Vol. 10 (2) Fall 2001

InterRidge News

Initiative for international cooperation in ridge-crest studies

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United States

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InterRidge News is published twice a year by the InterRidge Office, Ocean Research Institute, University of Tokyo, 1-15-1 Minamidai, Nakano, Tokyo 164-8639, Japan. Editors: Agnieszka Adamczewska and Marek Kaczmarz.
Tel: +81 3 5351 6820; Fax: +81 3 5351 6530; E-mail: intridge@ori.u-tokyo.ac.jp http://www.intridge.org

InterRidge Office Updates

Contents continued...

Errata sheet for InterRidge news, Spring 2001 issue, vol. 10.1

☞ Pp. 11. New IR Hotspots-Ridge Interactions working group is incomplete, the following two members were omitted: Dr. Garrett T. Ito (USA), Dr Lucy M MacGregor (U.K.).

☞ Pp. 71. Dr. Graciano P. Yumul, Jr. (The Philippines) is missing from the list of the InterRidge National Correspondents.

☞ Pp. 72 Dr Jian Lin (USA) is not listed as a member of the InterRidge Steering Committee. Dr Lin is the chair of the Hotspots-Ridge Interactions Working Group and is an ad hoc member of the IR Steering Committee.

InterRidge Office Updates

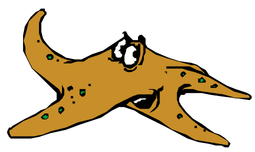
The InterRidge Wishhhhhh List....

On suggestion of the IR Steering Committee, we have opened the InterRidge Wishhhhhhh list to facilitate and porom ote sample exchange between ridge scientists. Please submit requests for samples, to the IR Office. I would like to encourage all ridge scientist to check the Wishhhh list and share samples with your international colleagues. The success of this initiative is dependent on YOU! Below are three requests for samples. If you have such samples to share, please contact the appropriate scientists.

I wish I could get my hands on ....
Requested samples.....

Request for:
CHIMNEY SAMPLES

Samples of manganese encrusted chimneys as well as hydrothermal or hydrogenous ferromanganese samples and associated sediments collected from any other midoceanic ridge system".
Contact: Ranadip Banerjee
<banerjee@darya.nio.org> or
<banerjee@csnio.ren.nic.in>



SEARCH FOR GRAPHITE

Sediment trap deposits collected nearby vents, and/or grab samples of particulates from vents (0.0X to 1 gram quantities). Old collections are OK.
If such materials are available in your drawers, please contact: Jacques Jedwab
<jjedwab@ulb.ac.be>

ROCK SAMPLES
Rock samples from Laxmi Basin, Laxmi continental block or any protruding seamounts in eastern Arabian sea for physical/chemical studies
Contact: A. Shivaji (ashivaji@hotmail.com)

Wishhhhhh list ....

Would you like to get your hands on certain samples; be they rocks, crabs or tubeworms!
Send your 'wish list' to the InterRidge office and we will post it on the IR website and print it in the next issue of IR news.
Cooperation is the key to good science!

InterRidge Office Updates

Coordinator's Update

Member Nations

The membership of Nations actively involved in InterRidge activities continues to grow. This year, Korea has joined InterRidge as an Associate Member nation. Dr Sang-Mook Lee, from the Deep-Sea Resources Research Center is the Steering Committee representative for Korea. This brings the total number of countries actively involved in InterRidge to eleven. Additionally, Austria has joined as a corresponding member for the first time, with the hope of upgrading their membership status with InterRidge in the near future. Monica Bright is the national correspondent for Austria.

The continually increasing number of nations actively involved in InterRidge will ensure that a highly international ridge community will utilise their expertise to define and refine scientific questions and focus interests, thereby, strengthening the InterRidge programme and the future "Project plan". As a consequence, the highly international planning process will be of direct benefit to individual scientists and national programs for the nations involved, while at the same time the "Project plan" will provide opportunities for the involvement of other nations. For more information read about Next Decade Workshop, below.

Upcoming InterRidge meetings

The number of InterRidge workshops, and other meetings continues to increase. An ever increasing demand to pool resources and expertise, on an international level, in order to maximise research output and minimise costs for individual nations is the driving force for organising more international meetings.

InterRidge MOMAR Workshop

The 2nd MOMAR workshop will take place in June 2002, in the Azores, Portugal. See also the advertisement in the back of this issue. The latest information can be obtained from the IR website.

The 2nd International Symposium on Deep-sea Hydrothermal Vent Biology

The 2nd International Symposium on Hydrothermal Vent biology, Brest, France was a huge success. Extended abstracts from this meeting will be published in the Cahiers De Biologie Marine (CBM) in 2002.

InterRidge Theoretical Institute (IRTI): Thermal Regime of Ocean Ridges and the Dynamics of Hydrothermal Circulation

The first ever IRTI will have a short course component, which will focus on the modelling aspects of the dynamics of hydrothermal circulation in the crust, a field excursion and a workshop component to synthesize the current models, debate controversies, and outline the future directions for collaborative research. The IRTI will be held 9-13 September 2002, at the University of Pavia, Italy, for more information see the back of this issue of IR news or look on the IR website.

SWIR Workshop

A workshop to synthesise current knowledge and identify areas, both disciplinary and geographically that require investigation and decide on future direction of research in this area is scheduled for 17-19 April, 2002 at SOC, UK. Abstract submission deadline is 15 January.

Next Decade Workshop

The aim of this workshop will be to devise a new InterRidge "Project plan" for the next decade. The current InterRidge programme is nearing the end of its 10 year plan and it is time for the international community to convene together and develop the "Next Decade" InterRidge Science Plan. Representatives from Principal and Associate member nations have formed the "Next Decade working group" and will develop the "Next Decade Project Plan" based on the discussions during the Next Decade Workshop, 10-12 June 2002, Bremen, Germany. All of the International Ridge Community is encouraged to submit white papers with ideas and opinions to the InterRidge Office (intridge@ori.u-tokyo.ac.jp) with their views about the next decade of international Ridge research.

InterRidge Steering Committee meeting

The next Steering Committee meeting will be hosted by Dr Riccardo Tribuzio, 13-14 September 2002, Italy.

Steering Committee

Chris Fox has finished his term as the Chair of the Event Detection and Response and Observatories Working Group. Thank you to Chris for his work with InterRidge. This Working Group has been renamed as "Monitoring and Observations Working Group" and is now Co-Chaired by Javier Escartin (France) and Ricardo Santos (Azores, Portugal), both of whom will become ad hoc steering committee member from next year.

Working Groups

At the last Steering Committee meeting, the Working Group "Event Detection and Response and Observatories" was renamed to "Monitoring and Observations Working Group" and is now Co-Chaired by Javier Escartin (France) and Ricardo Santos (Azores, Portugal). The main objective of this working group is to organise the second MOMAR workshop and to follow though with establishing observatories on the sea floor.

The Biology working group met

InterRidge Office Updates

in Brest, France during the IR Hydrothermal vent Symposium. Possible topics of future work were discussed and are summarised on page 10 of this issue.

InterRidge Outstanding Student Presentations

The IR Steering committee has decided to encourage students involved in Ridge research by awarding certificates of Excellence and prize money to best student presentations at IR meetings. The first such meeting where the IR Outstanding Student award was handed out was The 2nd International Symposium on Deep-sea Hydrothermal Vent Biology. The competition was tough and from over 40 students, the best presentations were awarded to Florence Pradillion (France) and Jason Flores (USA). Congratulations to you both! Background about both students is provided below and abstracts of their presentations are included on page 13 of this issue of IR news.

Students are encouraged to participate in future IR meetings and to present their work. Outstanding Student Awards will be given out during the upcoming SWIR workshop (UK) and the IRTI (Italy, 2002).

InterRidge homepage

We are continuing to upgrade and improve our web site to maximise information transfer and make it user friendly. To make our homepage more interactive we have divided it into two frames. The latest information about meetings, announcements and any other current, ridge related items is now at your fingertips, accessible directly from the left hand side frame on our homepage. The larger, right hand side frame contains the familiar menus with lots of ridge related information. Due to the volume of information on our website a brief outline of what can be found there is provided on page 9 of this issue as well as being available from our website at the following URL: http://www.intridge.org/latest.htm

We encourage you to make use of our website and all the information that is available there. As always, any comments and suggestions are welcome and remember that I always like to receive updates and new information about meetings and ridge related cruises, as well as job vacancies and other ridge related bits and pieces of information.

Agnieszka Adamczewska
InterRidge Coordinator
November 2001

IR Outstanding Student Award Winners

at the 2nd International Symposium on Deep-sea Hydrothermal Vent Biology

Florence Pradillion received a "Magistère" of cellular and molecular biology (University Claude Bernard, Lyon), and a "DEA" of Physiology of Invertebrates (University Pierre et Marie Curie, Paris). She started her DEA project in 1999 in the group of Marine Biology of Françoise Gaill at the University Pierre et Marie Curie. This project was on Alvinella pompejana reproduction and development. After that, she started her PHD thesis on the same project and is expecting to finish her PHD in October 2002.

Jason Flores graduated in 1995 from the College of Charleston in South Carolina (USA) with a Bachelor of Science in Biology. While there he was involved in several research projects including one of his own on the behavioral ecology of Tursiops truncatus (the bottlenosed dolphin) under the direction of Prof. Phillip Dustan. Following graduation, Jason participated in an international research program conducted at Kristineberg Marine Research Station (Sweden) during which he became interested in comparative invertebrate physiology. Jason returned to the US to attend graduate school at Moss Landing Marine Laboratories (CA) where he worked with Prof. James Nybakken studying the respiratory adaptations of the deep-sea pennatulid Umbellula lindahli to low oxygen environments. During this time Jason taught invertebrate zoology labs at MLML and also worked part-time as an intern for the Monterey Bay Aquarium helping to develop and maintain their deep-sea exhibit. Jason completed his Master of Science in Marine Science (San Francisco State University) in 1999 and moved on to Penn State University to work with Prof. Chuck Fisher on the structural and functional characteristics of the hemoglobins of the polymorphic tubeworm, Ridgeia piscesae, from the Juan de Fuca Ridge. His research has been supported by a Penn State Graduate Fellowship and the NOAA West Coast National Undersea Research Center as well as the National Science Foundation.

Abstracts of these outstanding presentations are on page 13 of this issue of InterRidge news.

InterRidge Office Updates

InterRidge Publications

The following InterRidge publications are available upon request. Fill out an electronic request from at http://www.intridge.org/act3.html
or contact the InterRidge office by e-mail at intridge@ori.u-tokyo.ac.jp

InterRidge News:

Past issues of InterRidge News, are avalable starting with the first issue published in 1992 until the present. Information about the research articles published in each issue can be found on the InterRidge website:
http://www.intridge.org/irn-toc.htm

The InterRidge News issues published from 2000 (ie. InterRidge News 9.1 and all following issues) are available as downloadable PDF files from the same URL address on the InterRidge website, using Adobe Acrobat 4.0 or later versions.

Workshop and Working Group Reports:

InterRidge MOMAR (MOnitoring the Mid-Atlantic Ridge) workshop report, April, 1999.
InterRidge Mapping and Sampling the Arctic Ridges: A Project Plan, pp.25, December 1998.
ODP-InterRidge-IAVCEI Workshop Report: The Oceanic Lithosphere and Scientific Drilling into the 21st Century, pp.89.
InterRidge Global Working Group Workshop Report: Arctic Ridges: Results and Planning, pp.78, October 1997.
InterRidge SWIR Project Plan, pp.21, October 1997 (revised version).
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 Ridge 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 Meso-Scale Workshop Report: 4-D Architecture of the Oceanic Lithosphere, pp.15, May 1995.
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 Global Working Group Report 1994: Indian Ocean Planning Meeting Report, pp.3, 1994.
InterRidge Meso-Scale Working Group Meeting Report, Cambridge, UK, pp.6, 1992.

Workshop and Symposium Abstract Volumes:

InterRidge Workshop: MOMAR (MOnitoring the Mid-Atlantic Ridge) Abstract Volume, pp.82, Oct. 1998.
InterRidge Workshop: Mapping and Sampling the Arctic Ridges Abstract Volume, pp.30, Oct. 1998.
First International Symposium on Deep-Sea Hydrothermal Vent Biology Abstract Volume, pp. 118, Oct. 1997.
Fara-InterRidge Mid-Atlantic Ridge Symposium Results from 15°N to 40°N. J. Confer. Abs. 1(2), 1996.
ODP-InterRidge-IAVCEI Workshop: The Oceanic Lithosphere and Scientific Drilling into the 21st Century, pp.126, 1996.

Steering Committee and Program Plan Reports:

InterRidge STCOM Meeting Report, Kobe, Japan, 2001.
InterRidge STCOM Meeting Report, WHOI, USA, 2000.
InterRidge STCOM Meeting Report, Bergen, Norway, 1999.
InterRidge STCOM Meeting Report, Barcelona, Spain, 1998.
InterRidge STCOM Meeting Report, Paris, France, 1997.
InterRidge STCOM Meeting Report, Estoril, Portugal, 1996.
InterRidge STCOM Meeting Report, Kiel, Germany, pp.22, 1995.
InterRidge STCOM Meeting Report, San Francisco, USA, 1994.
InterRidge STCOM Meeting Report, Tokyo, Japan, 1994.
InterRidge STCOM Meeting Report, Seattle, USA, pp.6, 1993.
InterRidge Meeting Report, York, UK, 1992.
InterRidge Meeting Report, Brest, France, pp.39, 1990.
InterRidge Program Plan Addendum 1997, pp.10, January 1998.
InterRidge Program Plan Addendum 1996, pp.10, April 1997.
InterRidge Program Plan Addendum 1995, pp.10, 1996.
InterRidge Program Plan Addendum 1994, pp.15, 1995.
InterRidge Program Plan Addendum 1993, pp.9, 1994.
InterRidge Program Plan, pp.26, 1994.

InterRidge Mailing List Sign up Form

Or sign up on the web at:

http://www.intridge.org/signup.htm

You can use this form to join our regular mailing list to receive InterRidge News, or to be placed on our electronic mailing list and to be put on the electronic directory on the web (http://www.intridge.org). Currently there are over 2800 scientists active in mid-ocean ridge research on our mailing list. The electronic directory contains a listing of each researcher's field of interest and expertise as well as their full address information. Links are also provided to personal or departmental web pages.

Indicate whether you would like to

- ☐ receive electronic notices and information (include your e-mail address)
- ☐ receive the IR news and be on our mailing list
- ☐ this is a change of address notice

Name (Title, First, Last)

____

Department/Institute ________________________________

Address _______________________________________

____

City __________________ State/County __________________

Post Code __________________ Country __________________

Phone: __________________ Fax: __________________

(country code) (area code) number (country code) (area code) number

E-mail: _______________________________________

WWW: _______________________________________

What are your fields of interest/expertise?

☐ Back-Arc Basins	☐ Gravity	☐ Plate kinematics
☐ Biochemistry	☐ Heat Flow	☐ Rheology
☐ Biogeography	☐ Hydrology	☐ Seafloor Morphology
☐ Biology	☐ Hydrothermal vents/plumes	☐ Sedimentology
☐ Crustal structure	☐ Larval Dispersion	☐ Seismology
☐ Ecology	☐ Law/Policy	☐ Structural geology
☐ Electromagnetism	☐ Magnetism	☐ Sulfide Ores
☐ Engineering/Instrumentation	☐ Microbiology	☐ Tectonics
☐ Event detection and response	☐ Modeling	☐ Undersea Technology
☐ Genetics	☐ Ophiolites	☐ Volcanology
☐ Geochemistry	☐ Petrology	☐ Other ________

Send to (address also on the reverse side): InterRidge Office, Ocean Research Institute, University of Tokyo, 1-15-1 Minamidai, Nakano, Tokyo 164-8639, Japan

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InterRidge Office Updates

InterRidge Website

http://www.intridge.org/

The InterRidge office maintains an extensive web site containing various types of information including upcoming meetings, scheduled ridge related cruises, job vacancies as well as 9 different databases. These databases on the InterRidge website were initiated in response to a request by the international community to have a 'centralised' clearing house for information collected by scientists all over the world so that relevant information is readily available to everybody at one site. A brief summary of what can be found on the InterRidge website is available at:
http://www.intridge.org/latest.htm

We are pleased that the use of the InterRdige website is steadily increasing and we continue to encourage you make use of this resource and to continue to submit the latest information to our office. To make our homepage more interactive we have divided it into two frames. On the left hand side frame you now have at your fingertips the latest information about meetings, announcements and any other current, ridge related items. The right hand side frame contains the familiar menus, the general contents of which are outlined below. As always any comments and suggestsions are always welcome.

The new alias for the IR website makes the URL easy to remember, you can now access the InterRidge home site by simply typing http://www.intridge.org

1) Information section

This section provides links to Ridge related meetings, cruises and other miscellaneous information, as well as a little bit about InterRidge structure and its role, including: Latest ridge related News; an introduction to what is InterRidge, with a short description of the InterRidge programme, outlining the objectives of the programme as well as management structure and national membership of InterRidge; as well as a calendar of international conferences, meetings and workshops.

2) Activities section

This section is concerned with the scientific and management structure of InterRidge. The menus in this section are relatively unchanged from the ones that were present on the original home page. This section includes an outline of the scientific purpose of InterRidge; a description of the activities of the IR working groups, which are responsible for directing different aspects of ridge research. An outline of the current working groups and updates of their activities can be found here. Here you can also find links to major projects that InterRidge is currently involved in and projects that are directly relevant to InterRidge activities - such as MOMAR and Marine Protected Areas project. Additionally, in this section, you can find a list of all the publications distributed by the InterRidge office as well as a list of the InterRidge National Correspondents, and their contact details, from all of our Member Nations.

