will end in April 1999.

The future of global ridge research lies increasingly in those areas of seafloor spreading that have not yet been studied by the international community. At the end of 1996 the BRIDGE Steering Committee was happy to give its support to InterRidge's Project Plan for investigation of the South West Indian Ridge. The Committee recognised that, "the geographically focused approach advocated in the plan was similar to the approach adopted by the BRIDGE Programme for the mid-ocean ridge in the north Atlantic. This approach has proved very successful at this slow spreading ridge and has every chance of providing a sound scientific rationale for study of the very slow spreading Southwest Indian Ridge." BRIDGE wished InterRidge, "every success in co-ordinating international investigations into this important very slow spreading region of the ridge system. The success of this study would provide invaluable results to add to our understanding of the fast-spreading East Pacific and slow-spreading Atlantic ridges."

The InterRidge baton has now passed from Durham to Paris. May we thank Roger Searle, Heather Sloan and Ruth Williams for their untiring co-operation and collaboration and wish Mathilde Cannat and Cara Wilson a warm welcome and successful terms in office.

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The British Mid-Ocean Ridge Initiative is a thematic programme of the Natural Environment Research Council. Background information on BRIDGE can be found at the web site maintained by the BRIDGE-supported research unit at Southampton Oceanography Centre:

http://www.soc.soton.ac.uk/CHD/bridge/

USA: RIDGE

Since its inception, RIDGE has issued Science Plans to "present the scientific strategy to be implemented over the next five years to ... achieve the objectives of the RIDGE Initiative." After compiling the results of a public solicitation for input to the Science Plan, the RIDGE Office and Steering Committee are in the process of revising the second of these Science Plans for the next 5 years. The new Science Plan will likely be distributed in December of 1997.

RIDGE, USSAC, and NSF co-sponsored a Conference on the Magnetization of the Oceanic Crust convened by H. Paul Johnson (U. Washington) and Dennis Kent (LDEO) in October of 1996. Approximately 50 participants attended the Conference, which began by reviewing marine magnetic anomalies from an historical perspective, followed by a full day discussion of results from new studies of near-bottom magnetometer surveys and from the drilling program. Working groups met to discuss the scientific problems that require immediate attention from the community in the following areas: magnetic source layer and crustal structure, zero-age magnetization and crustal formation, short-term variability (less than 1 MY) of the anomaly signal, and long-term variability. A short summary of the meeting appears in the January 1997 Issue of RIDGE Events, and a detailed article should appear soon in Eos.

RIDGE and the NOAA VENTS Program co-sponsored a Workshop on the Detection and Rapid Response to Volcanic Events on the Mid-Ocean Ridge convened in March by Bob Embley and Hugh Milburn (NOAA/PMEL), Marv Lilley (U. Washington), and Jim Cowen (U. Hawaii) in March. Approximately 65 participants attended this Workshop, which focused on: needs and methods for enhancement of event detection, scientific questions/hypotheses that can be addressed with rapid response to volcanic events, and the technology, logistic, and techniques for making measurements during the initial phase (days to weeks)of an event. A Workshop Report will be available through the RIDGE Office in the next few months.

RIDGE, JOI/USSAC, the NOAA VENTS Program, and the University of Washington Volcano Systems Center co-sponsored a Workshop on the Subsurface Biosphere at Mid-ocean Ridges, convened in March by Kim Juniper (U. du Quebec, Montréal), Marv Lilley and John Baross (U. Washington). Over 100 participants attended this Workshop, which focused on: critically reviewing evidence for microbial life at the ridge crest and elsewhere, the nature of the physical and geochemical environment within young ocean crust, the diversity and phylogeny of organisms potentially living in the subsurface, physiological adaptations of organisms to the subsurface environment and their influence on geochemical processes, and research strategies for sampling and observing the subsurface biosphere. A Workshop Report will be available through the RIDGE Office in the next few months.

RIDGE is involved with several Workshops and Meetings over the next several months:

- Summer School on Active Processes at Mid-Ocean Ridges, Lake Myvatn, Iceland, Aug. 26 - Sept. 5, 1997; convenors: John Sinton, Bob Detrick, Freysteinn Sigmundsson.
- RIDGE Workshop on Mantle Flow and Melt Generation Beneath Mid-ocean Ridges: Constraints from MELT and Other Experiments, Providence, Rhode Island, October 4-6, 1997; convenors: D. Forsyth, A. Chave, E. Stolper.
- First International Symposium on Marine Hydrothermal Vent Biology, Madeira, Portugal, October 19-23, 1997; Organized by InterRidge

The RIDGE Office is now distributing CD-Roms containing multibeam bathymetry from the Northeast Pacific Ridges, and the Mid-Atlantic Ridge. These CD-Roms contain raw multibeam files, gridded terrain models and images, and navigation information. Contact the RIDGE Office for purchase information. As always, information related to the RIDGE Program, a list of current RIDGE announcements, and a RIDGE calendar of events are available on the RIDGE website.

You can contact the RIDGE Office at:
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Ocean Drilling Program (ODP) Update

The JOIDES Office moved to Woods Hole in October 1996 and inherited the implementation of major changes in the Ocean Drilling Program (ODP). These changes had been proposed by the Planning Committee (PCOM) under the guidance of the Cardiff JOIDES Office in response to external reviews of the Program, and included focusing of the scientific effort into major themes, and reorganization of the JOIDES Advisory Structure to be better aligned with the goals of future scientific ocean drilling.

The ODP Long Range Plan published a year ago identifies the fundamental scientific problems that will be addressed through drilling into the early part of the 21st century, and separates them into two major themes. "Dynamics of Earth's Environment" encompasses a range of scientific problems related to understanding how our planet's environment - in particular the atmosphere, hydrosphere and biosphere — changes in response to natural and anthropogenic perturbations. "Dynamics of Earth's Interior" focuses on examination of the properties and processes within the lithosphere in order to advance our understanding of the structure of Earth's outer layers, global mass and energy fluxes, mantle dynamics, and deformation processes. Within these broad themes, several "core" themes, three specific initiatives, and a pilot project are identified which capitalize on new scientific frontiers, an interdisciplinary approach, greater collaborations with other international geoscience programs, and advancements in drilling technologies.

Relevance of proposed drilling legs to the ODP Long Range Plan was considered by the Planning Committee when it met in December 1996 to determine the drilling schedule for FY'98 (and the early part of FY'99) (Table 1). Within "Dynamics of Earth's Environment", two legs will be devoted to key objectives related to understanding climate, and two to investigating sea-level changes. Leg 177 will study the paleoceanographic and climatic history of the southern high latitudes that will provide the sedimentary sequences needed to expand the biostratigraphic, paleoceanographic, and paleoclimatic history of the Southern Ocean during the Cenozoic — a period marked by major changes in southern hemisphere paleogeography. Leg 181 is another in the series of ODP legs designed to examine the Global Conveyor Belt Model of Ocean circulation in key "gateway" areas, and will drill on the eastern New Zealand Plateau and its margins to reconstruct the stratigraphy, paleohydrography and dynamics of the Pacific Deep Western Boundary Current, which plays a fundamental role in the input of deep water to the world's oceans. Leg 178 will be the first in a series of Antarctic drilling legs aimed at understanding the timing, extent, and variability of glaciation of the Antarctic continent. It will provide an unprecedented high-resolution record of Antarctic continental climate over the past 6-10 Ma. Leg 182 (in FY'99) will drill an array of holes across the Cenozoic carbonate shelf in the Great Australian Bight to document the way in which this large, cool water carbonate platform evolved throughout the past 65 Ma.

Of particular relevance to the InterRidge community are the four drilling programs that will address objectives within "Dynamics of Earth's Interior". Leg 176 will deepen Hole 735B on a wave cut terrace along the Atlantis II Fracture Zone to investigate the structure of the lower oceanic crust at a slow-spreading ridge. Leg 179 will drill a hole into basement on the Ninety East Ridge in the Indian Ocean for installation of a broadband ocean seismometer and instrument package in support of the International Ocean Network (ION) program. Leg 180 will be the first in a proposed two-leg program to investigate the role and nature of low-angle faulting in continental breakup, and the evolution of conjugate rifted margins in the western Woodlark Basin, Papua, New Guinea. Drilling will initially characterize, and subsequently monitor, the in situ properties (stress, permeability, temperature, physical properties, and fluid pressure) of the active low-angle fault zone, and determine the vertical motion history of both the down-flexed upper plate and the unloaded lower plate. Finally, Leg 183 (in FY'99) will investigate the origin, growth, compositional variation, and subsid-

Table 1.

FY 1998 and early FY 1999 JOIDES Resolution Operations Schedule				
Leg	Destination	Cruise Dates	Port of Origin	No of Days
176	Hole 735B	15 Oct.- 10 Dec. 97	Cape Town 10-14 Oct. 97	56
177	Southern Ocean	15 Dec. 97- 9 Feb. 98	Cape Town 10-14 Dec. 97	56
178	W. Antarctic Peninsula	14 Feb. - 11 Apr.	Punta Arenas 9-13 Feb.	56
179	NERO/Hammer Drilling Test	16 April - 30 May	Cape Town 11-15 April	44
180	Woodlark Basin	4 June - 30 July	Singapore 30 May - 3 June	56
181	SW Pacific Gateways	4 Aug. - 29 Sept.	Townsville 30 July - 3 Aug.	56
182	GAB Cenozoic Carbonates	4 Oct. - 29 Nov.	Wellington 29 Sept. - 3 Oct.	56
183	Kerguelen LIP	4 Dec. 98 - 2 Feb. 99	Fremantle 29 Nov. - 3 Dec.	60

ODP Update continued...

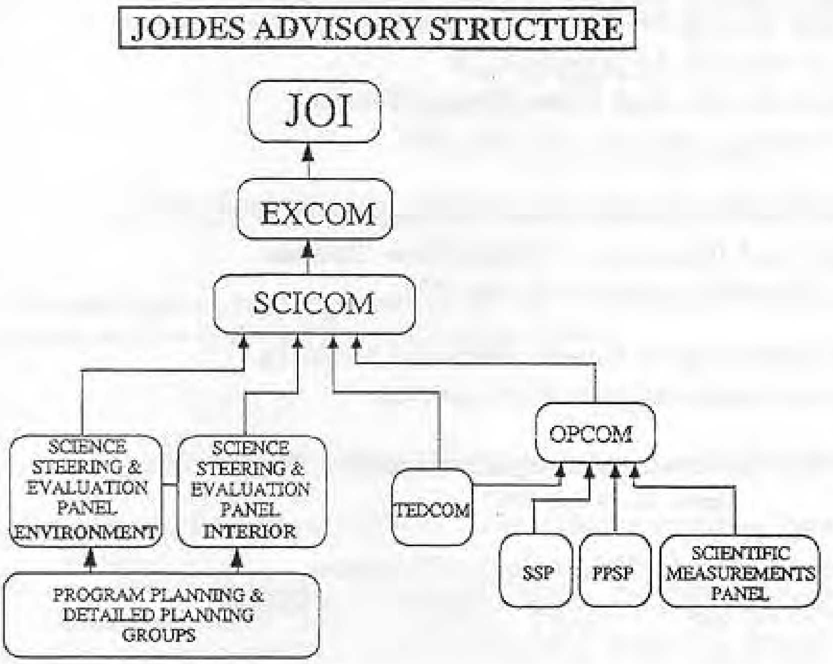

Figure 1.

ence history of the Kerguelen Plateau and Broken Ridge in the southeastern Indian Ocean — one of the largest oceanic Large Igneous Provinces (LIP).

In order to better tackle the scientific objectives, technological initiatives, and collaborations with other international geoscience programs required by the Long Range Plan, the ODP has revised and simplified the science advisory structure (Figure 1). The new JOIDES Science Advisory Structure will be headed by a Science Committee (SCICOM) that will provide long-term oversight on the direction of the Program. They will receive scientific advice from two Science Steering and Evaluation Panels (SSEPs) that are aligned with the two overall LRP programmatic themes, and a number of short-lived Program Planning Groups (PPGs), that may be set up to promote both active collaboration with other international programs, and the submission of drilling proposals on new initiatives within the LRP. An Operations Committee (OPCOM) will be created as a sub-committee to SCICOM to handle logistical and scheduling issues, and to oversee operational planning, equipment needs, and the short- and long-term technological developments necessary to accomplish the drilling legs. This new structure is being phased in during 1997 and is expected to be fully in place by January 1998.