3) InterRidge databases section

One of the major objectives of InterRidge is to facilitate the advancement of ongoing work of individuals, national and international groups by providing centralised information and data-exchange services. Thus, we maintain a number of databases that contain data submitted from Ridge scientists from around the world. We rely on contributions from individuals to continuously update the information and increase the number of records. I would like to take this opportunity to encourage everyone to become familiar with the databases on our website and contribute information on a regular basis to ensure that this important resource contains current and up to date information. A list of the databases maintained by InterRidge with a brief introduction can be found on our web site at:
http://www.intridge.org/data1.html

The IR office also maintains a database with contact details of scientists involved in ridge reserach. To add your name and contact details to the electronic database just click on the "Mailing list sign up" on the home page and fill in the signup form.

Furthermore, you can calculate the spreading rate of the sea floor at any place around the globe!

Hydrothermal Ecological Reserves Page:
http://www.intridge.org/reser-db.htm

This page lists all the current ecological reserves that have been proposed at hydrothermal vents. These vary in breadth and scope; at Juan de Fuca the Canadian government has proposed the Endeavour vent field as a pilot marine protected area, while other reserves consist of requests from individual scientists conducting experiments in specific areas. There is also an on-line form to submit reserves to the page.

InterRidge Office Updates

Overview of InterRidge Working Groups

More information on working groups can be found on our website;
http://www.intridge.org/act2.html

Arctic Ridges
Objective: Coordinate planning efforts for mapping and sampling the Arctic Ridges.
Current Activities: Coordination of international cruise to the Gakkel Ridge in 2001.
Chair: Colin Devey (Germany)
WG members: G.A. Cherkashov (Russia), B.J. Coakley (USA), K. Crane (USA), O. Dauteuil (France), V. Glebowsky (Russia), K. Gronvold (Iceland), H.R. Jackson (Canada), W. Jokat (Germany), Y. Kristoffersen (Norway), P.J. Michael (USA), K.J. Young (Korea), N.C. Mitchell (UK), H.A. Roeser (Germany), H. Shimamura (Japan), Y. Nogi (Japan), C.L. Van Dover (USA).

Back-Arc Basins
Objectives: Summarize past work on Back-Arc Basins and coordinate future studies.
Current Activities: Compiling report on past work in Back-Arc Basins.
Chair: Sang-Mook Lee (Korea)
WG members: Ph. Bouchet (France), J.-L. Charlou (France), K. Fujioka (Japan), E. Grácia (Spain), P. Herzig (Germany), J. Ishibashi (Japan), Y. Kido (Japan), S-M. Lee (Korea), R. Livermore (UK), S. Scott (Canada), R.J. Stern (USA), K. Tamaki (Japan), and B. Taylor (USA).

Global Digital Database
Objective: Establish a database of global multibeam bathymetry and other data for mid-ocean ridges and back-arc basins.
Current Activities: Compiling data.
Chair: Philippe Blondel (UK)
WG members: J.S. Cervantes (Spain), C. Deplus (France), M. Jakobsson (Sweden), K. Okino (Japan), M. Ligi (Italy), R. Macnab (Canada), T. Matsumoto (Japan), K.A.K. Raju (India), W. Ryan (USA), and W. Weinrebe (Germany).

Biological Studies
Objectives: Objectives of the New biology WG are outlined on page 11 of this issue of IR news.
Chairs: F Gaill (France) and S.K. Juniper (Canada).
WG members: M. Biscoito (Portugal), O. Gierre (Germany), J-H. Hyun (S. Korea), A. Metaxas (Canada) T. Shank (USA), K. Takai (Japan), P. Tyler (UK) and F. Zal (France)

Global Distribution of Hydrothermal Activity
Objectives: Target key areas of the global MOR that should be explored for hydrothermal activity and coordinate international collaboration to explore them.
Current Activities: Organizing the InterRidge Theoretical Institute on the Thermal regime of Ocean Ridges and the Dynamics of Hydrothermal Circulation to be held 9-13 September 2002, Italy.
Chair: Chris R. German (UK)
WG members: E. Baker (USA), Y.J. Chen (USA), D. Cowan (UK), T. Gamo (Japan), E. Grácia (Spain), P. Halbach (Germany), S.-M. Lee (Korea), G. Massoth (N.Z), J. Radford-Knoery (France), A-L. Reysenbach (USA), D.S. Scheirer (USA), S.D. Scott (Canada), K.G. Speer (USA), C.A. Stein (USA), V. Tunnicliffe (Canada) and C.L. Van Dover (USA).

Hot Spot-Ridge Interactions
Objectives: This WG was formed during the 2000 Steering Committee meeting to promote and facilitate global research to better understand the physical and chemical interactions between mantle plumes and mid-ocean ridges and their effects on seafloor geological, hydrothermal, and biological processes.
Current Activites: The agenda for this new WG is being developed.
Chair: J. Lin (USA)
WG members: R.K. Drolia (India), J. Dyment (France), J. Escartín (France), J. Freire Luis (Portugal), E. Grácia (Spain), D.W. Graham (USA), K. Hoernle (Germany), G.T. Ito (USA), L.M. MacGregor (UK) N. Seama (Japan), F. Sigmundsson (Iceland)

Monitoring and Observatories
Objectives: Develop detection methods of transient ridge-crest seismic, volcanic and hydrothermal events, and the logistical responses to them.
Current Activites: Organisation of the second MOMAR workshop. Objectives of the workshop are listed on page 12 of this issue of IR news.
Chairs: Javier Escartin (France) and Ricardo Santos (Azores, Portugual)
WG member: K. Mitsuzawa (Japan)

SWIR
Objective: Coordinate reconnaissance mapping and sampling of the Southwest Indian Ridge.
Current Activities: Organisation of the SWIR workshop.
Chair: Catherine Mével (France)
WG members: M. Canals (Spain), C. German (UK), N. Grindlay (USA), C. Langmuir (USA), A. Le Roex (South Africa), C. MacLeod (UK), J. Snow (Germany), T. Kanazawa (Japan) and C.L. Van Dover (USA).

Undersea Technology
Objective: Foster the development of undersea technology and disseminate information about it.
Chair: Spahr C. Webb (USA)
WG members: J.R. Delaney (USA), H. Momma (Japan), J. Kasahara (Japan), M. Kinoshita (Japan), A. Schultz (UK), D.S. Stakes (USA), P. Tarits (France) and H. Villinger (Germany).

Updates on InterRidge Projects

SWIR Working Group

Catherine Mével (mevel@ccr.jussieu.fr)

Laboratoire de Geosciences Marines, Université Pierre et Marie Curie, France

Ten years ago there was very little knowledge about this ultra slow ridge. Now we have complete bathymetric coverage of the ridge from the RTJ to the BTJ. This is a major achievement which has been facilitated by the InterRidge programme. In parallel to the mapping, a systematic sampling of the ridge axis has been conducted. It is now possible to evaluate the influence of the Marion and Bouvet hotspots on the ridge, both on the morphology and the chemistry. however, seismic studies are still required to understand the deep structure of the ridge.

Hydrothermal activity along this ridge is still very poorly known. Several nephelometry signals have been documented with MAPRs mounted on the TOBI cable between 58° and 65°E. Moreover, dead chimneys have been collected at 64°E. Hydrothermal deposits associated with serpentinites have also been documented in the eastern portion of the ridge. To date, however, no active field with associated biology has been observed. Further studies are required to get some idea about the distribution of hydrothermal activity on this ultra slow spreading ridge.

A workshop to synthesise the current knowledge gained and to decide future research on the Indian Ridge has been scheduled. The SWIR working group will be terminated at the workshop to be held in April 17-19, SOC, UK.

Biology Working Group

Kim Juniper[1] (juniper.kim@uqam.ca) and Françoise Gaill[2] (francoise.gaill@snv.jussieu.fr)

[1]GEOTOP, Université du Québec à Montréal, Canada
[2]Laboratoire de Biologie Marine, Université Pierre et Marie Curie, France

InterRidge Biology WG Meetings

The InterRidge Biology Working Group met in Brest, France on October 7, during the the InterRidge Hydrothermal Vent Biology Symposium. Members discussed possible topics for future work of the newly reconstituted working group and identified the following items for near-term action:

1) Code of Conduct/Best Practices Statement

As a follow-up to the InterRidge Workshop on the Management and Conservation of Hydrothermal Vent Ecosystems, members agreed to develop a brief Code of Conduct or Statement of Best Practices for future research activities at deep-sea hydrothermal vents. The document will be limited to proposing practices for research activities only. However, members agreed that development of such a code and adherence to it would aid in establishing the InterRidge as an authority for the provision of advice on management and conservation of vent ecosystems to regulatory agencies and to industries, such as ecotourism, bioprospecting and deep-sea mining. A draft code/statement will be circulated amongst WG members over the next few months, with the goal of producing a final document by 1st March, 2002.

An open discussion on conservation issues was held during the Hydrotherm al Vent Biology Symposium in Brest, on the evening of October 10. More than 80 symposium participants attended the discussion that began with a brief presentation of legal and jurisdictional aspects of deep-sea conservation by Lyle Glowka. Mr. Glowka is an environmental lawyer specialising in applications of the Biodiversity Convention and the Law of the Sea Convention to conservation issues.

2) Data Base/Inventory

Members agreed to examine once again the possibility of establishing a data base and inventory of biological collections from hydrothermal vent ecosystems. This idea dates back to the formation of the original Biology WG. Voluntary participation has been disappointing despite the potential value of the data base for fostering collaborations and sharing of samples, potentially reducing sampling impact on heavy-use areas and providing opportunities for research to scientists without access to deep submergence facilities.

Members agreed to explore the

Updates on InterRidge Projects

possibility of obtaining funding from a private foundation, to develop the data base, placing emphasis on the contribution of the effort to knowledge of marine biodiversity. Funding would be used to hire a post-doc to visit laboratories holding significant collections of vent organisms and develop a data base.

3) Remote Observation Applications for Biology - Workshop

Members pointed out the need for vent biologists to catch up with other disciplines in developing techniques and approaches that would allow them to take advantage of cabled and autonomous seafloor observatories that are presently at various stages of development and planning. A location and date for an InterRidge workshop on "Remote Seafloor Observation Tools and Applications for Hydrothermal Vent Biology" will be explored by the WG over the coming weeks, with the goal of holding a workshop with the next year.

MOMAR

Javier Escartin[1] (escartin@ccr.jussieu.fr) and Ricardo Serrão Santos[2] (ricardo@dop.uac.pt)

[1]Laboratoire de Géosciences Marines, Université Pierre et Marie Curie, Paris, France
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II MOMAR Workshop – Towards planning of seafloor observatory programs for the MAR region. June 2002, Horta (Azores, Portugal)

The mandate of MOMAR (MOnitoring the Mid Atlantic Ridge) is to encourage multidisciplinary studies at the Mid-Atlantic Ridge, with the ultimate goal of developing observatory-type efforts on the Azores area, encompassing the Lucky Strike, Menez Gwen and Rainbow hydrothermal vents, to characterize this portion of the ridge and understand the integration of tectonic, volcanic, biological and hydrothermal systems in space and time. The chosen site is logistically favourable for repeated or permanent observations due to its close proximity to the Azores islands (Lucky Strike<200nm from Faial island). Background information on the area of interest and on scientific goals of the MOMAR project may be found in the Scientific Report of the first MOMAR Workshop (Lisbon, Portugal, 1998): http://triton.ori.u-tokyo.ac.jp/~intridge/momar/report.htm

The immediate task is the organization of a II MOMAR Workshop, that will take place in May 2002 in Horta (Azores, Portugal), hosted by the University of the Azores, IMAR and the ISR - Associated Laboratory. This workshop intends to bring together scientists working on active mid-ocean ridge processes interested in long-term, in-situ observations in the MOMAR area. Due to the multidisciplinary nature of observatory studies, and the technological challenges posed, the Workshop will encompass all disciplines, including Biology, Fluid Chemistry, Geochemistry, Geology, Geophysics, Oceanography, and Engineering. The Workshop should:

a) define the scientific objectives to be pursued in the next 5-10 years: integration of biological, volcanic, tectonic, hydrothermal and oceanographic processes in time and space
b) identify the technology and instrumentation available for observatory-related studies, and future developments required: AUVs, moorings, ROVs, submersibles, data collection/storage/transmission, etc.
c) define the type of experiments to carry out in the future and establish a realistic implementation plan based on the scientific goals, as well as technological and funding constrains
d) define the procedures for management and integration of scientific data
e) establish links with existing national and international observatory-related projects: data and connector standards, transfer of technology
f) discuss and evaluate management proposals of study sites, and aspects related with scientific interpretation and dissemination for the general public
g) discuss and evaluate possibilities and strategies for funding of the observatory

We plan to have two days of discussions among different working groups, with very few key talks, and one day to write the results. The working groups will be determined based on the number of attendants and their expertise. The precise format of the Workshop, details on the schedule, official announcement and registration will be announced at a later time, not later than January 2002. Visit the InterRidge homepage for the latest information on the MOMAR workshop.

InterRidge Outstanding Student Award Winners

Presentation abstracts from the the 2nd International Symposium on Deep-sea Hydrothermal Vent Biology

Temperature sensitivity in embryos of the thermophilic hydrothermal worm *Alvinella pompejana*

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Temperature sensitivity is one key factor that controls the distributions of marine organisms. The role of temperature may be particularly important at deep-sea hydrothermal vents, where steep temperature gradients occur at centimeter scales and organisms are unusually thermotolerant. The polychaete *Alvinella pompejana* build tubes on the walls of hydrothermal chimneys, where they are exposed to high temperatures (20-50°C and exceptionally higher). The influence of temperature on early life-history stages remains completely unknown. Studies of embryology and larval development at vents are important to our understanding of how these highly specialized species locate and colonize new sites in a dynamic and ephemeral habitat. However, the study of embryos and larvae from hydrothermal vents is always problematic because of the high pressures at which the larvae must be reared. The larvae of siboglinid polychaetes ("vestimentiferan" tubeworms) have now been reared from both cold seeps and hydrothermal vents. Here, we use pressure vessels to rear early embryos of *Alvinella pompejana* for the first time, and to investigate temperature sensitivity in these early life-stages. Our results show a large difference in temperature tolerance between adults and embryos, that precludes the possibility of direct development in adult colonies. The data also suggest that early embryos might disperse long distances with currents, in a state of developmental arrest, completing development only when encountering the moderate temperatures found near the bases of hydrothermal chimneys.

Structural and functional plasticity of the extracellular coelomic fluid hemoglobins from the polymorphic vestimentiferan tubeworm, *Ridgeia piscesae*

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All vestimentiferan tubeworms require hydrogen sulphide (H_2S) to fuel carbon fixation by their endosymbionts and some species may be exposed to potentially lethal levels. The key to handling H_2S in vestimentiferans lies in the extracellular hemoglobins contained in the vascular blood and coelomic fluid which are capable of reversibly binding oxygen and sulfide. Different vestimentiferan species are exposed to very different environmental H_2S levels. *Riftia pachyptila* is routinely exposed to relatively high sulfide concentrations in its ephemeral, high flow hydrothermal vent habitats along the East Pacific Rise while cold seep species such as *Lamellibrachia luymesi* are adapted to stable, low-sulfide environments. The polymorphic vestimentiferan *Ridgeia piscesae*, inhabiting sites along the Juan de Fuca Ridge (JdFR), offers a unique opportunity to observe one tubeworm species that can thrive in either ephemeral high-sulfide or diffuse low-sulfide habitats. We have begun a detailed analysis of the vascular blood and coelomic fluids from two very different morphotypes of *R. piscesae* from very distinct environments. One morph (short-fat) inhabits areas of relatively active, diffuse flow chimneys, and the other (long-skinny) morph is found in areas of very low flow on the basalt. Our results to date show that structural differences in the 400 kDa coelomic fluid hemoglobin between *R. piscesae* morphotypes appear to relate to differences in the sulfide binding characteristics which may be a result of environmental adaptations along the JdFR.

International Ridge-Crest Research: Biological Studies

Hydrothermal vent and seamount fauna from the southern Kermadec Ridge, New Zealand

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Seamounts are both prominent and widely distributed features in the marine environment. However, within the New Zealand region very little is known about their physical and biological processes. Since 1998, NIWA scientists have studied a variety of seamount habitats to better understand the role and dynamics of seamounts in the marine environment, particularly their ecological uniqueness. One aspect of this is the discovery of a diverse vent fauna associated with the active hydrothermal venting of southern Kermadec arc volcanoes.

Associated with the convergent Pacific–Australian plate boundary, the southern Kermadec arc volcanoes form an active arc front of 13 edifices between 37° and 35°S (Wright, 1997). A number of these volcanoes have active hydrothermal vents (de Ronde et al., 1999), including Rumble III, Rumble V, and Brothers (Fig. 1). Aspects of their volcanism and venting are becoming better known, but to date there has been no description of the vent biology. Here we present a first preliminary description of the southern Kermadec vent biology.

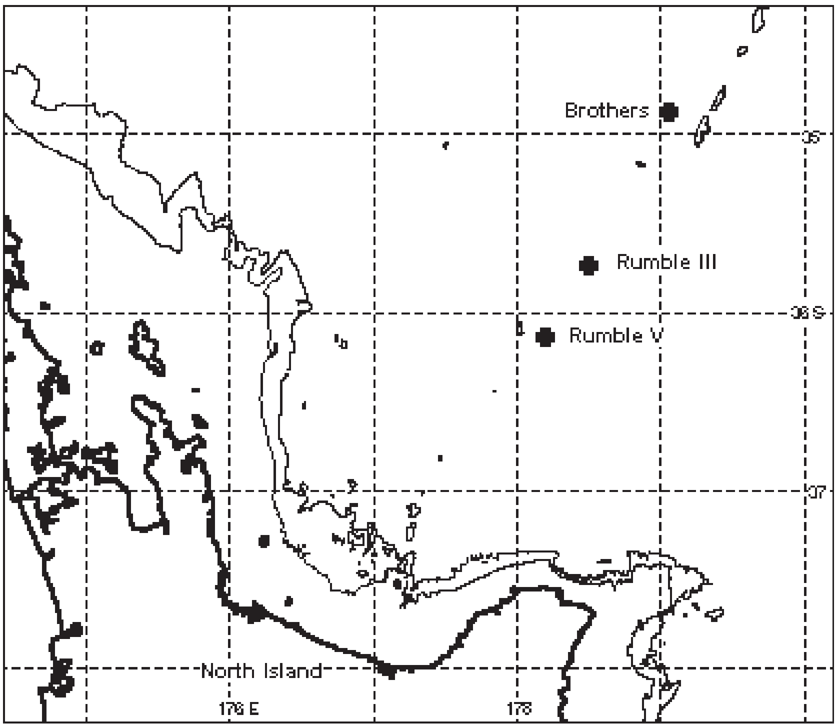

Figure 1. Location of the southern Kermadec seamounts, to the northeast of the North Island of New Zealand.