There will also be some changes to the proposal submission and evaluations process. The ODP proposal deadlines will be changed to 15 March and 15 September of each year. New guidelines for proposal preparation and submission are being developed that will facilitate the nurturing of exciting scientific ideas, and will eventually lead to a new evaluation process (that will include external review) for fully-developed drilling proposals. These new guidelines are expected to come into effect for the 15 September deadline. Hence, if you are considering submitting a new or revised proposal at that time, check with our web site, or the JOIDES Office for new requirements.

Throughout this reorganization, it is important to keep in mind that the science conducted by ODP is ultimately driven by the quality of proposals submitted by the geoscience community. The goals of the Long Range Plan are ambitious and will require a strong commitment on the part of the international scientific community, and the development of partnerships with other major global geoscience initiatives (such as InterRidge) in order to meet the new scientific challenges.

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*** New Deadlines for ODP Proposals: September 15 and March 15 ***

Upcoming Meetings and Workshops: Calendar

Modern Ocean Floor Processes and the Geological Record
Geological Society of London, Burlington House, Piccadilly, London, UK, 20-21 May 1997

American Geophysical Union Spring Meeting
Baltimore, MD, USA, 27-30 May 1997

Chapman/CSEDI/JOI/USSSP Conference:
The History and Dynamics of Global Plate Motions
Marshall, CA, USA, 17-22 June 1997

American Malacological Union: Deep-Sea Mollusca
Santa Barbara, CA, USA, 22-27 June 1997

CONCORD Workshop (Conference of Cooperative Ocean Riser Drilling)
Japan, 22-24 July 1997

RIDGE and Nordic Volcanological Institute:
Summer School on Active Processes at Mid-Ocean Ridges
Iceland, 26 August - 5 September 1997

MAST 3 Advanced Study Course: "Benthic Communities Fueled by Chemosynthesis"
Paris, France 1-19 September 1997

Fourth Underwater Science Symposium
Newcastle upon Tyne, UK, 18-20 September 1997

InterRidge Steering Committee Meeting
Barcelona, Spain, 18 & 19 September 1997 (Provisional)

Eighth Deep Sea Biology Symposium
Monterey, CA, USA, 22-27 September 1997

RIDGE Workshop on Mantle Flow and Melt Generation Beneath Mid-Ocean Ridges:
Constraints from MELT and Other Experiments
Providence, RI, USA, 4-6 October 1997

Oceans'97
Halifax, Nova Scotia, Canada, 6-9 Oct. 6-9 1997

International Symposium on Hydrothermal Vent Biology
Madeira, Portugal, 20-24 October 1997

Conference on Marine Benthic Habitats and
their Living Resources
Noumea, New Caledonia, 10 - 16 November 1997

GEOSCIENCE 98
Keele University, Keele, Staffordshire, UK, 14 - 18 April 1998

Geological Association of Canada and the
Mineralogical Association of Canada Joint Annual Meeting
Quebec City, Canada, 18-20 May 1998

Upcoming Meetings and Workshops

Modern Ocean Floor Processes and the Geological Record

20-21 May 1997
Geological Society of London, Burlington House, Piccadilly, London

This meeting is sponsored by the Geological Society, The Natural Environment Research Council's BRIDGE Programme and The Challenger Society for Marine Science.

Tuesday 20th May

Session 1: Crustal accretion at modern and ancient mid-ocean ridge systems

Magmatism and Tectonism in Ophiolites: Clues to Modern Spreading-Ridge Processes, *C.J. MacLeod (University of Wales)*

Structure of the Axial Magma Chamber and Magmatic Processes at Fast Spreading Ridges: Constraints from the Oman Ophiolite, *G. Yaouancq (University of Wales), C.J. MacLeod & F. Boudier*

In situ Geological Study of Two Contrasting Segments of the MAR between Oceanographer and Hayes Fracture Zones (35N-33 30'N): Comparison with the Second-Order Segments South of the Azores (38N-36N) *E. Gr'cia (Southampton Oceanography Centre), D. Bideau, Y. Lagabrielle & L.M. Parson*

Structure, Petrology and Seafloor Spreading Tectonics of the Kizildag Ophiolite (Turkey): an Ancient Analogue of Slow-spreading Oceanic Lithosphere, *Y. Dilek (University of Miami) & P. Thy*

Is the Oceanic Moho a Serpentinisation Front? *T.A. Minshull (University of Cambridge), M.R. Muller, C.J. Robinson, R.S. White & M.J. Bickle*

The Formation of Podiform Chromitite, *S.J. Edwards (University of Greenwich) & J.A. Pearce*

Session 2: Alteration of oceanic crust and evaluation of hydrothermal fluxes

Tracing the Evolution of Hydrothermal Fluids in the Upper Oceanic Crust: Constraints from DSDP/ODP Hole 504B, *Damon A.H. Teagle (University of Michigan), Jeffrey C. Alt & Alex N. Halliday*

Initial Isotopic and Petrological Investigations of Low Temperature Hydrothermal Alteration of the Upper Crust, Juan de Fuca Ridge, ODP Leg 168, *A. Hunter (University of Leeds) & the ODP Leg 168 Scientific Party*

Sr-Isotopic Alteration of the Troodos Ophiolite and the Structure of Ocean Ridge Hydrothermal Systems, *M.J. Bickle (University of Cambridge), D.A.H. Teagle, J. Beynon & H.J. Chapman*

Dyke by Dyke Hydrothermal Alteration in the Troodos Ophiolite, Cyprus, *G.M. Penwright (University of Leeds), J.R. Cann & A.C. Barnicoat*

Rare Earth Element (REE) Mobility in a Mineralised Alteration Pipe within the Troodos Ophiolite, Cyprus, *D.M. Wells (Southampton Oceanography Centre) & R.A. Mills*

Poster session at the Royal Institution of Great Britain

Construction of the upper ocean crust in the Troodos ophiolite, Cyprus, *Joe Cann (University of Leeds), Ross Andren, Richard Hunt, Richard Smith & Richard Thompson*

High-MgO Dikes (i.e. ~15 wt%MgO) from ODP Leg 153 and their Implications for Parental Melt Compositions, *P. Kempton (British Geological Survey)*

An Analysis of Petrologic Metamorphic Processes in the Moho Transition Zone by a Comparison of Alpine Ophiolite and MAR Samples, *L. Bolou (University of Geneva)*

Dissecting an Active Hydrothermal Deposit: The Strontium- and Oxygen-Isotopic Anatomy of the TAG Mound, *Damon A.H. Teagle (University of Michigan), Jeffrey C. Alt, Hitochi Chiba, Susan E. Humphris & Alex N. Halliday*

Irreversible Geological and Geochemical Processes at Ultra-fast Spreading Centers (South EPR), *Sergei M. Sudarikov (VNIIOkeangeologia, St Petersburg)*

Geochemical Hydrothermal Processes in the Western Sector of the Hellenic Volcanic Arc, *S.P. Varnavas (University of Patras), P. Halbach, M. Halbach, E. Rahders & P.S. Megalovasilis*

Continued on next page...

Upcoming Meetings and Workshops....Modern Ocean Floor Processes

Behaviour of Rare Earth Elements (REE) and High Field Strength Elements (HFSE) During Differentiation in Oceanic Magma Chambers - An Example from the Mid-Atlantic Ridge, ODP Leg 153, *V. Marchig & K.P. Burgath (Bundesanstalt für Geowissenschaften und Rohstoffe, Hannover)*

Tectonic strain and recent evolution of the Broken Spur segment, MAR 29N, *R.C. Searle (University of Durham), N.C. Mitchell, J. Escartin, P.A. Slootweg, S.M. Russell, P.A. Cowie, S. Allerton & C.J. MacLeod*

Correlation Between Acoustic Texture and Surface Geology Along the Mid-Atlantic Ridge Between 27(N-30(N And 36(N-38(N, *Ph. Blondel (Southampton Oceanography Centre) & L.M. Parson*

Wednesday 21st May

Session 3: Refining our understanding of ore formation

Tectonic Setting of Mineralization in the Troodos Ophiolite, *Simon Allerton (University of Edinburgh) & Christopher Pawley*

The Chemistry of Interstitial Waters from Sediment Hosted Spreading Centres: Clues as to the Sub-Surface Circulation of Hydrothermal Fluids and their Control on the Formation of Massive Sulphide Deposits, *R.H. James (University of Bristol), J.M. Gieskes, J. Ishibashi, R.A. Zierenberg, Y. Fouquet, D.J. Miller, M.R. Palmer & the ODP Leg 169 Shipboard Scientific Party*

Anatomy of Sediment Hosted Seafloor Massive Sulphide Deposits: Preliminary Results from ODP Leg 169 Drilling in Middle Valley and Escanaba Trough, *R.C. Duckworth (James Cook University) & the Leg 169 Shipboard Scientific Party*

Overview of the Tectonic Setting, Genesis and Significance of Hydrothermal Sediments of the Mesozoic Tethyan Ocean, *A.H.F. Robertson (University of Edinburgh), S. Varnavas & P. Degnan*

Preservation of Metalliferous Sediments from TAG and Oman, *H. Goulding (Southampton Oceanography Centre), R.A. Mills & R.W. Nesbitt*

Ancient Vent Chimney Structures in Palaeozoic Massive Sulphides of the Urals, *R.J. Herrington (The Natural History Museum, London), V.V. Maslenikov, B. Spiro, V.V. Zaykov & C.T.S. Little*

Session 4: Site colonisation: evidence from modern systems and the geological record

A Segment Scale Study of the Broken Spur Vent Field: the Extent of the Plume, Faunal Migration and Seafloor Activity, *B.J. Murton (Southampton Oceanography Centre), C.R. German, P.J. Herring, D.R. Dixon, K. Doos, A. Coward, M.D. Rudnicki & L. Redbourn*

Microdistribution of Fauna at Pacific and Atlantic Hydrothermal Vents, *J.T.P. Copley (Southampton Oceanography Centre) & P.A. Tyler*

The Fossil Record of Hydrothermal Vent Communities, *C.T.S. Little (The Natural History Museum, London)*

Relics and Antiquity Revisited in the Modern Vent Fauna, *V. Tunnicliffe (University of Victoria, Canada) & A. G. McArthur*

Registration:

Anyone interested in attending the above conference should register with the convenor as soon as possible enclosing the appropriate registration fee. Abstract booklets and Accommodation details will be supplied to those who have registered.

Fees (for all or any part of the meeting):

Associates/Junior Associates of the Geological Society...........5 pounds
Fellows of the Geological Society..10 pounds
All other delegates..20 pounds

Payment BY CHEQUE ONLY PLEASE payable in pounds sterling to "MSG" (Marine Studies Group of the Geological Society)

CONVENOR: Dr Keith Harrison, BRIDGE Programme Manager, Department of Earth Sciences, University of Leeds, Leeds LS2 9JT, UK, Tel: +44 (or 0 within UK) 113 233 5241, Fax: +44 (or 0 within UK) 113 233 5259, BRIDGE@earth.leeds.ac.uk

Upcoming Meetings and Workshops....

American Geophysical Union Spring Meeting

Special Session-OS01: High-Latitude Gas Venting, Hydrates, and Mass Wasting

27-30 May, 1997, Baltimore, MD, USA

Geological/geophysical poster papers showing observations and/or data relevant to methane venting, gas hydrates, and mass wasting phenomena and their inter-relationships along Arctic and Antarctic continental margins and shelf seas. Multi-disciplinary contributions or groups of papers covering everything from multi-channel hydrate studies to chemosynthetis-based vent biota are especially welcome.

Conveners:
Joan Gardner, Naval Research Laboratory, Code 7420, Washington, DC, 20375-5350, Phone: 202-404-1094, Fax: 202-767-0167, E-mail: gardner@qur.nrl.navy.mil; and
Peter Vogt, Naval Research Laboratory, Code 7420, Washington, DC 20375, Phone:202-404-1102, Fax: 202-767-0167, E-mail: vogt@qur.nrl.navy.mil

Chapman Conference on The History and Dynamics of Global Plate Motions

June 17-22, 1997
Marconi Conference Center, Point Reyes National Seashore, Marshall, California

Preregistration Deadline: May 5, 1997

Conveners:
Mark Richards, University of California, Berkeley
David Bercovici, University of Hawaii
Mike Coffin, University of Texas
Michael Gurnis, California Institute of Technology
Richard Gordon, Rice University
Larry Lawver, University of Texas
Richard O'Connell, Harvard University
Joann Stock, California Institute of Technology

Conference Scope:
Since the development of the theory of plate tectonics, the work of scientists who develop plate motion reconstructions and the work of scientists who model mantle convection and global plate motions have been performed in relative isolation. However, advances in geodynamic modeling and seismic imaging of the Earth's interior now offer many possibilities for integrating our knowledge of the history of plate motions with our emerging understanding of mantle dynamics.