In November 2000, NIWA undertook a short still-camera and towed-sled survey of Rumble III from R/V Kaharoa, during which hydrothermal-vent fauna new to science or to New Zealand waters was recorded. One key indicator species of vent fauna proved to be an undescribed species of bivalve, genus *Bathymodiolus* – the same species known previously from a dead valve from the Brothers seamount, northeast of Rumble III. Two sled trawls caught appreciable numbers of this species, from those very recently settled to specimens of shell length 150mm.

A second survey on R/V Tangaroa was carried out in May 2001. The objectives included faunal inventory of several seamounts, based on photographic records and benthic sampling principally from Rumble III, Brothers caldera, and Rumble V volcanoes. Photographic transects were carried out in a starburst pattern centred on the summit of each of Rumble III and Rumble V seamounts. Video and still cameras were mounted in an acoustic frame, and towed slowly along each transect at 3–4 m above the sea floor, from each summit to 1000–1100 m on the flanks. While video pictures were taken continuously, the digital camera was activated remotely; frame position was continuously monitored using an acoustic system from the ship. In addition, a total of 52 epibenthic tows were completed from all three seamounts.

Species diversity, density and substratum type proved to be highly variable, indicating that the distribution of bottom type and fauna was very "patchy", both within and between seamounts. This was particularly evident on Rumble III for Bathymodiolus, the distribution of which, based on camera and video work, appeared localized to a single transect, and to about 100 m distance. Bathymodiolus was more widespread in distribution on Rumble V.

On inactive seamounts large organisms, particularly the cnidarians: Gorgonacea (especially species of Keratoisis, Narella, Paragorgia, Metalogorgia and Chrysogorgia), Scleractinia (especially species of Enallopsammia, Solenosmilia, Desmophyllum and Caryophyllia), Antipatharia (especially species of Antipathes, Parantipathes, Bathypathes and Leiopathes) and to a lesser extent the sponges, Porifera (Hexactinellida: gen. et. spp. indet.), characterize sessile macrofauna. Such sessile macrofauna is effectively absent from active seamount features, except for isolated regions on their flanks or bases.

The fauna of the actively venting seamounts is appreciably different from that of adjacent inactive seamount and ridge-systems. A provisional list of taxa from these seamounts contains some 100 species, but a number of Phyla await processing. Groups for which we have a more complete description are the Crustacea, Mollusca and Echinodermata, upon which the following account is based.

Amongst decapod Crustacea a suite of species belonging to the hydrothermal-vent specific genus Alvinocaris (preliminary sorting identifies 3 species), and several additional presently unidentified shrimp genera and species, are recognized. These are all associated with the most actively venting environments.

The brachyuran fauna associated with these vents comprises four closely related Carcinoplax species, including one likely new to science; three species attributed to Pilumnoplax, two possibly new to science; one of Bythograea (for the first time recognized from New Zealand waters); one to a similarly sized crab species that presently cannot be attributed to genus or species; three majiids (spider crabs), one hitherto unknown species attributed to Sphenocarcinus, the near-cosmopolitan Archaeopsis thomsoni (also for the first time recorded from New Zealand waters), and one leg of a large-bodied species attributed to the genus Platymaia (although the species is unlike any other in the relative proportions of leg segments, and in the extent of spination); the bizarre parthenopid Tutankhamen, also newly reported for New Zealand waters; and one portunid, provisionally attributed to Ovalipes molleri. Of these, Bythograea, Gen. et. sp. indet. and possibly one species attributed to Pilumnoplax are likely vent specific, whereas most others, despite their presently being known only from vent and proximal environments, or newly recorded from New Zealand waters, are likely to represent ambient deep-sea intruding fauna. The occurrence of Ovalipes ?molleri is unusual, as this species is known from northernmost New Zealand from shallow water, and central-eastern New Zealand (Chatham Rise) from approximately 400m depth; it has not earlier been recorded from seamount habitat, nor from the depths at which it occurs here; portunid crabs are known from vent environments, but are not ecologically limited to them. Of the 14 species recognised from this region, only species of Carcinoplax, Pilumnoplax, Archaeopsis and Ovalipes are recognized with more widespread regional distributions.

The galatheid fauna (Crustacea: Anomura) comprises 13 species, of which only one can be attributed to species (Phylladiorhynchus pusillus — a widespread and common species, historically referred to Galathea); 12 of these galatheids are known only from this complex of vents. Of these 13 species, 8 are referable to the genus Munida, and only one of them is known from any other deep-sea location around New Zealand. Two of the species are referable to Munidopsis (s.l.), with both presently known only from the most active venting region on Brothers seamount; one further species is referable to each of the genera Eumunida and Alainius. The anomuran fauna of Brothers seamount comprises one further small-bodied lithodid — a species of Paralomis, similar to but not conspecific with P. jamsteci. This vent-dwelling Paralomis also differs from P. sp. (sensu Macpherson, 1990), a species rarely found in, but widely distributed throughout our waters.

Twelve barnacle species (Crustacea: Cirripedia) are represented in vent- and proximal samples, of which a relatively high proportion can be attributed to genus and species (reflecting both relatively intense and recent interest in this group); 8 of them appear to be unique to this complex of active seamounts. New records for New Zealand waters are made for species in the genera Annandaleum, Metaverruca, Trianguloscalpellum and Amigdoscalpellum, but most are replacement names for species previously recorded in the genera Verruca and Arcoscalpellum (Foster, 1978; Buckeridge, 1983). Neolepas, a vent-specific genus of barnacle represented in our waters by N. osheai only, is known from Brothers seamount, solely from areas of active venting (Buckeridge, 2000). Another remarkable find for the region is from the genus Chionelasmus, of which a unique specimen from Rumble III is only the second-known from New Zealand waters; the specimen is provisionally attributed to C. darwini, the same as that recorded by Foster (1981) from the Kermadecs; Chionelasmus is not indicative of vent environments. Only two of the species known from this area, Poecilasma kaempferi and Smilium acutum, are widely distributed throughout New Zealand waters, and both are abun-

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dantly represented in collections from non-venting environments.

Mollusca numerically dominate the fauna from these vents, with the largest and most abundant being at least one, but possibly two species of mussel referable to Bathymodiolus. Specimens that reach total lengths of ~350 mm have now been recovered, with species being most abundant on Rumbles III and V. Live individuals are unknown from Brothers. Large gastropods are uncommon, but one, a species attributed to Gmynobela, appears limited to areas of active venting; these specimens differ from any referred to the genus Phymorhynchus typical of vents (Warén and Bouchet, 2001) or ambient deep-sea environment (sensu Bouchet and Warén, 1980: 25-27, Figs 70-73). At least locally, Bathymodiolus, Gmynobela, and a number of smaller presently unidentified gastropod species found amongst vent samples are likely to be true vent fauna. Surprisingly, the two largest and most frequently collected gastropods from and proximal to these vent sites are Fusitriton magellanicus and Ranella olearium - neither vent specific, with both widely distributed throughout New Zealand waters, most often on soft sediments of the continental shelf and plateau. The most abundant gastropod from this region is the small Nassarius ephamillus, a species also widespread in geographic and bathymetric distribution throughout our waters.

Figure 2. A new genus of large bodied asteroid, on a dense bed of Bathymodiolus sp., from Rumble III seamount at a depth of 380 m.

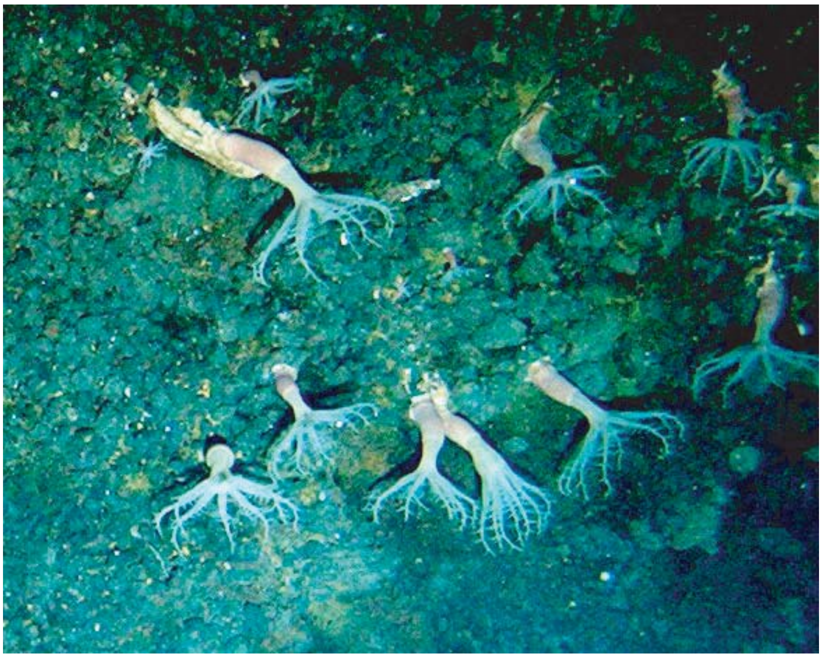

Figure 3. The soft coral Anthomastus robustus, at 500 m depth from Rumble V seamount.

The asteroid (Echinodermata: Asteroidea) fauna of these active seamounts is not particularly diverse, in the sense that only 10 species are known, but its composition is remarkable in that a disproportionate number of these species are new to science or to New Zealand in general. In addition to one new genus and species of large asteroid (Fig. 2), the fauna contains a further 3 new species, and a further genus and species newly reported from the southwest Pacific. The following have been identified to date: Allostichaster sp., Anseropoda sp., Coronaster sp., Cosmasterias dyscrita, Henricia compacta, Leilaster radians (previously known from the North Pacific and Atlantic Oceans), Mediaster sp., "New genus new species", Plutonaster complexus and Smilasterias sp. Amongst these species only Cosmasterias dyscrita and Henricia compacta are, elsewhere, both common and widely distributed. Four groups, Anseropoda sp., Smilasterias sp., Mediaster sp., and the large starfish referred to as "New genus new species", are known only from this region - the latter likely the only true vent endemic.

The ophiuroid (Echinodermata: Ophiuroidea) fauna of this region is quite diverse, with 19 species recognized, although 11 have not been, or presently cannot be attributed to species. At the generic level the majority are widely distributed, but at the species level, Asteroschema bidwillae, Ophiomyces sp. and Ophioscolex sp. are rare, and Ophiomyces sp. and Ophioscolex sp. probably represent new species, the former seemingly endemic to Rumble III.

The dissimilarity in fauna between active-venting and inactive seamounts north of New Zealand may reflect a variety of factors including the obvious spatial control of unique vent-fauna and substrate stability. The lack of the latter may preclude establishment of long-lived sessile species, and likely limit the establishment of associated smaller-bodied sessile and mobile community structures. Carbon dating (C^{14}) of two large-bodied (to ~ 3m colony height) gorgonian species of Keratoisis and Paragorgia reveal minimum colony ages of ~ 350 and 500 years respectively (with, no way of determining natal and most recent portions of any given colony due to damage and growth form, thus, absolute age cannot be determined). The degree of substratum stability required for such long-lived species is unlikely to exist in an environment associated with active volcanism. With the exception of the byssally attached Bathymodiolus mussel, the fauna of these active seamounts is accordingly characterized by a diverse assemblage of small-bodied mobile species.

In brief, the fauna of each seamount can be characterized as follows:

Rumble III: the main groups represented were crustaceans (especially Brachyura and Galatheidae), Gastropoda, and echinoderms (Opiuroidea contained 10 species). There are likely to be two species of the large vent mussel Bathymodiolus. Starfish were often observed on the mussel beds, in particular a large bodied asteroid, similar to Scleracterias, but warranting separate generic recognition (Fig. 2).

Rumble V: Brachyura, Galatheidae, and Ophiuroidea again dominate the identified fauna. The mussel Bathymodiolus and small prawns of the genus Alvinocaris are vent species. The bizarre solitary soft coral Anthomastus robustus, previously known only from the Gulf of Mexico, is locally abundant (Fig. 3).

Brothers: Barnacles and Galatheidae were dominant crustaceans, with echinoderms and vent prawns also notable.

Many of the species now reported from these seamounts are new records for the New Zealand region, and/or new species. At least 33 species have not been recorded from other seamounts in New Zealand. Few species proved common to each of the active seamounts. Moreover, the vent fauna of the deeper Brothers caldera differs appreciably from that of shallower Rumble III and V seamounts, with the former characterised by barnacles and prawns and the latter by extensive Bathymodiolus-based communities. A comparison of fauna taken from sites of active venting with that from inactive seamounts identifies the vent fauna to be truly unique.

Acknowledgements

We would like to thank Don McKnight (NIWA), John Buckeridge (Auckland University of Technology, New Zealand) and Gary Williams (California Academy of Sciences, California, USA) for identification of echinoderm, cirripede and octocoral taxa respectively. Science staff and crew of Kaharoa and Tangaroa are warmly thanked for assistance at sea. Funding for this research is provided by New Zealand Foundation for Research Science and Technology contract # C01X0028.

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International Ridge-Crest Research: Biological Studies

ATOS cruise
R/V L'Atalante, ROV Victor, June 22nd - July 21st 2001

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Hydrothermal vents present extreme environmental conditions where, nonetheless, life can thrive, exposed to high hydrostatic pressure and fluid temperature, bathed in water enriched in toxic compounds such as heavy metal, hydrogen sulphide, and even radionucleids, toxicity of which is well known especially concerning their potential damage to DNA. Despite the harsh conditions, vents are colonised by a luxuriant and very productive fauna based on bacterial chemosynthesis that is apparently well adapted to living in such conditions.

The hydrothermal environment provides a natural pollution laboratory in which to study the potential for resistance and adaptation in marine species exposed to chemical and physical contaminants produced by natural geological forces. The data obtained in these "natural laboratories" can be used o model perturbations in non-vent marine species, which are being exposed to anthropogenic pollution for a shorter time period. Hydrothermal vents are also characterised by the abundance of micro organisms that could play an important role in detoxication and remediation.

ATOS (ROV Victor/L'Atalante) is the single oceanographic cruise of the European project VENTOX (EVK3-CT1999-00003) co-ordinated by David Dixon (SOC, UK) and including 10 English, Portuguese and French partners. It is a 3 years project, which started in March 2000.

The aim of this interdisciplinary project is to carry innovative research into the specialised adaptations and processes found in representatives of the mid-Atlantic deep-sea hydrothermal vent fauna and its associated microbial populations under a potentially toxic environment. The project is based on the comparison of 3 hydrothermal vent fields on the mid-Atlantic Ridge (Menez Gwen, Lucky Strike, and Rainbow) presenting different depth, geological, geochemical and biological characteristics (Fig. 1). This zone has been intensively studied during past European projects; MARFLUX/ATJ (3rd PCRD) and AMORES (4th PCRD). This 1 month long ATOS cruise provided an opportunity to perform 19 dives of the French ROV Victor (from 8 to 20 hours on the bottom) on the hydrothermal fields Menez Gwen (37°51'N, 31°31'W, 850 m), Lucky Strike (37°17'N, 32°16'W, 1650m) and Rainbow (36°13'N, 33°54'W, 2350m).

To reach the scientific objectives of the program, the cruise combined in an integrated multidisciplinary approach:

1) video observation, imaging and mosaicking,
2) in situ analysis (ALCHIMIST, Fig. 2),
3) sampling (organisms, water, substrate) for on board or on shore analysis,
4) in vivo experiments at atmospheric pressure or in situ simulated conditions (using IPOCAMP flow-through pressure chamber (Fig 3), linked to the chemical regulation device SYRENE).

The mooring during the cruise on the Menez Gwen vent field of 6 acoustically retrievable cages filled with mussels will allow to carry out experiments on live organisms after the cruise in the land-based labora-

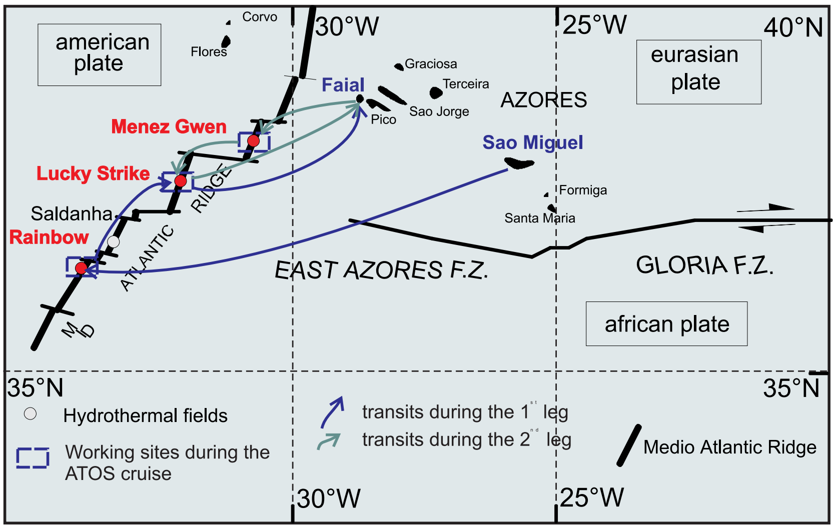

Figure 1. Schematic design of the ATJ and of the hydrothermal vent fields studied during the ATOS cruise.