The purpose of this conference is to bring together the plate reconstruction and mantle dynamics communities in order to foster innovative cross-disclipinary science, better integrate the geologic record of plate motions into geodynamic models, and bring a higher level of maturity to geodynamic models of the forces acting on plates.

Topics of discussion will include:
- Dynamic models for plate motions
- Advances in mapping Phanerozoic plate motions
- Plate boundary forces and fault systems
- Rapid plate motion changes
- The nature of the hotspot reference frame
- Seismic imaging of subducted plates
- Integration of plate motion data and geophysical models

Continued on next page...

Conference Format:

- Keynote addresses by leaders in the field of plate motion reconstructions and geodynamics.
- Poster sessions providing opportunities for conference participants to view and discuss the latest results.
- Formal and informal discussions, with a focus on forming interdisciplinary working subgroups to address the goals outlined above.
- Tutorial sessions to help the plate reconstruction and geodynamics communities understand the nuts-and-bolts of each others' work. These sessions will address such topics as error analysis in plate reconstructions, the basic physics of mantle convection and plate driving forces, available software for plate tectonics work, etc.
- A field trip to view the famous Franciscan and Salinian geology of both sides of the San Andreas Fault, which can be seen within a few minutes drive from the conference site. The field trip will occur in the middle of the conference to encourage interactions among participants.

MAST 3 Advanced Study Course "Benthic Communities Fuelled by Chemosynthesis"

1-19 September 1997, Paris, France

An "Advanced study course" (MAST 3) will be held in Paris from 1st to 19th September 1997. It will deal with "Benthic communities fuelled by chemosynthesis". It will be funded under the EC MAST 3 programme for undergraduate and graduate students.

If you know anyone who would be interested please contact:

Dr. Jean-Francois Pavillon,
Institut Oceanographique de Paris
E-mail address: 100670.615@compuserve.com.

Fourth Underwater Science Symposium

18-20 September 1997, Newcastle upon Tyne, UK

Organized by the Society for Underwater Technology

This fourth Symposium, planned and organised by the Underwater Science Grooup (USG) of the Society for Underwater Technology, will bring together experts and enthusiats from the diverse underwater science community. At this low-cost event delegates will enjoy presentations and posters on current scientific diving activities and technology, and published proceedings.

The 1997 Symposium will have a varied programme which aims to reflect the broad interest of the USG, and to stimulate discussion on diving technology and scientific methods in areas such as oceanography, marine biology, marine geology, underwater archaeology, and photography. Papers on the main conference thenme are encouraged from professional scientists, engineers, students and others with an interest in all disciplines of marine science and technology.

For further information please contact:

Jean Pritchard, Conference Organiser, Society for Underwater Technology, Innovation Centre, Exploration Drive, Offshore Technology Park, Bridge of Don, Aberdeen AB23 8GX, UK
Tel: +44 12224 823 637 Fax: +44 1224 820 236

Oceans'97 Conference

6 -9 October 1997
World Trade and Convention Centre, Nova Scotia, Canada

Sponsers: IEEE/MTS
Email: d_mckeown@bionet.bio.ns.ca
Website: http://www.seimac.com/oceans97

Oceans'97 is an international conference sponsored by IEEE/MTS. The emphasis in the technical program is on ocean applications of technology. The conference is being held from Oct. 6th - 9th at the World Trade and Convention Centre In Halifax, Nova Scotia, Canada, and our abstract deadline is fast approaching.

We are still accepting abstracts in all topic areas, many of which are of direct interest to InterRidge participants.

We currently have extra emphasis for abstracts on technologies related to:

1. Air/Sea Interaction
2. Oceanographic Instrumentation
   - Sediment Measurement
   - Novel Instruments/Sensors
   - Optical Instruments
   - General
3. Polar and Severe Environments Instrumentation
4. Satellite/Airborne Remote Sensing
   - SAR Ocean Observations
   - Radar Modelling, Analysis and Simulation
   - HF Radar Observations: Currents & Winds
   - Satellite Scatterometer Measurement of Sea Surface Winds
   - Optical Observations of Marine Ecology and Constituents
5. Active/Passive Remote Sensing
6. Water Current Measurements
   - State of Current Measurement Systems
   - Performance of ADCP's
   - Turbulence/Bottom Sensors
   - New Developments
   - Surface Drifters
7. Wave and Tide Sensors
8. Real Time Observations
9. Geophysical Monitoring
10. In-situ Measurement
11. Data from Refurbished Sensors

If you wish to submit an abstract in any of these topics, please send it to: d_mckeown@bionet.bio.ns.ca

Upcoming Meetings and Workshops....

Second Announcement

1st International Symposium on Deep-Sea Hydrothermal Vent Biology

20-24 October, 1997
International Conference Center of Funchal, Madeira, Portugal

Registration Deadline: 23 May, 1997

Following a recommendation by the InterRidge Biological Studies *Ad Hoc* Committee, an International Symposium on deep-sea hydrothermal vents biology is being organized under the auspices of InterRidge. The object of this Symposium is to bring together the international community of scientists involved in research on deep-sea hydrothermal vents and cold seeps and to provide a forum for presentation of results in the following topics:

- Biogeography/Evolution/Genetics/Taxonomy
- Ecology/Micro-distribution/Temporal Evolution
- Microbiology/Ultra-thermophiles/Bacterial Symbiosis
- Physiology/Adaptation
- Biological Cycles/Larval Dispersal/Plankton
- Cold Seeps

World Wide Web Sites:

This circular and additional information concerning the Symposium are available at the following WWW sites:

http://www.mmf.uma.pt/events/vent_biol_symp.html
http://www.lgs.jussieu.fr/~intridge/calendar.html
http://ridge.unh.edu/meetings/ventbio

Scientific Committee:

Dr. Robert R. Hessler - Chair - Scripps Institute of Oceanography, UCSD, USA
Dr. Daniel Desbruyères - IFREMER, France
Dr. Charles Fisher - Pennsylvania State University, USA
Dr. Daniel Prieur - Station Biologique de Roscoff, France
Dr. Verena Tunnicliffe - University of Victoria, Canada
Dr. Paul Tyler - Southampton Oceanographic Centre, UK

Organizational Committee

Manuel Biscoito - Museu Municipal do Funchal (História Natural), Portugal; biscoito@tethys.uma.pt
Craig Cary - College of Marine Studies, University of Delaware, USA; caryc@strauss.udel.edu
David Dixon - Plymouth Marine Laboratory, UK; d.dixon@pml.ac.uk
Heather Sloan - American Museum of Natural History, USA; sloan@amnh.org

Conference Proceedings

The Symposium Proceedings will be published in a separate citable volume. The Organizational Committee will act as editors for this publication. The manuscript submission deadline will be 1 January 1998. Participants wishing to contribute should indicate a provisional title on the Registration Form below. *A firm commitment to contribute a manuscript to the proceedings volume must be given at the Symposium.* A form will be available at registration along with submission guide lines.

Continued on next page...

Upcoming Meetings and Workshops.... Hydrothermal Vent Biology Symposium

Symposium Schedule

Sunday 19th October

18-19:00	Registration
19-20:00	Reception

Monday -Thursday 20-23th October

9:15-10:00	Official Inauguration , Conference Opening (Monday) Invited Speaker (Tuesday-Thursday)
10:00-10:30	Coffee
10:30-12:30	Morning Session
12:30-14:15	Lunch
14:15-15:00	Invited Speaker
15:00-18:00	Afternoon Session
18:00-20:00	Poster Session/Wine and Cheese

Friday 24th October

9:00-13:00	AMORES Team Post-cruise Meeting and/or
10:00	Whole-day Excursion to the north of the island
14:30	Half-day Excursion

Notes:

- Oral presentations will be allotted 15 minutes followed by 5 minutes for discussion.
- A banquet will be given by the Regional Government of Madeira.
- A half-day excursion may be scheduled mid-week depending on the number of contributed presentations.
- Lunch will be available from several restaurants within easy walking distance from the Conference Center. Average price per meal per person in Madeira is $10 USD (lunch) and $20 USD (dinner).

The new Marine Biological Station of Funchal will be officially inaugurated during the Conference. This event will take place around 18:30 (date not yet fixed) and all Symposium participants are invited to take part in it.

Education

Biology teachers from local high schools will be invited to attend the symposium through the Education Department of the Museum. Their participation will provide us with an excellent opportunity to disseminate knowledge of deep-sea biology and import a sense of its value to the community.

Workshop on InterRidge International Sample Exchange Agreement

There will be an formal session one evening to discuss parts of the InterRidge International Sample Exchange Agreement. This discussion will be led by Lauren Mullineaux and Daniel Desbruyères, co-chairs of the InterRidge Biological Studies *ad hoc* working group.

For further information please contact one of the above web sites, or the InterRidge Office at intridge@ext.jussieu.fr.

First Announcement

Conference on Marine Benthic Habitats and their Living Resources: Monitoring, Management & Application to Pacific Island

10-16 November 1997, Noumea, New Caledonia

Convenors: H. Gary Greene (MLML)
Gregor M. Cailliet (MLML) cailliet@mlml.calstate.edu
Jean-Marie Auzende (IFREMER) auzende@noumea.orstom.nc
Rene Grandperrin (ORSTOM)

Sponsors: IFREMER, ORSTOM, SOPAC, MLML, IOC/WESTPAC

Continued on next page...

Upcoming Meetings and Workshops.... Marine Benthic Habitats

The primary goals of this conference are to: 1) bring together geologists and biologists studying the relationship between marine geology and living marine resources, including marine biodiversity and fisheries; and2) provide a synthesis of the in situ technology available to study and monitor the benthic submarine environment. The ultimate goal is technology transfer to Pacific Island nations.

At the 1996 SOPAC (South Pacific Applied Geoscience Commission) meeting, it was strongly recommended by the island nations that a habitat conference be organised in the region. The government of France and its French Territory New Caledonia, through IFREMER (Institut Francais de Recherche pour l'Exploitation de la Mer) and ORSTOM (Institut Francais de Recherche Scientifique pour le Developpement en Cooperation), has agreed to host the conference in Noumea, New Caledonia. The conference is under the joint sponsorship of SOPAC and the IOC (Intergovernmental Oceanographic Commission), specifically its regional subsidiary body IOC/WESTPAC. Other sponsors are being encouraged to join. SOPAC will do the regional organising, working with the Territory of New Caledonia, IFREMER, ORSTOM and IOC/WESTPAC to help bring in participants from other countries and island nationals.

The two main subjects related to marine habitats are fisheries and biodiversity. It is well known that many marine fisheries around the world are declining radically. Thus, studies aimed at understanding the importance of fishery habitats are important for management purposes, especially if harvest refugia can be established to help replenish certain living resources. Pacific rim countries may need assistance in investigating their fishery habitats to develop sustainable resource use. In addition, biodiversity is a subject of international concern, resulting in formation of the Commission on Biological Diversity (CBD). Because human activities have deleteriously affected both terrestrial and marine habitats, there is concern that the diversity of species occupying these habitats will decline, perhaps even leading to extinction of some species.

Much pioneering work on marine habitats and their role in hosting myriads of species, some of which support fisheries, has been done in the USA, the UK, France, Canada, Australia and New Zealand. However, such research has just begun in the South Pacific. For example, since 1991, New Caledonia has been carrying out an EEZ (Exclusive Economic Zone) survey program, ZoNeCo, aimed at evaluating its potential marine resources using swath mapping surveys, physical oceanographic measurements and exploratory fishing.

The main objectives of the conference will be to: 1) inform participants of present-day methodologies for studying marine habitats, fisheries and biodiversity; 2) interpret case histories relative to South Pacific interests, demonstrating how these techniques have been applied to marine habitats (bays, lagoons, coral reefs, shelf and slope environments, seamounts and ridges); 3) identify crucial habitats and resources; 4) propose a training component, especially for South Pacific nationals, on such techniques as ROVs (Remotely Operated Vehicles), submersibles, acoustic surveys, GIS (Geographic Information Systems), GPS (Global Positioning Systems), etc., with the idea of developing these further in future sessions; and 5) establish the parameters for habitat monitoring systems to assist in management and sustainability of resources, giving consideration to the implementation of the Global Ocean Observing System (GOOS) in the region.

We envision a set of speakers from both temperate and tropical areas who have successfully combined geophysical techniques and biological investigations. They will present summaries of their research on marine habitat characterisation and how it relates to biological associations. Talks should concentrate on habitats and living resources that are similar to those encountered in the South Pacific so that technology transfer and management are enhanced. To maximise benefits to conference participants, South Pacific organisations, including SOPAC, IOC/WESTPAC, FFA (Forum Fisheries Agency), SPCFP (South Pacific Commission, Fishery Programme), SPOCC (South Pacific Organisations Coordinating Committee) and SPREP (South Pacific Regional Environmental Programme), should work together to assemble existing geophysical and living resource datasets for the region so they can be mutually used by both disciplines.