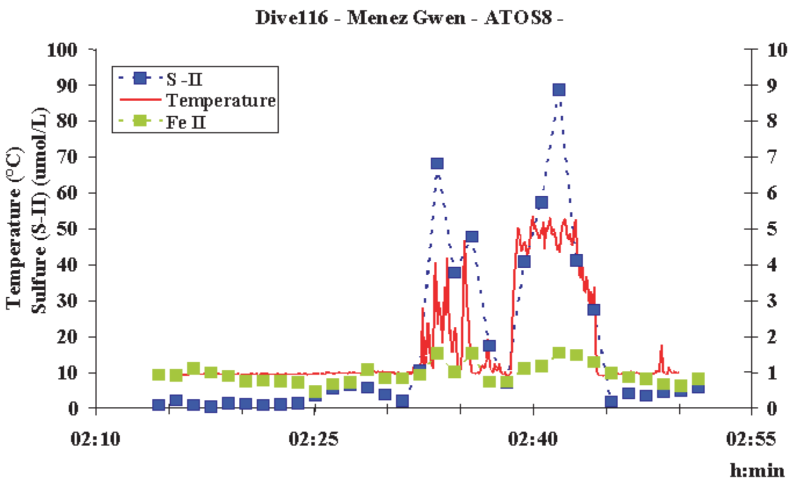

Figure 2. In situ chemical analysis obtained with ALCHIMIST

tory located at Horta (LABHORTA).

The strategy adopted was identical on the 3 study fields. The video recognition of known sites allowed to choose the working spots. Autonomous probes (temperature and pH) were deployed within designated study sites which were subject to small scale video imaging to determine the main faunal assemblages constituting the ecosystem. Chemical characterisation of the ecosystem at the micro habitat scale was carried out using in situ analysis (in situ analyser ALCHIMIST, T/pH probe, trial of a flowmeter) and discrete water sampling in order to quantify the rates of exposure to various "toxic" compounds (e.g. sulphide, metals, ΣCO_2). Finally, the organisms, which inhabited the environment within the study areas were sampled (with their substrate whenever possible) and preserved for later analysis to determine their temperature adaptation ability or metal bioaccumulation.

Concurrently, in vivo experimentations at ambient pressure or in situ simulated conditions (using IPOCAMP flow through pressure chamber connected to the chemical regulation device SYRENE) represented an important part of the work on board. The bivalve Bathymodiolus azoricus, present in the 3 study fields was the preferred experimental target. The main objectives of this in vivo part of the project were the study of:

- the background levels of DNA damage, DNA repair efficiencies in vent organisms and their responses to mutagen challenge.
- uptake rates of methane and sulphide by vent mussels under different environmental conditions and establishing the limits on the conditions necessary to maintain the symbiotic associations between mussels and sulphur- and methane-oxidising bacteria.
- the bioaccumulation of metals by vent fauna. Sampling was done in conjunction with the microhabitat studies and comprised of two parts: firstly the study of mercury bioaccumulation in the food web by sampling of different species of each site and secondly to understand the bioaccumulation and detoxication processes developed by the bivalve B. azoricus.
- the selective adaptation of hydrothermal fauna to temperature. The study species were the bivalve, B. azoricus and the shrimp, Mirocaris fortunata. Sampling was done in conjunction with the microhabitat studies. The experimental work was based on in vivo acclimatisation to temperature or thermal shock to obtain evidence about either a selective adaptation to temperature and/or an adaptive response by induction of heat shock proteins.
- adaptation of hydrothermal crustaceans to hypercapnia. The shrimp, Rimicaris exoculata, present in large densities on the Rainbow field and the crab, Segonzacia mesatlantica, were subjected to enriched CO_2 environments, under atmospheric or in situ pressure to determine the effects of hypercapnia, combined with hypoxia, on the respiratory

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acid base balance and metabolic status of the crustaceans.
- sulphur and iron recycling by the vent shrimp R. exoculata and their associated bacteria. A combination of sampling of organisms and mineral substrates and in vivo experiments were developed to determine the functioning of the association between the shrimp and micro-organisms with a particular focus on the adaptations to mineral sulphides.

A specific set of samples (water, organisms and substrates) were collected to isolate new extremophilic micro organisms or extremophiles able to perform bio-transformations potentially useful for bio-remediation.

A land-based aquarium and experimental laboratory facility (LabHorta) was set up on the island of Faial, Azores, to which quantities of vent organisms have been transported by shuttle craft from the Menez Gwen vent field by the Portuguese vessel l'Archipelago. Up to late September, four out of six cages have been recovered to supply work going on in that laboratory. Immediately after the ATOS cruise, scientists worked on a variety of species (crabs, shrimps, limpets and mussels), which were obtained in a variety of different ways, but more recently the work has concentrated largely on Bathymodiolus azoricus, a species most suited to cage maintenance and recovery. Experiments have been conducted, both at ambient and high pressure, on a variety of different aspects of their biology, including blood physiology, animal behaviour and growth, DNA damage, and heavy metal bioaccumulation and toxicity. It is envisaged that work will continue at LabHorta until the weather conditions deteriorate in November.

Preliminary results show that the condition of the mussels maintained in the cages was better than anything achieved before using other recovery methods.

The French ROV Victor demonstrated during its first campaign, devoted to the study of the hydrothermal ecosystem, an important working potential regarding its ability to work at the micro-habitat scale to study the mixing zone of hydrothermal fluid and seawater as well as the ecology or ethology of benthic invertebrates. Even though it has been designed for longer dives, it was proven efficient for short dives (12 hours) combining video observations, in situ analysis and sampling of fresh organisms for subsequent in vivo experiments.

Figure 3. The Ipocamp flow through pressure chamber.

Acknowledgements

We would like to acknowledge captain M. Houmard and the N.O. l'Atalante crew, P. Triger and the VICTOR team for the efficiency and availability they showed to use this new and promising submersible. The hospitality of our Portuguese colleagues in Ponta Delgada and Horta was also greatly appreciated.

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Retrievable cages open up new era in deep-sea vent research.

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Hydrothermal vent mussels, previously placed in cages over active vents on the mid-Atlantic Ridge, have been brought to the surface in 25 minutes, using acoustic recovery, to supply an aquarium and vent biology laboratory set up in Horta, Azores, Portugal. This new development allows access to living hydrothermal vent fauna long after a dive cruise has ended, thus significantly extending organism availability and offering exciting new possibilities for physiological, behavioural, reproductive and biotechnological studies.

Previously, experimental work on deep-sea hydrothermal vent organisms has been seriously hampered by animal availability, and biological studies on living vent fauna have tended to be restricted to shipboard studies carried out on specimens recovered using either a deep-sea submersible or ROV. During recovery, animals are often subjected to extended transit periods, regularly taking several hours, from the time that they were first collected, using either a suction device (slurp gun) or a telemanipulator. This protracted collection undoubtedly leads to stress, which affects the condition of the animals and therefore the quality of the results. Here we describe the novel use of acoustically-retrievable cages to recover vent mussels (Bathymodiolus azoricus), their associated epi-fauna (Lepetodrilus sp. etc.) and crabs, Chaceon affinis, from a deep-sea vent site (Menez Gwen: 37°50´N 31°31´W, 828 metres bathymetric depth), 144 nautical miles from Horta.

The cages, 1.25m square, had a frame constructed of glass reinforced plastic angle plate, fixed with stainless steel bolts, which were covered in 2cm wide plastic mesh. A weighted rubber skirt around the cage base diverted sulphide- and methane-laden fluid through the bottom to supply the mussels with the conditions they need for survival. In order to prevent the mussels, both inside and out, from irreversibly anchoring the cages to the seabed with a mass of tough byssus threads, the cages were supported on short legs, 15 cm high. The flotation spheres used for recovery were made of 1000m rated syntactic foam. The cages, with their floats, transponders and acoustic releases (Sonardyne, UK) attached, were first dropped to the seabed using 100 kg sinker weights. These drop weights were then released by the French ROV Victor 6000, which then manoeuvred the cages into position over a suitable diffuse vent fluid outlet (Fig. 1). Mussels were cleared from around the cage base using the ROV manipulator and placed in the open-top cages (each cage took between 2 and 3 hours to fill). A temperature

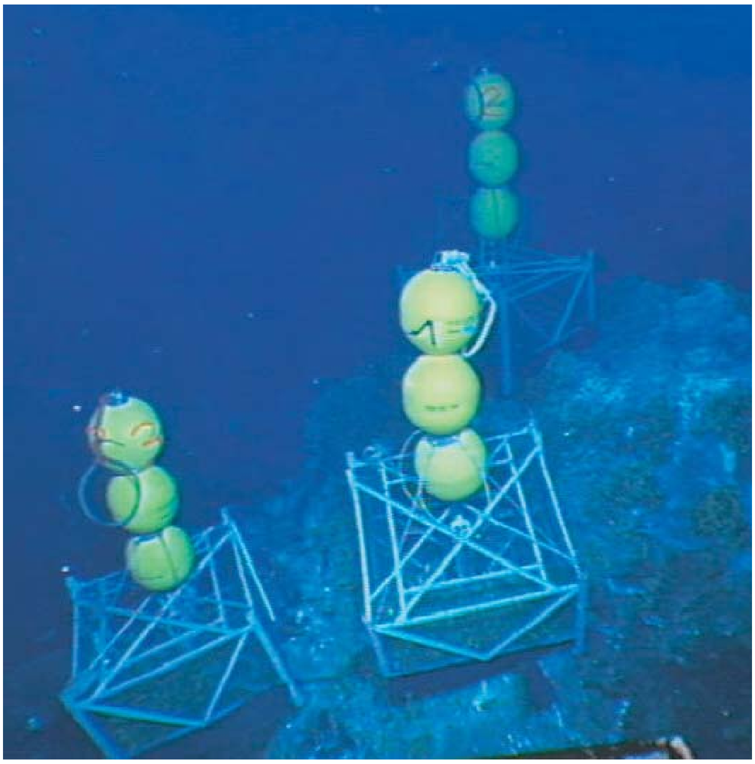

Figure 1. Three cages in position on a mussel dominated part of the Menez Gwen vent field.

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Figure 2. Cage at the time of recovery on board the R/V Arquipélago. The broken shells date back to when the cage was loaded using the ROV.

Figure 3. Mussels in the aquarium at LabHorta, showing extended feet and syphons.

probe inserted through the cage mesh indicated that vent fluid was reaching the mussels.

Six cages were filled with approximately 500 mussels each at Menez Gwen during the EU-funded ATOS cruise, 21 June-19 July 2000, and the first cages were successfully recovered on July 31st (Fig. 2) and August 6th. Further recoveries are planned over the next 4 months. Cage recovery is being carried out by the Portuguese R/V Arquipélago operated out of Horta. Each cage was fitted with its own acoustic release and following an appropriate signal from the surface, an anchor weight was released which allowed the cage to float to the surface. A transponder signal was used to confirm the position of the cage, both on the bottom and on the surface. During the 15 hours transit, the mussels were held in chilled seawater at 7-8°C, their natural ambient temperature, and were subsequently held in a containerised cold room at Horta at a similar temperature.

Despite the marked change in ambient pressure they experienced during recovery, amounting to around 80 bars, the mussels showed signs of normal behaviour (as observed previously with the Nautile submersible), i.e. syphon and foot extension, within a few minutes of being placed in tanks on board the R/V Arquipélago. Animal condition after several weeks in the cage, based on gill colour and thickness, mantle thickness, and readiness to extend their syphons and secrete new byssus, was good, as was their survival both before and after recovery. Those dead shells that were present in the cage (<2% of total) were clearly the result of mortalities that had occurred during the original cage loading using the ROV manipulator claw, some of which were observed at the time, since the shells were crushed. The presence of the dead mussels attracted two large *Chaceon affinis* specimens into the cage. The mussels are now being maintained in the laboratory (LabHorta) in aquaria (Fig. 3) fitted with oxygen and methane diffusion tubes and are being pulse fed with a solution of sodium sulphide to give a final concentration in the aquaria of up to 100µmol/L.

Other vent organisms currently being maintained in aquaria at Horta include the shrimp, *Mirocaris fortunata*, the crab *Segonzacia mesatlantica*, limpets, *Lepetodrilus* sp. and a pycnogonid.

Experiments are currently in progress, at 1 and 80 bars pressure, on a range of physiological and molecular processes, including DNA repair. Vent organisms inhabit an environment that is typified by high levels of heavy metals and radioactive radon gas. Given their long evolutionary history, their special adaptations to living in what is arguably the most naturally contaminated environment on the face of the planet, holds promise for important new breakthroughs of relevance to bioremediation and biotechnology. Apart from the dramatically improved animal quality, this new approach to recovery opens up deep-sea vent biology to experimental studies over time scales, and at a level of experimental sophistication, which is simply

Figure 4. Interior views of LabHorta laboratory complex showing high pressure chamber (IPOCAMP – Universitié Pierre et Marie Curie, Paris) and stock and experimental aquaria.

not possible using a research ship. Coupled with the establishment of LabHorta (Fig. 4), a permanent land-based laboratory for vent studies, in the Azores, heralds the beginning of an important new era in deep-sea vent research.

Acknowledgements

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Recent developments in international law relating to activities around hydrothermal vent ecosystems.

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Introduction

To date, regulation of activities (including scientific research), in and around hydrothermal vents under international law has been virtually non-existent. Two main international treaties are of direct relevance, namely the United Nations Convention on the Law of the Sea (done at Montego Bay, Jamaica, 10 December, 1982, hereinafter referred to as UNCLOS) and the Convention on Biological Diversity (done at Rio De Janeiro, June, 1992, hereinafter referred to as the Biodiversity Convention). However neither of these treaties adequately deal with the conflict between preservation of these ecosystems on the one hand, and scientific research and the exploitation of hydrothermal vent mineral, biological and genetic resources on the other. This is due, in large part, to the fact that many hydrothermal vents are found in the high seas beyond the jurisdiction of any one State.

While neither UNCLOS nor the Biodiversity Convention adequately resolve this conflict some efforts

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are now underway at both regional and national levels to bring hydrothermal vents within regional and national regimes of marine protected areas (MPA's).

This paper provides a brief overview of existing legal regulation of the activities around hydrothermal vents as well as some of the recent developments at regional and national levels.

Multilateral treaties

UNCLOS has established a comprehensive international legal regime for the regulation of deep sea-bed mining. This regime is set out in Part XI of UNCLOS and in the subsequent Agreement relating to the Implementation of Part XI (1994). However, as Glowka has noted, the genetic resources of hydrothermal vent ecosystems, not mineral resources, are their "most immediately exploitable and potentially lucrative natural resource" (Glowka, 2000).

Yet genetic and other biological resources are not specifically mentioned in UNCLOS or the 1994 Agreement. The deep sea-bed mining regime only applies to hydrothermal vents' "solid, liquid or gaseous mineral resources". Biological and genetic resources fall outside the scope of this regime.

The deep seabed mining regime does not specifically refer to either hydrothermal vent ecosystems or their potential resources simply because their existence and potential use was not known at the time of its negotiation (United Nations, 1995). To read into the provisions of Part XI of UNCLOS an intention that was clearly not held by the parties to the treaty at the time of its negotiation would be contrary to accepted principles of treaty interpretation.

As such, hydrothermal vent genetic and biological resources are freely accessible under the high seas legal regime. This is reinforced by the provisions of UNCLOS that deal specifically with marine scientific research. Under Article 238 of UNCLOS "all States irrespective of their geographical location, and competent international organizations have the right to conduct marine scientific research". While UNCLOS recognises the right to carry out marine scientific research on the high seas it does not specifically regulate how that research may be carried out.

To a limited extent, and to their credit, many scientists recognise both the absence of legal regulation of their activities, and the need for them to adopt a precautionary approach to their research and its impact on hydrothermal vent ecosystems (see for example, Mullineaux, et.al., 1998). This has led in turn to the creation of a series of informal research reserves. However, this reserve system is one regulated entirely by consensus within the scientific community conducting research in these areas. Similarly it seeks to preserve hydrothermal vent ecosystems for further scientific research; research which of itself may at times be destructive of the very ecosystems in need of protection.

One also suspects that it will not be long before both competing research interests and, more significantly, commercial interests undermine the effectiveness of the informal arrangement within the scientific community.

The Biodiversity Convention

The only other multilateral treaty of potential relevance is the Biodiversity Convention. Article 1 of the Biodiversity Convention lists its objectives as the "conservation of biological diversity, the sustainable use of its components and the fair and equitable sharing of the benefits arising out of the utilization of genetic resources." It establishes a framework of general flexible obligations aimed at implementing the objectives listed in Article 1. These include obligations to create plans, strategies, or programs for conservation and sustainable use under Article 6. (Downes & Fontaubert). States must identify and regulate activities that threaten biodiversity under Articles 7, 8 and 9.

However, these obligations are subject to several very significant qualifications. Firstly, these obligations are subject to, and therefore secondary to a State's sovereign right to exploit its own resources and to set its own environmental policies.

More significantly, Article 4 restricts the Biodiversity Convention's application to the territory of States that are parties to the Convention. It has no application beyond the limits of national jurisdiction. Given that the overwhelming majority of hydrothermal vent ecosystems are located on the deep ocean floor of the high seas, an area beyond any State's jurisdiction, the Biodiversity Convention will generally not apply to hydrothermal vents and their surrounding ecosystems. Since the Biodiversity Convention is the main international legal instrument dealing with Biodiversity, it is, as Glowka has noted, ironic that such unique, complex and diverse ecosystems fall outside its

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scope (Glowka, 1996).