Below is a list, developed during our meetings in early 1996, that should serve as an outline of all the possible topics that could be covered in the 1997 SOPAC conference. We will refine this list after hearing from potential sponsors and participants.

Focuses:

- Lagoons and Bays
- Shallow Reefs
- Deep Reefs
- Shelf and Slope
- Seamounts and Ridges
- Deep-sea Trenches and Canyons

Continued on next page...

Upcoming Meetings and Workshops.... Marine Benthic Habitats

Technology and Methodoly to Assess Habitats and Resources:

- Geophysical Techniques (sub-bottom profiling, bathymetry, side scan sonar, etc.)
- Direct Observations (snorkelling, SCUBA (Self-Contained Underwater Breathing Apparatus), DOVs (Diver Operated Vehicles), Manned Submersibles,etc.)
- Remote Sensing (ROVs, satellite images such as the SPOT HRV, aerial photography, etc.)
- Optical Imaging
- Hydro-Acoustics
- Destructive Sampling (trawls, cores, dredges, etc.)
- Physical Oceanographic and Water Quality Measurement Tools (currents, salinity, temperature, oxygen, nutrients, chlorophyll, etc.)

Mangement and Conservation of Habitats and Resources:

- Characterisation and Quantification of Habitats
- Life History Studies of Dominant, Habitat-Specific Organisms
- Use of Habitats by Organisms (food, shelter, movements, etc.)
- Sustainability of Resources
- Effects of Natural and Anthropogenic Impacts (extraction, noxious species, harmful algal blooms, sedimentation, erosion, predator outbreaks, etc.)
- Harvest Refugia
- Social, Political and Economic Considerations

Interpretation and Analytical Techniques:

- Geographical Information Systems (GIS)
- Computer Interfacing and Analysis
- Mathematical Modelling
- Visualisation Techniques
- Environmental Impact Analyses
- Global Ocean Observing System (GOOS)

Report and Proposal Writing:

- Write Report of Conference
- Write Proposal to Initiate Work from Conference
- Evaluate Funding for Future Work
- Submit 1-3 to conference sponsors and potential donors.

Geological Association of Canada/ Mineralogical Association of Canada Joint Annual Meeting

Quebec City, Canada, 18-20 May 1998

Email:hebert@ggl.ulaval.ca http://www.ggl.ulaval.ca/quebec1998.html

The Geological Association of Canada/Mineralogical Association of Canada Joint Annual Meeting will be held in Quebec City on May 18th - 20th, 1998. Included in the scientific program are two field trips and one special session which will be devoted to the study of ophiolites. The pre-congress field trip will focus on Thetford Mines ophiolite which is one of the best preserved pieces of oceanic lithosphere in continental North America. The post-congress field trip will be held on Betts Cove ophiolite, Newfoundland, a world famous sequence of magmatic, volcanological and sedimentary features. The topic of the Special Session is: Ophiolites: Recent discoveries and implications for the genesis of the lithosphere.

The first notice will be released in April 1997 and the first circular in September 1997. Registrations will be made using the World Web Net system. For details see our home page: http://www.ggl.ulaval.ca/quebec1998.html or e-mail hebert@ggl.ulaval.ca.

Announcements...

Recent Publications

Publication of a special section on the TAG hydrothermal field in *Geophysical Research Letters*

Results of the international collaboration to monitor the TAG hydrothermal field on the Mid-Atlantic Ridge at 26°N, 45°W, are reported in a special section of 23 papers in *Geophysical Research Letters* (Vol. 23, no. 23, November 15, 1996) edited by Peter A. Rona(rona@ahab.rutgers.edu) and Richard P. Von Herzen (rvonh@red.whoi.edu). Theses papers report findings of a coordinated series of cooperative cruises and dives with Japanese, Russian and US submersibles between 1993 and 1995 that performed baseline measurements and established a seafloor observatory that monitored the active sulfide mound in the TAG field before, during, and after drilling by Ocean Drilling Program Leg 158 in October-November 1994. The papers are of broad interest with reference to innovative monitoring methods and the response of a major hydrothermal field on a sediment-free ocean ridge to drilling.

Mid-Ocean Ridges: Dynamics of Processes Associated with Creation of New Ocean Crust

Published by the Royal Society as Philosophical Transactions: Mathematical, Physical and Engineering Sciences, Series A, Volume 355, Number 1723, 15 February 1997

The proceedings of the Discussion Meeting held at the Royal Society 6-7 March 1996. The discussion and volume were organized and edited by J. R. Cann, H. Elderfield and A. Laughton.

For ordering details see the following web pages: **www.pubs.royalsoc.ac.uk** or **www.royalsoc.ac.uk/rs**

Contents

The Handbook of Seafloor Sonar Imagery

Philippe Blondel and B. Murton
Southampton Oceanography Centre, Southampton, SO14 3ZH, UK

Exploration of the deep seafloor has made huge advances in the last decades. These steps ahead have been made possible in large part by the development of sonars and digital processing. Sonar imagery has enabled the scientific community to discover the wide variety of geological environments present on the seafloor. Yet, sidescan sonar is not always straightforward to use and interpret, and there was no comprehensive text on the subject.

The *Handbook of Seafloor Sonar Imagery* aims to fill this gap. The first of its kind, this book is targeted at scientific readers from a postgraduate level onward. The first chapters of the book explain the different kinds of sonar, their modes of operation, and the different levels of processing achievable (in theory and in practical applications). Synthetic tables present the technical characteristics of instruments, and allow easy comparisons between their capabilities for each type of objective and survey.

Most of the book is devoted to geological interpretation of sonar images, and to the reasoning which led to each interpretation. Based on many types of different sonars from around the world, these examples show all types of seafloor environments: deep-ocean trenches and collision margins (Chapter 4), mid-ocean ridges (Chapter 5), abyssal plains (Chapter 6), continental margins (Chapter 7), coastal, Arctic and in-shore environments (Chapter 8).

The last two chapters of the book focus on the recognition of image anomalies and sonar artifacts (how to detect them, and how to avoid them if possible), and on the growing field of Computer-Assisted Interpretation (including Geographical Information Systems, expert systems, and image processing).