Despite this, to date the international community has shown little inclination to revisit the issue of hydrothermal vents and their genetic and biological resources or the question of preservation of hydrothermal vents within the context of the Biodiversity Convention. The issue has been raised (but not debated) in several international forums in recent years, including the Biodiversity Convention Subsidiary Body on Scientific, Technical and Technological Advice in Jakarta in 1995, at the fourth meeting of the Biodiversity Convention Conference of Parties, in Bratislava in 1998, and in several United Nations fora (Glowka, 2000). Despite there being widespread recognition of the need for action, a comprehensive multi-lateral resolution of this issue seems a long way off.

European measures to protect hydrothermal vent ecosystems

UNCLOS recognises that States often co-operate on a regional basis. An example of this is the Paris Convention for the Protection of the Marine Environment of the North East Atlantic (1992), otherwise known as the OSPAR Convention.

The sea area covered by the OSPAR Convention is the North-East Atlantic extending westwards to the east coast of Greenland, eastwards to the continental North Sea coast, south to the Straits of Gibraltar and northwards to the North Pole (WWF: 2000). The OSPAR Convention has been signed and ratified by Belgium, Denmark, the Commission of the European Communities, Finland, France, Germany, Iceland, Ireland, the Netherlands, Norway, Portugal, Spain, Sweden, the United Kingdom, Luxembourg and Switzerland.

Annex V of the OSPAR Convention sets out two important obligations of the contracting parties. They are:

- "protection of the maritime area against the adverse effects of human activities.. to conserve marine ecosystems and ... restore marine areas,
- to develop strategies.. for the conservation and sustainable use of biological diversity" (WWF, 2000)

Following the Sintra Statement, OSPAR is now also committed to promoting "the establishment of a network of marine protected areas to ensure the sustainable use and protection and conservation of marine biological diversity and ecosystems." (Sintra Statement 1998).

Considerable work is now being carried out by parties to the OSPAR Convention and other interested parties, such as WWF, to design mechanisms to implement these obligations, the most significant being to develop an overall framework for MPA's within the context of the OSPAR Convention.

It is still very early days, and it will be quite some time before a comprehensive regime is in place. However, much work has been done to identify what further steps are required for the parties to the OSPAR Convention to set up a network of MPA's.

Much of this mirrors what is already being done within the context of implementing the European Communities Habitat Directive (Council of the European Comm., 1992), which also envisages a comprehensive network of protected areas on land and at sea (WWF, 2000). Under the Habitat Directive, threatened species and habitats or species and habitats in rapid decline are the main priorities for a protected area system currently being established. (WWF, 2000)

In terms of MPA's, the most important provisions of the Habitat Directive are contained in Articles 3, 4, and 6. Article 3(1) provides for the establishment of "a coherent European ecological network of special areas of conservation". This network is to be composed of sites hosting the natural habitats listed in Annex 1 and habitats of the species listed in Annex II of the Habitat Directive. These sites are to be selected with a view to "enable the natural habitat types and the species habitats concerned to be maintained, or where appropriate, restored at (sic) a favourable conservation status in their natural range." (Habitat Directive, Article 3(1)).

Under Article 4(1), Member States are obliged to propose a list of sites (selected in accordance with criteria set out in Annex III) with natural habitat types set out in Annex I or which contain species set out in Annex II native to their territory.

Following agreement with the relevant Member State under Article 4(2), under Article 4(4) the Commission of the E.C. can then designate such sites as a site of Community importance. As soon as a site of Community importance is listed on a draft list the site in question becomes subject to the provisions of Article 6.

Under Article 6 if the Member State in which the site is located enacts legislation and conservation measures then such areas become known as special areas of conservation. Those are then subject to restrictions on uses that are likely to have significant impact on habitats or species.

Lucky strike

Both the OSPAR Convention and the Habitat Directive have potential application to the Lucky Strike vent field situated southwest of the Azores and located within Portugal's Exclusive Economic Zone (WWF, 2001). The actual vent sites are of very limited size and like all known hydrothermal vents have a very fragile ecosystem. Yet there is extensive scientific research going on at this site, which is largely unregulated (WWF, 2001).

Given the work that has already been done by OSPAR in relation to MPA's, it would appear to be a prime candidate to be designated as an MPA under the OSPAR Convention. WWF, amongst others, has recognised this and has made submissions and recommendations to OSPAR that Lucky Strike be pro-

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posed as an MPA to OSPAR by Portugal. Although this proposal has not yet been fully formulated and much work remains to be done (including developing suitable management plans), such designation would be a positive development.

In addition to WWF's proposal to OSPAR, it would also appear that the Habitat Directive has potential application to Lucky Strike. Under Annex I of the Habitat Directive "Submarine Structures made by leaking gases" are designated as natural habitats of Community importance. Lucky Strike could potentially be brought within the provisions of the Habitat Directive discussed above.

Hydrothermal Vents as Marine Protected Areas under Canada's Oceans Act

One of the very first hydrothermal vent areas discovered, the Endeavour Hot Vents Area, is also one of the first such areas to be designated a MPA under domestic legislation. The Endeavour Hot Vents Area has been designated as a pilot Marine Protected Area ('MPA') under Canada's Oceans Act, 1996.

The Oceans Act lays the foundation for Canada's development of a "comprehensive Oceans strategy, based on the principles of integrated management, shared stewardship, the precautionary approach and sustainable development" (Canada: 1998). It has one underlying policy objective: "to further conservation and protection of living marine resources and their habitats." (Canada, 1998)

Pilot MPA's are the first stage in implementation of this policy, which stems from Canada's obligations under Article 194.5 of UNCLOS and the Biodiversity Convention (Canada, 1998). The main purpose in establishing pilot areas is to provide an opportunity to "learn and test different applications of MPA identification, assessment, legal designation, and management" (Canada & British Columbia, 1998).

However, upon completion and evaluation of this pilot area, formal designation as an MPA may or may not occur. It is therefore to early to say whether or not the Canadian measures will be effective in regulating activities around hydrothermal vent ecosystems. They are nonetheless an important first step.

The Canadian experience may yet act as a model for an effective legislative response elsewhere in the world and possibly as a model for future international co-operation.

Conclusion

It is clear that the existing international regime, and in particular UNCLOS and the Biodiversity Convention, provide inadequate protection for the complex ecosystems of hydrothermal vents. Many issues surrounding the risks posed by scientific research and the exploitation of the genetic, biological and mineral resources of hydrothermal vents remain unresolved. Yet these ecosystems are of immense importance in terms of preserving biodiversity, and in their potential for future scientific research and commercial exploitation.

Developments at both regional and national levels are encouraging. However, the greatest need for regulation appears to be on the high seas. There is clearly a need for a comprehensive international response. It is not yet clear when that will occur.

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The distribution of isotope signatures in MAR peridotites between 12 and 36°N and two main kinds of mantle substratum bellow ridge axis

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Introduction

The different geochemical parameters of residual peridotites as well associated basalt's can be used as efficient indices to estimate petrogenetic conditions typical of mid-ocean ridges, and reconstruct geodynamic regimens occurring during accretion of the oceanic lithosphere. By now a big data set on isotope geochemistry of basaltic glasses sampled along the 60 000km Mid-Ocean Ridge System has been accumulated. In contrast, such data for mantle derived peridotite recovered at mid-ocean ridges are scarce. The main reason for the smaller data set lies in analytical difficulties of isotope composition of mantle derived peridotites because the concentrations of trace and rare earth elements in these rocks are very low. Other contributing reasons include a strong influence on isotope characterestic of abyssal peridotites alteration processes: serpentinization and carbonate formation. This principal point for use of isotope data for interpretation of abyssal peridotites origin is discussed in detail in (Snow et al., 1993). In this study we are trying to consider spatial distribution of the isotope signatures in MAR peridotites along the ridge axis strike between 12 and 36°N in terms of primary (magmatic) and secondary (metamorphic) processes that accompanied accretion of the oceanic lithosphere.

Object of Investigation

We have used representative collection of MAR-Peridotites that includes all of mineral types of oceanic mantle derived peridotites. This collection consists of up to 50 samples already analysed by XRF for bulk chemistry and Electrone Probe for mineral chemistry. Thirty two samples were selected from this collection and analysed by mass-spectrometry using a multichannel mass-spectrometer ("Finnigan-MAT 261", see bellow). Samples examined were collected during expeditions of the R/Vs: "Akademik Boris Petrov" (1985-1991), "Akademik Fersman" (1990-1999), "Professor Logachev" (1995-2000) and "L'Atalante" (1992). The data presented in Fig.1 for samples obtained at Sites 12ABP-17; 16ABP-25,56,68,71,75; FR-03,12,16,23 were published earlier (Silantyev et al., 1995; 2000) or are in process of submission (Silantyev et al., in press). The new data on concentration and isotope composition of Sr, Rb and Nd in MAR peridotites sampled between 12° and 36°N are presented in Table 1.

Significant parts of the samples examined, judging by relic spinel composition, are representing a typical abyssal harzburgites characterized by different melting degree. Usually these rocks consist of orthopyroxene altered to bastie serpentine, olivine replaced by serpentine and relics of brown-red accessory spinel. Rarely, relic clinopyroxene is present in rocks examined. Amphibole of pargasite or edenite composition and small amount of brown phlogopite were detected in some samples from the 15°20'N region, Atlantis FZ, and Oceanographer FZ. A minor group of peridotites selected for this study was characterised by dunites composed of olivine completely replaced by serpentine and relic spinel. An unusual type of peridotites from this group was recovered from the east slope of the Rift Valley immediately to the north of the 15°20'FZ: this rock was a phlogopite-bearing dunite.

Analytical methods

About 500-700mg of peridotite sample was placed into the closed quartz-glass beaker and is washed with dilute nitric acid on a hotplate for 15 minutes. After drying, the sample was crushed with a jasper mortar, weighed, spiked with mixed ^{146}Nd-^{149}Sm and ^{84}Sr-^{85}Rb solutions and is placed in an oven at 120°C for 2-5 days in a mixture of HF and HNO_3. Some of the samples are treated with concentrated nitric acid at 150°C for 2 h to evaluate the influence of contamination processes. The results showed good reproducibility and on whole, no signs of secondary processes in studied isotopic systematics. Rb, Sr, Sm and Nd separation was then carried out according to the standard method of two-stage

Table 1. Concentration and isotope composition of Sr, Rb, Sm and Nd in MAR peridotites sampled between 12° and 36°N.

Sample#	Latitude, North	Longitude, West	MAR Region	Rock Description	Rb, ppm	Sr, ppm	Sm, Ppm	Nd, ppm	$^{87}Rb/^{86}Sr$	$^{87}Sr/^{86}Sr$ ± 2s	$^{147}Sm/^{144}Nd$	$^{143}Nd/^{144}Nd$ ± 2s
F62-2	12.91°	44.82°	MAR, Rift Valley	Harzburgite	0.146	7.036	0.036	0.099	0.06001	0.709047 ± 19	0.22257	0.513091 ± 26
12ABP23-12a	13.11°	44.90°	MAR, Rift Valley	Harzburgite	0.387	4.185	0.231	0.728	0.26745	0.709104 ± 26	0.19262	0.513055 ± 18
3869-4-1a	14.75°	44.98°	Logachev Field	Harzburgite	0.316	9.207	0.039	0.171	0.09927	0.708412 ± 21	0.13767	0.512879 ± 25
F69-9a	25.50°	45.24°	MAR, Rift Valley	Pyroxenite	0.169	164.9	0.316	1.256	0.00296	0.709018 ± 16	0.15272	0.513029 ± 16
F69-8	25.50°	45.24°	MAR, Rift Valley	Ultramafic Mylonite	0.153	4.251	0.088	0.421	0.10409	0.709016 ± 21	0.12695	0.513091 ± 19
F52-5	25.49°	45.26°	MAR, Rift Valley	Harzburgite	0.122	6.152	0.052	0.205	0.05736	0.708918 ± 22	0.15382	0.512687 ± 24
16ABP41-3	30.07°	42.17°	Atlantis FZ	Harzburgite	0.322	3.481	0.034	0.099	0.26753	0.709246 ± 21	0.20705	0.513233 ± 21
16ABP25-2	33.65°	38.90°	Hayes FZ, WRTI	Massive peridotite	0.395	5.266	0.382	0.995	0.21715	0.709125 ± 22	0.23251	0.513121 ± 14
16ABP25-4	33.65°	38.90°	Hayes FZ, WRTI	Massive peridotite	0.307	1.256	0.031	0.091	0.70824	0.709779 ± 69	0.20533	0.512579 ± 114
16ABP25-29	33.65°	38.90°	Hayes FZ, WRTI	Schistose peridotite	0.303	5.036	0.157	0.269	0.17382	0.708443 ± 32	0.20533	0.513257 ± 217
12ABP1-8	35.99°	35.30°	Oceanographer FZ	Harzburgite	0.226	6.471	0.120	0.189	0.10101	0.708922 ± 22	0.38280	0.513154 ± 28
12ABP1-18	35.99°	35.30°	Oceanographer FZ	Harzburgite	0.195	5.334	0.063	0.195	0.10573	0.708891 ± 24	0.19706	0.513121 ± 26
3840-6	36.23°	33.90°	Rainbow	Dunite	0.241	1.328	0.017	0.045	0.52486	0.708651 ± 27	0.22842	0.512904 ± 31
3840-7	36.23°	33.90°	Rainbow	Harzburgite	0.157	8.292	0.052	0.213	0.05476	0.708451 ± 23	0.14833	0.512927 ± 20

ion-exchange and extraction chromatography. The detailed description of the analytical procedure can be found in (Amelin and Semenov, 1996). All the measurements were performed with a Finnigan MAT-261 mass spectrometer equipped with 8-collectors under static mode at the Laboratory of Isotopic Geochronology and Geochemistry of the Institute of Precambrian Geology and Geochronology, St.Petersburg. The $^{143}Nd/^{144}Nd$ ratio were normalized within-run to $^{148}Nd/^{144}Nd$ = 0.241570 and then adjusted to a $^{143}Nd/^{144}Nd$ value of 0.511860 for La Jolla. The Sr isotope composition was normalized within-run to $^{88}Sr/^{86}Sr$ = 8.37521. The value of Sr isotope standard SRM-987 during this work was $^{87}Sr/^{86}Sr$ = 0.710238 ± 15 (2s, 6 runs). Assigned errors (2s) for $^{147}Sm/^{144}Nd$ and $^{143}Nd/^{144}Nd$ were ±0.3% and ± 0.000015, $^{87}Rb/^{86}Sr$ ±0.5%, $^{87}Sr/^{86}Sr$ ± 0.000025 according to the results of multiple analyses of standard (external reproducibility). The 2s errors cited in Table 1 for $^{143}Nd/^{144}Nd$ and $^{87}Sr/^{86}Sr$ reflect in-run precision and demonstrate the quality of these analyses. The blank level for Sm was 0.01 ng and 0.05 ng for Nd, 0.05 ng for Rb and 0.2 ng for Sr. The data obtained for BCR-1 during the course of this analytical work were: [Sr]=335.8 ppm, [Rb]=47.16 ppm, [Sm]=6.487 ppm, [Nd]=28.45 ppm, $^{87}Sr/^{86}Sr$ = 0.705053 ± 11, $^{87}Rb/^{86}Sr$ = 0.40615, $^{143}Nd/^{144}Nd$ = 0.512663 ± 9, $^{147}Sm/^{144}Nd$ = 0.13829. The La Jolla standard varied during course of this work from 0.511875 to 0.511912 ($^{143}Nd/^{144}Nd$ ratio) with mean value of 0.511882 ± 7 (n = 57).

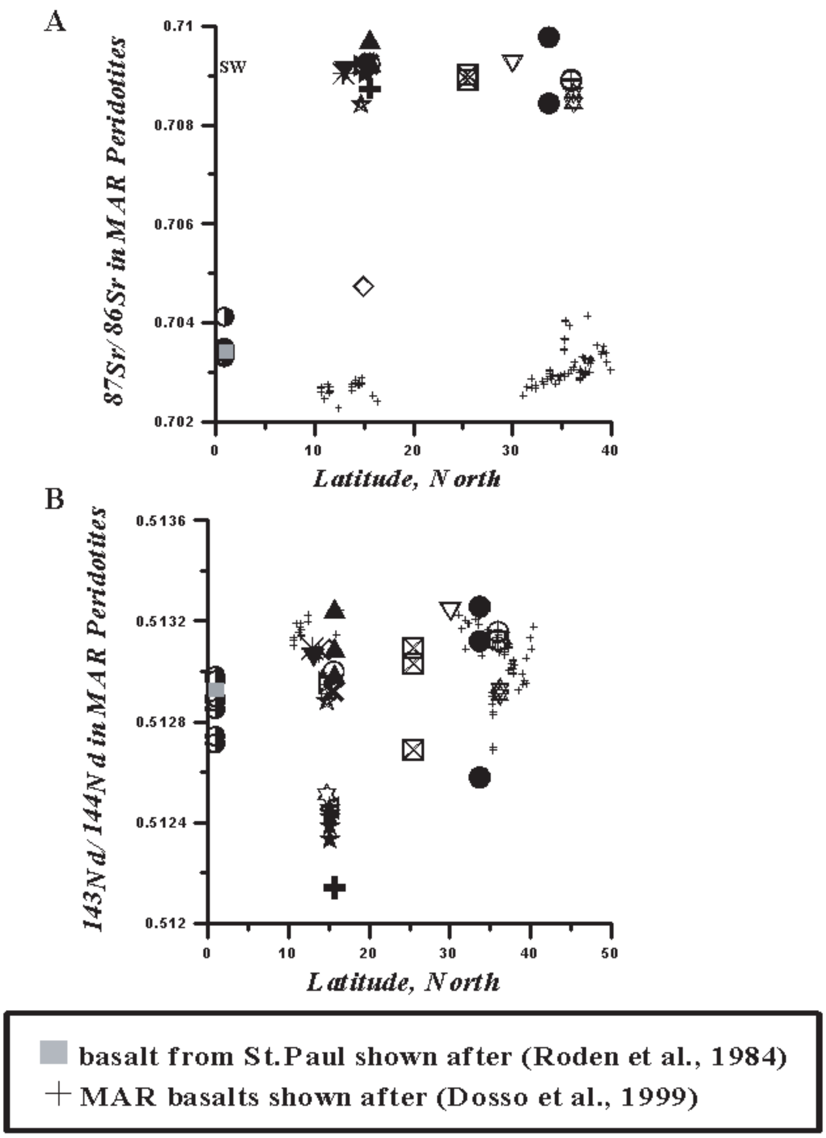

Figure 1. The distribution of isotope signatures in peridotites and associated basalts along the MAR axis strike. (A) - for $^{87}Sr/^{86}Sr$; (B) - for $^{143}Nd/^{144}Nd$.