The *Handbook of Seafloor Sonar Imagery* was published by Wiley-Praxis in March 1997, and is available at the price of 65£ (317 pp., hardback). More information about this book is available from the author (pbo@soc.soton.ac.uk) or from the publisher: John Wiley and Sons Ltd., Baffins Lane, Chichester PO19 1UD, UK (cs-books@wiley.co.uk; http://www.wiley.co.uk).

Erratum

Two errors have been detected in the paper :

"A geophysical and geochemical study of the Pacific-Antarctic Ridge south of Udintsev FZ : The Pacantarctic cruise with *R/V L'Atalante*", L. Géli et al, *InterRidge News,* Vol 5(2), Fall/Winter 1996

page 36 : Please replace the paragraph :

"Our data also indicate that the Hollister Ridge is not a chain of well defined, circular volcanoes. Instead, it is a quasi linear structure, extending over about 240 milles, 3000 meters high, and 13 miles wide at its base. This edifice seems to have a flat top that regularly widens towards the north-west."

with :

"Our data also indicate that the Hollister Ridge is not a chain of well defined, circular volcanoes. Instead, it is a quasi linear structure, extending over about 240 miles and deepening towards the North-East. It consists in a series of three volcanic constructions of elongated shape, trending N310 approximately. The central construction is 115 miles long, 3000 meters high, and 13 miles wide at its base. This latter edifice seems to have a flat top that regularly widens towards the north-west."

page 38 : In the caption of Figure 2, please replace :

"Depths are plotted vs distance (in km x 100) from the northern Euler pole of rotation related to the Pacific and Antarctic plates motion"

by :

"Depths are plotted vs distance (in km x 100) along the ridge axis, starting from an arbitrary origin."

Announcements...

French-US Collaboration on Oman Ophiolite Studies

Benoît Ildefonse

Laboratoire de Tectonophysique, CNRS, ISTEEM, Université de Montpellier II,34095 Montpellier Cédex 05, France

A new project on the Oman ophiolite, funded by CNRS and NSF, involves researchers from France (Benoît Ildefonse and David Mainprice, Montpellier University) and from the US (Douglas Toomey, University of Oregon, Eugene; William Wilcock, University of Washinton, Seattle and Steven Constable, Scripps, San Diego). The project is entitled "Small-scale electrical and seismic study in the Oman ophiolite: 3D extension of the structure mapping at the Oman paleo-spreading ridge", and its primary objective is to apply small-scale seismic and electrical methods to the Oman ophilite to study the bulk physical properties of the rocks (peridotites and gabbros) and sub-surface structures. The field work in Oman will collect near-surface seismic reflection/refraction and electrical sensitivity data over both crustal and mantle sections in order to characterize their seismic and electrical properties. Because of post-emplacement processses, such as weathering, the mantle section of the ophiolite appears to be much more porous than the crustal section. Its *in situ* seismic properties are not easily predicted, although it is expected to be be less resistive. We will quantify the seismic and electrical contrast between the sections *in situ* using standard methods and attempt to map the Moho at shallow depths. Knowledge of the regional paleo-Moho structure at depth will extend the existing surface geologic mapping into the third dimension and also allow comparison with geophysical studies conducted at sea. The anisotropy of seismic and electrical properties will be measured and compared with the same properties calculated from petrofabric data in order to estimate the effect of weathering and cracks. The project is also of economical interest to Oman because the porous mantle section is an aquifer in this region. After a succesful reconnaissance trip held last February, the field work is planned for February 1998.

Call for Piggy-Back/Host Proposals

The InterRidge Office proposes to act as a broker, matching projects which may be 'piggy-backed' with funded and scheduled cruises that have available time and space.

Proposals of both piggy-back projects and ship time will be published in InterRidge News and on the InterRidge World Wide Web Home Page (http://www.lgs.jussieu.fr/~ intridge). Proposal submission should include:

for ship time proposed:
- objectives and dates of the planned cruise
- ports of call, location of study
- equipment to be employed/deployed
- space (deck, lab, accommodation) and time available

for piggy-back project proposed:
- objectives and time required
- shipboard equipment/facilities required
- what equipment will be brought on board
- space required
- preferred location(s)

Submissions and enquiries should be directed, preferably by e-mail, to the InterRidge Office at intridge@ext.jussieu.fr.

InterRidge Researcher Electronic Directory/Mailing List

This form may be used to add your name to the InterRidge Researcher Electronic Directory, the mailing list, the electronic mailing list and/or as notification of change of address. The InterRidge Researcher Electronic Directory contains a listing of each researcher's field of interest and expertise as well as their full address information. The Directory is accessible on the World Wide Web via the InterRidge Home Page (http://www.lgs.jussieu.fr/~intridge) making it possible to carry out effective searches quickly and easily. If you would like to be listed in the directory please complete this form and send it to the InterRidge Office.

Please indicate whether you would like your name to appear on ☐ International Ridge Researcher Electronic Directory, ☐ the mailing list, ☐ the electronic mailing list (be sure to include your e-mail address), ☐ The Ridge Crest Biologist Directory. ☐ This is a change of address notice.

Name ______________________

Department/Institute ______________________

Address ______________________

____

City ______________ **State/County** ______________

Post Code ______________ **Country** ______________

Tel.: ______________ (country code, area code, number) **Fax.:** ______________ (country code, area code, number)

e-mail: ______________________

Name of your national ridge research program: ______________________

Which InterRidge Program Theme(s) is of interest to you?

☐ Active Processes ☐ Meso-Scale Studies ☐ Global Studies

What are your fields of interest/expertise?

☐ Biochemistry	☐ Gravity	☐ Plate kinematics
☐ Biogeography	☐ Heat Flow	☐ Rheology
☐ Biology	☐ Hydrology	☐ Seafloor Morphology
☐ Crustal structure	☐ Hydrothermal vents/plumes	☐ Sedimentology
☐ Ecology	☐ Larval Dispersion	☐ Seismology
☐ Electromagnetism	☐ Magnetism	☐ Structural geology
☐ Engineering/Instrumentation	☐ Microbiology	☐ Sulfide Ores
☐ Event detection and response	☐ Modelling	☐ Tectonics
☐ Genetics	☐ Ophiolites	☐ Volcanology
☐ Geochemistry	☐ Petrology	☐ Other ______

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The InterRidge Office
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