Isotope geochemistry of MAR Peridotites

It has been mentioned earlier that heavily serpentinized abyssal peridotites characterized by $^{87}Sr/^{86}Sr$ values close to ones in SW (sea water) 0.7090 and even more, and low $^{143}Nd/^{144}Nd$ values close to 0.512000 (SW also) (Snow et al., 1993). Extremely high $^{87}Sr/^{86}Sr$ values detected in some abyssal peridotites have been interpreted by Snow et al., (1993) as evidence for participation of detritic contaminant in SW circulation in the oceanic crust. Detritic contamination could be used for explanation of very low $^{143}Nd/^{144}Nd$ values in these rocks. With this assumption in mind we look at the spatial distribution of $^{143}Nd/^{144}Nd$ and $^{87}Sr/^{86}Sr$ ratios in peridotites sampled along MAR axis strike between 0 and 36°N.

This distribution based on data presented in Table 1 is shown in Fig. 1. Additionally, data from (Roden et al., 1984) as well data that will be published soon have been used also. As illustrated in this figure, all samples examined are divisible into a number of groups by their $^{87}Sr/^{86}Sr$ signature (Fig. 1a). One of these groups has $^{87}Sr/^{86}Sr$ values that are similar with SW as well lower than this. The second group is characterized by $^{87}Sr/^{86}Sr$ values higher than SW, as in the case described by (Snow et al., 1993). Variation of Sr isotope composition in peridotites belonging to first group is most likely caused by different degree of serpentinization or presence of secondary Aragonite.

Extremely high $^{87}Sr/^{86}Sr$ values characteristic of peridotites in second group are most easily understood in terms discussed by Snow et al., (1993). However, it is difficult to explain the big variation range of Sr isotope ratio established in peridotites sampled at the same dredge site (e.g. 16ABP56) and characterized by similar alteration degree. An significant shift toward $^{87}Sr/^{86}Sr$ decreasing, observed in Spinel and Amphibole bearing peridotites from St. Paul (Roden et al., 1984), may reflect very low degree of alteration of these rocks which is unusual for MAR peridotites. Referring to Fig. 1a, a lone sample from MAR just to the South of the 15°20'FZ also had a low $^{87}Sr/^{86}Sr$ value that corresponds to about 0.1 according to the W/R calculations. It can be seen graphically in Fig. 1a that most higher $^{87}Sr/^{86}Sr$ values in peridotites are corresponding to two MAR regions: MAR segments close to 15°20FZ, and near Hayes FZ. One of these regions is located in an area of big 14°48 geochemical anomaly, second one is adjacent to the south termination of the Azores superplume.

According to the simplified geodynamic model of the oceanic lithosphere accretion, basalts and residual peridotites, exposed at the same areas of axial zone of the mid-ocean ridges, are genetically related. It means that their compositions must be complementary. Therefore, the $^{143}Nd/^{144}Nd$ and $^{87}Sr/^{86}Sr$ values characteristic of basalts (mostly unaltered glasses) from MAR between 0° and 40°N presented in (Dosso et al., 1999; Roden et al., 1984) are plotted in Fig. 1 also. It should be realized that in these diagrams fresh basaltic glasses are compared with strong altered peridotites. The surprising thing is that a weak correlation between the distribution of $^{87}Sr/^{86}Sr$ values in basalts and associated peridotites exists. It is seen in Fig. 1a that increasing values of $^{87}Sr/^{86}Sr$ near 15°20 FZ and at MAR near 34°N are accompanied by higher than usual $^{87}Sr/^{86}Sr$ in peridotites from the same region. Perhaps such a correlation implies that metamorphic processes in the oceanic crust may be linked to magmatic activity in the MAR crest zone.

The distribution of the $^{143}Nd/^{144}Nd$ values in the MAR peridotites along ridge axis strike are plotted in Fig. 1b. Based on this diagram, it is possible to infer, by the isotope composition of Nd, that two main kinds of peridotites are widespread along the MAR axis strike between 0° and 36°N. The first kind of peridotite includes the majority of samples examined. The value of $^{143}Nd/^{144}Nd$ ratio in the first kind of peridotites is variable along the MAR axis strike in the same fashion as in the associated basalts. This isotopic correspondence can be followed from the St. Paul region (1°N) to the Rainbow area (36°N). The Nd isotopic variations in the peridotites of the first kind, as well as in the associated basalts are consistent with the distribution of alternating plume and spreading MAR regions, including the Equatorial area 14°48 anomaly, and the Azores superplume.

The second kind of MAR peridotites are characterized by very low values of $^{143}Nd/^{144}Nd$ and do not exhibit a correlation with isotope

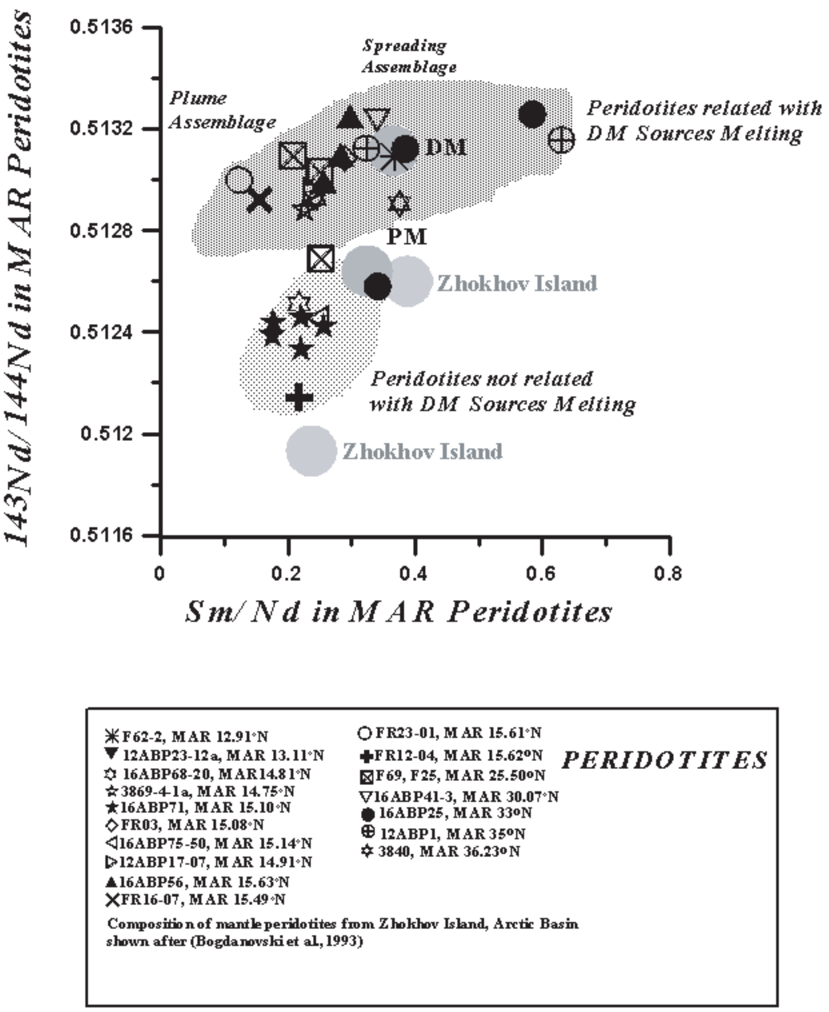

Figure 2. Sm/Nd versus $^{143}Nd/^{144}Nd$ ratios in peridotites from the MAR and two compositional fields corresponding to the main kinds of MAR peridotites. Composition of sub-continental mantle shown by the example of Zhokhov Island (Laptev Sea, Eastern Arctic Basin).

composition of Nd in the associated basalts. In other words, this kind of peridotite is not related isotopicaly with the products of magmatism in the Rift Valley. As Fig. 1b shows, peridotites of this kind are located mainly at the MAR near 15°20FZ and, perhaps, at MAR, 25°N and near the Hayes FZ.

It is apparent that the behaviour of Sm and Nd in peridotites in the mantle is determined by the following processes: 1) partial melting, and 2) interaction between mantle substratum and magmatic melts or fluids. The value of Sm/Nd ratio in residual peridotites is determined by partial melting degree because preferential accumulation of Nd as compare with Sm takes place in the residual melts. On other hand, repeated enrichment of mantle matter in open magmatic systems (such as bellow the mid-ocean ridges) is liable to essentially decrease the Sm/Nd ratio. Many early published studies demonstrate that in trace element acid-leaching experiments with altered MORB, the Sm/Nd ratio in these rocks decreases by no more than 5% . Serpentinization takes place under same temperature conditions as well the alteration of MORB. Therefore, it is logical to assume that the Sm/Nd ratio changes insignificantly in abyssal peridotites during serpentinization. If this is true, then the values of the Sm/Nd ratio given in Tab.1, as well all other already published data, correspond (or are close) to the primary values of this ratio in the samples examined. The variations of Sm/Nd ratio in the two kinds of MAR peridotites mentioned above are presented in Fig.2. It is evident from this figure that points corresponding to MAR peridotites of the first kind fall within the composition field related to the MAR array reflecting mixing between DM (Depleted Mantle) and HIMU or SHC (St.Helena) components. The upper composition field showed in Fig.2 includes two mantle peridotite types characteristic of spreading and plume MAR segments (right and left part of the figure respectively). It is obvious that plume and spreading peridotite types are in close association, indicating that magmatic processes in spreading and plume ridge segments are intimately related.

The MAR peridotites of the second kind fall into lower compositional field in Fig.2. This field is intermediate in the diagram Sm/Nd-$^{143}Nd/^{144}Nd$ between PM and the point corresponding to the composition of recrystallized subcontinental mantle (Zhokhov Island, see bellow). Almost all peridotite samples from MAR between 14 and 15°N, and two samples from MAR, 25°N, and Hayes FZ corresponded to this compositional field. The most unusual composition among samples from the second kind of MAR peridotites was a Phlogopite-bearing dunite (FR12-04) from the MAR, North of 15°20FZ. The geochemical features of this sample were very close to those representative of subcontinental mantle.

It should also be noted that sample FR12-04 was characterized by values of Sm/Nd and $^{143}Nd/^{144}Nd$ close to ones in different types of oceanic sediments (Fig.3).

The comparison of isotope composition of peridotites of the second kind with the ones in MAR

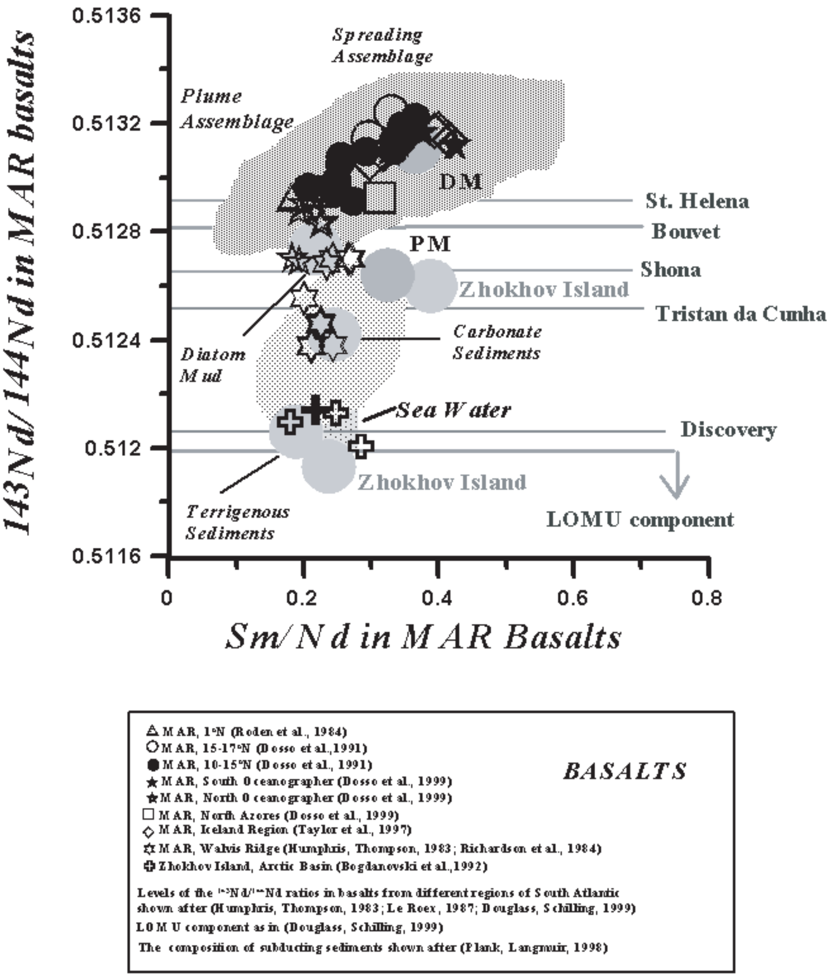

Figure 3. Sm/Nd versus $^{143}Nd/^{144}Nd$ ratios in the MAR basalts compared with two compositional fields of MAR peridotites and different types of oceanic sediments. Composition of sub-continental mantle and associated within plate volcanics shown also by the example of Zhokhov Island (Laptev Sea, Eastern Arctic Basin).

basalts is interesting from the point of view of interpretation of origin of these rocks. The compositional variation in MAR basalts sampled between 55°S and 65°N is shown in Fig.3. Both main compositional fields of MAR peridotites are plotted in Fig.3 for comparison with the compositional variation in MAR basalts sampled between 55°S and 65°N.

Our interpretation of the data represented in Fig.3, i.e. the variation of Sm/Nd and $^{143}Nd/^{144}Nd$ values, is that all of the North MAR and part of the South MAR basalts correspond to the ones in the MAR belonging to first kind of peridotites (plume and spreading assemblages). In contrast, basalts of within plate or OIB affinity from Discovery, Tristan da Cunha, Shona mantle plumes, and Walvis Ridge and some from the North Oceanographer compare favourably with MAR peridotites of the second kind. Origin of isotope signatures in basalts from South Atlantic plumes by (Douglas and Shilling, 1999) can be associated with three-component mixing between ambient astenosphere, the melts of plume origin, and low-µ (LOMU) component, which possibly represents subcontinental lithospheric mantle material. The isotope signatures of Walvis Ridge basalts could occur if they were formed from the following mantle sources: enriched mantle and depleted mantle (DM), as proposed by other investigators (Humphris and Thompson, 1983; Richardson et al., 1984). The isotope data on the basalts from the North Oceanographer region (North MAR) are consistent with the involvement of subcontinental material in their formation (Dosso et al., 1999). Thus, the principal point of discussion on the origin of MAR peridotites with very low $^{143}Nd/^{144}Nd$ is a possibility of interaction between melts of plume origin and mantle sources different from DM.

As an example of this magmatic association, in this article our main focus was on the geological objects with clearly manifested assemblage of mantle xenoliths of EM or PM origin and host basaltic lavas of within plate origin. The rock assemblage recovered at Zhokhov Island volcano (De Long Archipelago, Eastern Arctic) is a good example that illustrates the interaction between primitive mantle sources and typical within plate magmas. Olivine phyric basalts are the main type of extrusive rocks on the Zhokhov Island. Mantle xenoliths from these volcanics are represented by Spinel lherzolites a large number of them shows distinct signs of high-temperature interaction with magmatic melts. The isotope composition of xenoliths and host basaltic rocks from Zhokhov Island is plotted in Fig.2 and Fig.3 for comparison. It is clear from these figures that isotopic signatures of MAR peridotites belonging to second kind are attributable to the interaction of mantle substratum of PM origin with within-plate (or OIB in our case) magmas.

Conclusion

The above results may be summed up as follows:

1) Two main kinds of peridotite-basalt assemblages exist in the MAR. First one includes residual peridotites and associated basalts those related with melting of DM sources by different degree of participation of HIMU or SHC (St. Helena) components. This type of assemblage belongs to spreading or plume MAR regions. Both magmatic suites; spreading as well plumes are in close association.
2) The second kind of MAR peridotite-basalt assemblage, characterised by their isotope signatures were postulated to have been formed by participation in melting below the MAR component, which could represent subcontinental lithospheric mantle material. The isotope signatures in the MAR peridotites of the second kind could also be attributed to incorporation of sediment material from hydrothermal circulation into oceanic crust. However, in this case the most challenging question is posed by the sharply defined differences in the ratio of $^{143}Nd/^{144}Nd$ in mantle peridotites sampled at single sites along the ridge axis, while concurrently, serpentinization of abyssal peridotites obtained at different MAR areas generally appeared to be closely allied by temperature and W/R conditions.

Despite obvious effects of secondary processes, the data presented poses some intriguing questions on the primordial properties of the mantle below the MAR along its axis.

Acknowledgments

We are grateful to Dr. Henri Bougault for his useful suggestions on data presentation and constructive discussion. This research was funded by grant 00-05-64165 RFBR (Russian Foundation for Basic Research) and also by the Russian-French project «Key areas of MAR», French-American Project FARA, and Project "Processes along Mid-Atlantic Ridge Crest" under bilateral Russian-American Agreement on the World Ocean Study.

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Hydrothermal Plumes Along the Mid-Atlantic Ridge: Preliminary Results of CTD Investigations during the DIVERSE Expedition (July 2001)

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During the DIVERSE Expedition (cruise 05 Leg 03 of the R/V ATLANTIS, Chief Scientist: Cindy Lee Van Dover) we conducted CTD investigations in bottom waters of several Atlantic hydrothermal fields: Logatchev (14°45'N), Snake Pit (23°22'N), Broken Spur (29°10'Nb), Rainbow (36°14'N), Lucky Strike (37°17'N) and the Neptune's Beard site (12°55'N) where signs of presumptive hydrothermal activity have been observed during the Fall 2000 cruise of the R/V YUZHMORGEOLOGIA (Fig. 1).

We had a good opportunity to document the physical and chemical characteristics of hydrothermal plumes in a relatively short period of time on most of the known North Atlantic hydrothermal sites. Observations, mapping and sampling of active and non-active vents by dives simultaneously performed by DSRV Alvin led us to attempt to relate these plume characteristics to seafloor sources.

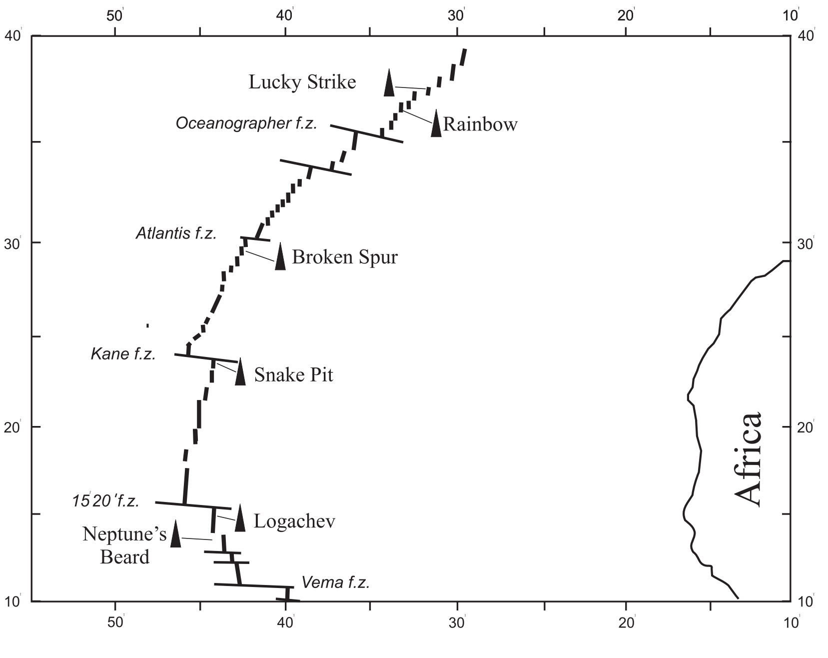

Figure 1. Location of sites of CTD investigations along the Mid-Atlantic Ridge

Results

At each site, from 3 to 5 still CTD stations in bottom waters with tow-yo casts between stations were conducted. Hydrothermal plumes were surveyed using a CTD equipped with a transmissometer, relay transponder and a rosette of 23 10 L Niskin bottles.

On recovery of the package, samples of plume waters were withdrawn for filtration under clean conditions through sterilized 0.2 µm Membrane filters. The filters were stored in sterile centrifuge polypropylene tubes and refrigerated at 5°C for further analyses upon return. Samples of high-temperature (348°C, Logatchev and 338°C, Snake Pit) hydrothermal fluids during Alvin dives at the Logatchev and Snake Pit areas were collected using Ti syringes. The samples were filtered and stored acidified (20 mL acid to 1000 mL of the fluid) with 0.5 normal solution of HNO_3. The temperature of the fluid was measured using a probe inserted into the clear fluid ~5 cm above the chimney orifice.

A background CTD-transmissometer plot was obtained at the DSDP Hole 395A, 22°45.3519'N / 46°04,8609'W. No evidence of hydrothermal activity in bottom waters were observed at this station.

Logatchev. Three stations were sampled over the main active field and Irina-2 complex. At all profiles

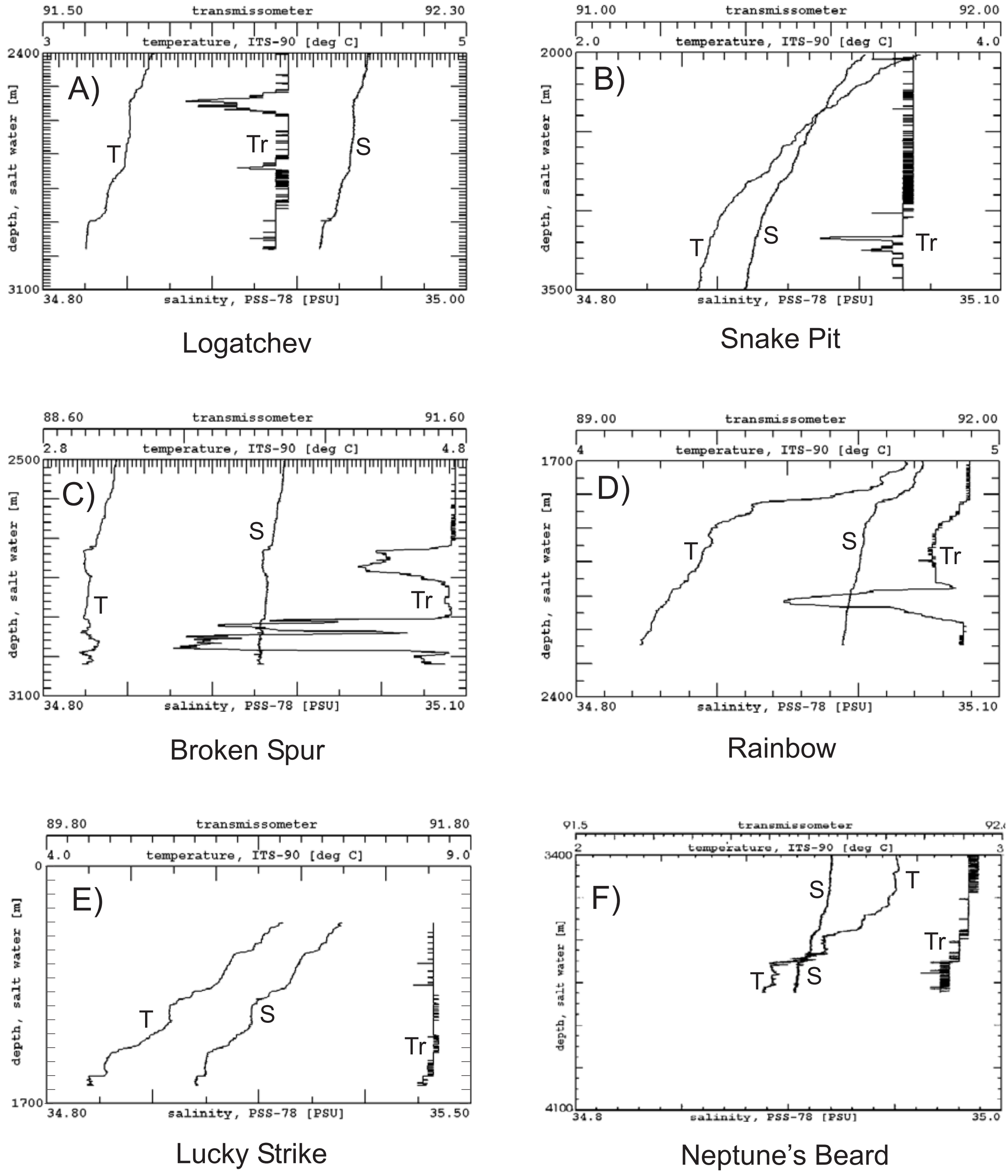

Figure 2. Examples of CTD-transmissometer plots at the six vent fields.

two distinct layers with high particle concentrations according to transmissometer data were observed (Fig. 2a). A most pronounced transmissivity signal (-0.284%) was obtained from the interval of 2500-2600 m depth (400-500 m above the bottom). It coincides with distinct negative temperature and salinity anomalies. The less pronounced signal (up to – 0.1%) corresponds to a lower horizon at 2700-2780 m depth (200-300 m from the seafloor) in conformity with positive anomalies of temperature and salinity. On the CTD-transmissometer plots, reflecting the structure of bottom waters above the Irina-2 site the 3rd maximum particle concentrations occur 30-60 m above the sea floor accompanied by the negative temperature and salinity anomalies.

Snake Pit. Five stations were sampled over the hydrothermal field. The strongest transmissivity response (-0.1-0.2%) was observed at 3180-3350 m depth (50-250 m from the seafloor) with no accompanied temperature and salinity variations in bottom waters (Fig. 2b).

Broken Spur. Four stations were sampled over the active hydrothermal field. At least two particle rich horizons in accordance with transmissometer measurements were observed (Fig. 2c). Unlike the Logatchev site, the most particle-rich layer occupied a lower position in the section of bottom waters (2900-3000 m depth) not far from the seafloor (30-50 m). The maximum deviation of light transmission from background level was -1.98%. The positive temperature anomalies and strong oscillations in salinity were characteristic in this horizon. In the water sample from this horizon a lot of particles were observed. An extremely strong signal was observed at a tow-yo profile to the North from this point during 180 m but then it disappeared sharply. At 2700-2800 m depth (~250 m above bottom) a less intense, but a more stable, (-0.36-0.67%) transmissometer signal was observed. It was accompanied by distinct negative anomalies of temperature and salinity.

Rainbow. Four stations were sampled along a S-N transect across the hydrothermal field. The strongest signal (-1.34%) was received from the horizon, 2125 m depth (150 m from the bottom) at a tow-yo cast with coordinates 36°13.80N/33°54.055W (Fig. 2d). No noticeable temperature nor salinity variations corresponding to this layer were detected. This signal was observed during 900 m from its maximum at N-S tow-yo profile and then came to an abrupt end. More stable was an anomalous layer at 1900-2050 m depth with 0.38% max deviation of light transmission from background level. It was observed along the entire profile. Variations of temperature and salinity at this horizon showed little distinction.

Lucky Strike. Four stations were sampled over the active hydrothermal field on a S-N transect. Only very weak anomalies of transmissivity (-0.05 to -0.08%) were observed 30-60 m above seafloor, accompanied by distinct negative anomalies of temperature and salinity (Fig. 2f). Significant variations of the latter parameters were also observed in a 400-500 m segment of bottom waters. The temperature of the vent waters according to the Alvin probe was 317°C.

Discussion

The structure of bottom waters above hydrothermal fields reflects the influence of different venting types. As a result, most plumes are distinctly layered. Each layer manifests itself in a decreasing of the transmissivity profile and (in most cases) associated anomalies in potential temperature and salinity.

For instance, different styles of venting observed at the Logatchev vent field lead to formation of three types of hydrothermal plumes in the ocean waters: buoyant, neutral buoyancy (effluent layer) and reverse buoyancy. The variations in the fluid buoyancy may be due to the effects of the vapour-liquid phase separation in the geothermal system at some depth below the seafloor. As a result, chlorinity of the liquid can be increased approximately three fold and the bulk of the gases CO_2 and H_2S must fractionate into the vapour-phase (Bischoff and Rosenbauer, 1987). When discharging, brines should form reverse plumes spreading not vertically upwards as usual buoyant plumes do, but descending to the bottom (Turner and Campbell, 1987; Sudarikov and Roumiantsev, 2000).

The strongest decrease of light transmission from background levels were observed in neutrally buoyant plumes. They were accompanied by the negative temperature and salinity anomalies formed by the entrainment of cold and less saline bottom waters, in accordance with the Atlantic model for plume formation (Speer and Rona, 1989). At some Atlantic hydrothermal fields, a positive temperature response is recorded in a buoyant plume at water levels of 50-60 m above the seafloor (Rudnicki, 1995). In the case of the Logatchev field, these close-to-bottom temperature anomalies are negative. The temperature drop could be the response for reverse plumes rather than buoyant plumes.

Influence of buoyant plumes should be reflected in the CTD-transmissometer plots as signals corresponding to positive anomalies of temperature and salinity.

Observations during Alvin dives throughout the cruise show that on some fields numerous discharge zones of diffuse flow (shimmering waters) through the sediments or pores in rocks and sulphide ores may play a significant role in fluid output. Though, its contribution to plume formation does not seem to be so great. Strong signals in buoyant and neutrally buoyant plumes (e.g. Broken Spur, Rainbow) correspond to intense discharge of high temperature fluids. In cases where the diffuse flow prevails over high temperature venting, it forms close-to-bottom (30-60 m) weak anomalies of transmissivity accompanied by significant variations in temperature and salinity in a larger segment of bottom waters (as was observed at the Lucky Strike area). Similar characteristics of the close to bottom part of the water column were observed at the Logatchev site, which is also characterised by shimmering waters. At the Snake Pit site it was observed in Alvin dives, that the greater part of the fluid discharge is diffuse flow. The data from CTD transmissometer plots for bottom waters in this area indeed show weak anomalies of transmissivity and absence of temperature and salinity variations.

It is interesting to compare the CTD data obtained at the Neptune's Beard area with data from the Lucky Strike hydrothermal site. In both cases we observed similar anomalies of transmissivity (~ -0.1%) immediately above the seafloor and temperature/salinity anomalies at several layers (Fig. 2 e,f).

Along with the decrease in measured fluid temperatures during Alvin dives, the alteration of the amplitude of the transmissivity signal at Lucky Strike was less than at Snake Pit and at Snake Pit it was less than at Logatchev. The same trend was observed in fluid temperatures measured during the cruise at these sites. Thus, in the Neptune's Beard area the prevalence of diffuse discharge could be expected rather than high temperature venting.

Acknowledgements

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Hydrothermal fluids at the Mid-Atlantic Ridge: Preliminary results from sub-seafloor electromagnetic sounding

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The MADRIGALS (Mid-Atlantic Deep-towed Resistivity and Induction Geophysics at Lucky Strike) cruise, undertaken in September 1999 on the RRS Charles Darwin, was a central component of the ISO-3D research project: an international research project, funded by the European Union under the Mast III programme. As part of this research cruise, a marine controlled source electromagnetic (CSEM) sounding experiment was carried out on the Lucky Strike segment of the Mid-Atlantic Ridge (Fig. 1). The topography of this segment is dominated by a 1500 metre high, 20 kilometre wide seamount, where both diffuse and high temperature venting have been observed. Previous sonar, diving and sampling investigations have yielded excellent information on the surface geological and geochemical characteristics of the hydrothermal system (e.g. Langmuir et al., 1993; Fouquet et al., 1995; Wilson et al., 1996). By determining the electrical resistivity structure within and beneath the seamount (at a resolution of tens of metres, to depths of several kilometres), the large-scale properties of the crust through which the fluid flows can now be investigated.

In a CSEM experiment, a low frequency electromagnetic signal (of the order of 0.1 to 10 Hz) is transmitted through the oceanic crust to an array of electric field receivers placed on the seafloor. The signal detected by the instruments is dominated by fields that have diffused through the crust, because of the rapid attenuation of fields in the water column. The distribution of electrical resistivity of the rocks below the seabed is determined by measuring the variation of electric field strength and phase as a function of source receiver separation and geometry, as the source is towed through the array of instruments.

During the cruise, the DASI (Deep-tow Active Source Instrument) transmission system (from the Southampton Oceanography Centre) and LEMUR (Low-frequency ElectroMagnetic Underwater Receiver) receivers (from the Southampton Oceanography Centre and University of Lisbon) were used. Previous CSEM experiments over other sections of mid-ocean ridge have already proven the capability of this instrumentation in such a setting (Evans et al., 1994; MacGregor et al., 1998; MacGregor et al., 2001).

The DASI transmitter consists of a 100 m long, neutrally buoyant, horizontal electric dipole (HED) streamed behind a towed vehicle. The height of this vehicle is control-

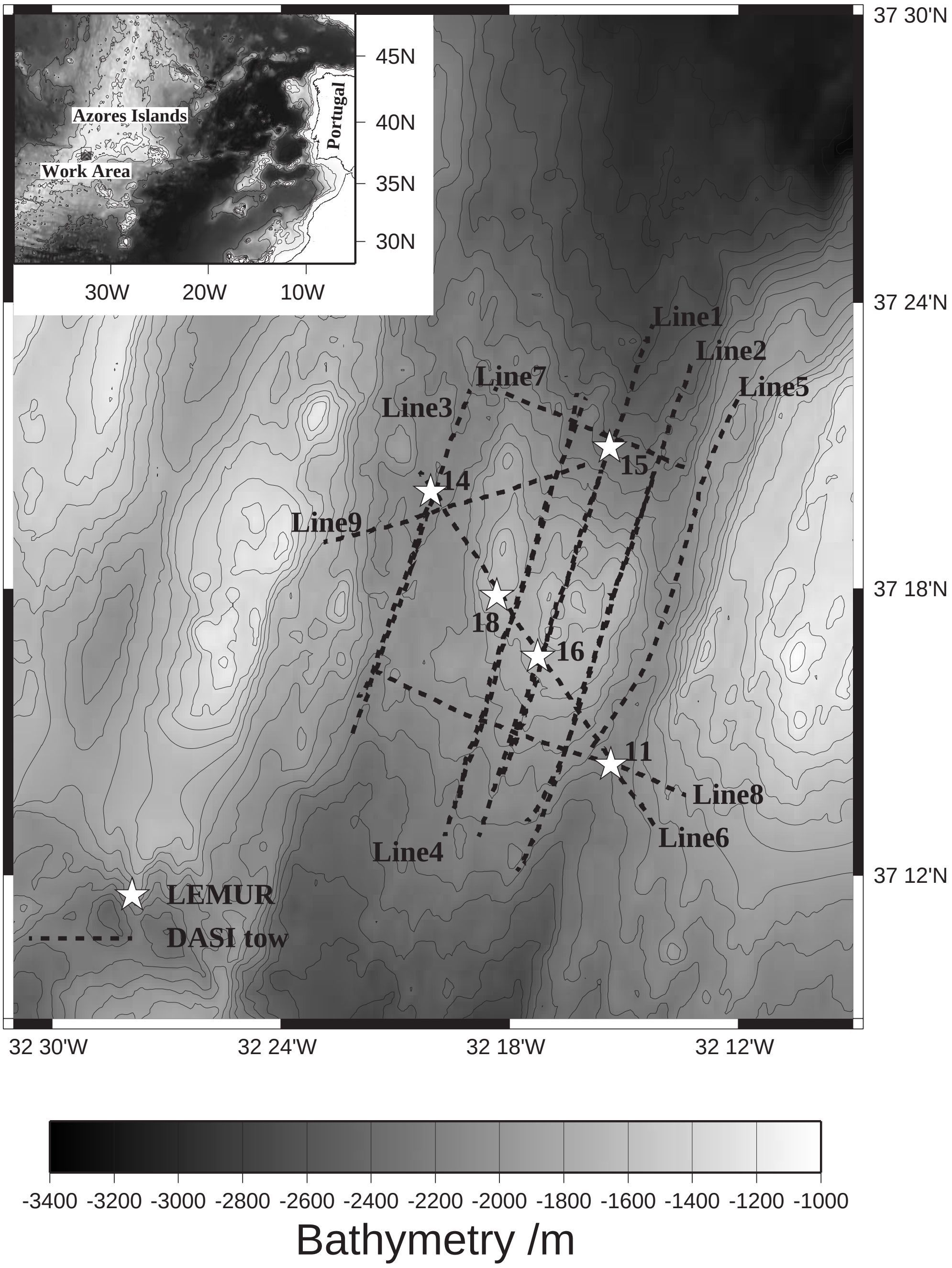

Figure 1. A swath bathymetric chart of the Lucky Strike segment of the Mid-Atlantic Ridge showing the locations of DASI as it was towed along the nine experiment lines, and the deployment positions of the LEMUR ocean bottom instruments. The contour interval is 100 m.

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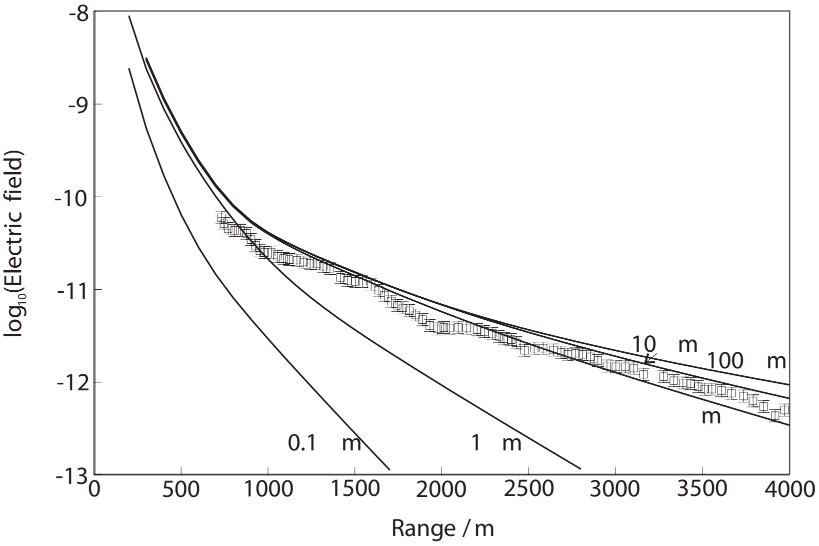

Figure 2. Data recorded by LEMUR 16 plotted with modelled halfspace responses. The black squares with error bars are 1 Hz data points recorded during Line 1, when the transmitter was to the north of the LEMUR, up to a source-receiver offset of 4 km. The five curves correspond to the predicted response of a uniform halfspace, for the resistivities indicated. All models shown were overlain by a halfspace of resistivity 0.3 Ωm, representing the seawater.

led using the deep-tow winch and monitored acoustically using an altimeter mounted on the towed vehicle. For most of the cruise DASI transmitted a 1 Hz signal, whilst being flown 70-80 m above the seafloor. It was necessary to fly DASI at a height of approximately 40 m when the transmission frequency was increased to 4 Hz, due to the faster attenuation of EM signals by seawater at higher frequencies. DASI transmission tows (Fig. 1) were arranged in order to provide good 3-dimensional coverage over the target area. Five LEMURs recorded data in this study. These instruments consist of an orthogonal pair of 13.5 m horizontal electric dipole sensors, and a 24-bit recording system.

The DASI transmitter was deployed for a period of eight days, and successfully transmitted over tracks totalling 212 km in length. The quality of data recorded by the LEMURs was excellent during this time, with a good signal to noise ratio being maintained up to source-receiver separations of 10 km, the maximum offset attained in the experiment.

Preliminary modelling of the data has been in terms of 1-dimensional resistivity structures. Modelling strategies used included: halfspace and layer-over-halfspace modelling (Chave and Cox, 1982) for the 1 Hz data recorded by each LEMUR; and 1-D Occam inversion (Constable et al., 1987) of subsets of the data from LEMUR 16, the instrument located at the summit of the seamount.

Figure 2 shows a portion of the data recorded by LEMUR 16, plotted against the response predicted by uniform halfspace models. It can be seen that, whilst the recorded data is almost fully bound by the 1 Ωm and 100 Ωm halfspace lines, it is not adequately predicted by such a simple model. The short-range signal (corresponding to shallow depths beneath the seafloor) follows the 1 Ωm halfspace line, whilst data at ranges greater than about 1300 m lie closer to the halfspace responses predicted by 5 and 10 Ωm. This result is consistent with increasing resistivity with depth.

The data can be better modelled by a resistivity halfspace, overlain by a single layer of a second resistivity (corresponding to the crustal layer 2A, overlying a more resistive layer 2B structure). Best-fit layer-over-halfspace models were obtained for each of the five LEMURs. However, investigation of the model space associated with this scenario revealed that a significant trade-off existed between layer thickness and layer resistivity when only 1 Hz data were used. Such a trade-off reflects that this portion of the dataset is more sensitive to the conductance of layer 2A (that is, the thickness divided by the resistivity), rather than the resistivity. The conductance was found to vary systematically between 94 S at LEMUR 11, the instrument furthest from the ridge axis, and 250 S at LEMUR 16, the instrument near the summit of the seamount. A greater conductance would be expected near the ridge axis where hydrothermal fluids with a potentially elevated temperature and/or salinity circulate in the crust.

One way to visualise the higher-dimensional structure present in the EM data is to normalise the electric field strength recorded by an instrument against that predicted by a simple 1-D resistivity model for the same source-receiver geometry. This has the effect of removing the range-dependent variation in the signal strength, highlighting areas that are experiencing an anomalous electric field strength (with respect to the 1-D model used). For this purpose, a 1-D layer over halfspace resistivity model (consisting of a 100 Ωm halfspace, overlain by a 200 m-thick layer of 2 Ωm) was chosen, based upon a typical result from the forward models obtained.

The results of normalising a portion of the 1 Hz data received by LEMUR 18 are shown in Figure 3. The normalised trend can be interpreted as implying that the resistivity is lower than the model within the axial zone. Clear systematic trends are also visible on this and other sections of normalised data. The shortest wavelength of these are

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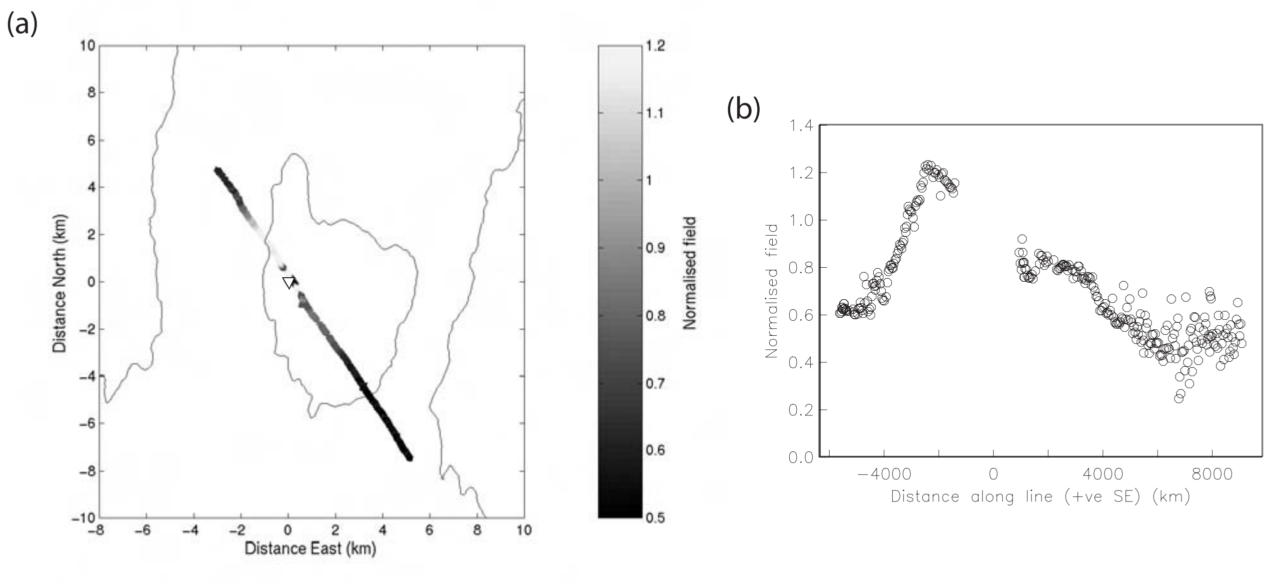

Figure 3. (a) Normalised electric field data, derived from a portion of the 1 Hz data recorded by LEMUR 18 (black triangle). The grey scale corresponds to the normalised electric field strength (data value divided by the corresponding result for a 200 m thick/2 Ωm layer over a 100 Ωm halfspace). Normalised data are plotted at the appropriate source location, in km East and North of the LEMUR. Receiver locations are shown by black triangles. The Lucky Strike seamount and median valley walls are outlined by the 1900 m depth contour. (b) The same data plotted against distance along the tow line.

due to variations in resistivity structure at scales which are within the resolution of this experiment, and not simply short-wavelength scatter. Indeed, the level of scatter in the data from this experiment is significantly lower than that from previous CSEM studies. This reflects the continuing development of, and improvements in, the instrumentation used.

Future analysis of this EM data will include 2-D inversion (Unsworth et al., 1993), and 3-dimensional forward modelling, using code developed as part of the ISO-3D research project (Flosadóttir and MacGregor, 2001). We hope that this will provide new information concerning the nature of the axial hydrothermal system fluid circulation.

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International Ridge-Crest Research: Back Arc Basins

Deep structure and geodynamic evolution of the Tonga-New-Hebrides region: geochemical, geochronological and seismotomographic data.

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Introduction

The complex geometry of the convergence boundary between the Australian and Pacific plates in the Tonga-New Hebrides region results from the active tectonic processes which have taken place since the early Cenozoic. The Cenozoic evolution of this relatively small region involved repeated changes in the configuration of plate boundaries and subduction polarity associated with opening of the North Fiji Basin (Daniel et al., 1977; Carney et al., 1985; Taylor et al., 2000). The present boundary between the two plates runs along the North and South New-Hebrides trenches, Hunter and Fiji fault zones and the Tonga trench (Fig.1).

The existing geodynamic and tectonic models of the recent evolution of the Tonga-New-Hebrides region are based on synthetic analysis of bathymetry, satellite-derived gravity, seismicity, magnetism, and GPS measurements, as well as petrological, geological, geochemical, and stratigraphic evidence. The structure of the plate convergence zone and the direction and rate of plate motions acquired the present form about the Neogene-Quaternary boundary. In the early Cenozoic, Santa-Cruz, Vanuatu, Fiji, and Lau islands belonged to the Australian plate and made up a single island arc. The Oligocene and Miocene volcanism produced calc-alkaline to shoshonitic island-arc volcanic series. At that time, the Pacific plate subducted westward beneath the

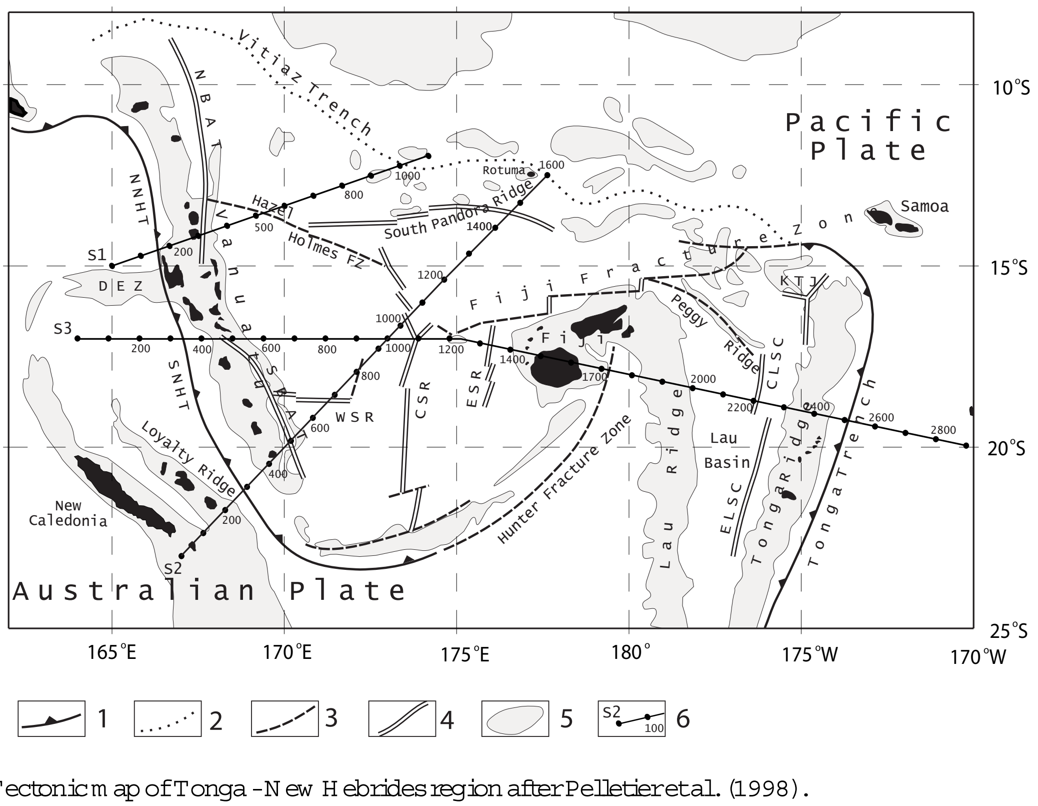

Figure 1. Tectonic map of Tonga - New Hebrides region after Pelletier et al. (1998).
1 - present-day deep trenches; 2 - Vitjaz paleotrench; 3 - faults, 4 - rift zones; 5 - uplifts; 6 - seismic tomography profiles with distance marks (km). Where: NNHT - North New Hebrides trench; SNHT - South New Hebrides trench; NBAT - North back-arc trench; SBAT - South back-arc trench; WSR - West Spreading Ridge; CSR - Central spreading ridge; ESR East spreading ridge; KTJ - King triple junction; CLSC - Central Lau spreading centre; ELSC - East Lau spreading centre.

Australian plate along the Vitiaz and Tonga trenches. The initiation and development of spreading zones there led to the opening of the Fiji basin. The plate convergence along the Vitiaz trench ceased, and a new opposite-dipping subduction zone arose to the south-west, along which formed the Vanuatu island-arc system. Paleomagnetic studies provide evidence of 90° counter-clockwise rotation of the Fiji plate and 30°-40° clockwise rotation of the Vanuatu island arc (Malahoff et al., 1982). The North-Fiji basin opening was chiefly controlled by the development of Central and East spreading ridges (Fig.1). The spreading centers in the Lau basin opened later, about 3 Ma ago, as attested by absolute dating and detailed airborne magnetic studies. Simultaneous spreading of the oceanic lithosphere in the North-Fiji and Lau back-arc basins caused destruction of the Vitiaz trench (south of 12°S as far as the junction with the Tonga trench), induced the development of the Fiji fault zone, and displaced the Tonga trench axis to the east. However, the exact time of the last spreading reversal and the onset of the North-Fiji basin opening remains unclear and varies from 11 - 13 to 3.5 Ma, depending on the source.

The opening of back-arc spreading centres in the North Fiji and Lau basins accelerated convergence in the two subduction zones, up to 24 cm/year in the northern part of the Tonga trench (16°S) and about 16 cm/year in the south (22°S), based on GPS data. The spreading rates in the corresponding latitudes of the Lau basin are 16 and 8 cm/year, respectively (Pelletier et al., 1998). In the Vanuatu island arc, the subduction rate varies from 15-17 cm/year (North New Hebrides trench) to 10-12 cm/year (South New Hebrides trench), but the pure convergence rate of the Australian and Pacific plates is lower. The spreading rates in the back-arc spreading centres in both Vanuatu and Tonga collision zones are about 8-10 cm/year. However, at the junction of the Vanuatu island arc with the D'Entrecasteaux fault zone, the convergence rate is as low as 4-5 cm/year (Pelletier et al., 1998; Taylor et al., 1995), possibly, because the relatively thick and heterogeneous crust of this block impedes its subduction beneath the island arc.

The results of original geochemical and geochronological investigations presented in this paper allow us to define more exactly the time of main events in the geodynamic development of Tonga-New Hebrides region and gives the basis for interpretation of deep structure of this area obtained from the teleseismic tomography.

Geochemistry and absolute age of the magmatic unites

The rock samples studied were collected in 1988 during the 13th R/V "Academician Alexandr Nesmeyanov" cruise under dredging on two sections from east and west slopes of New Hebrides trench (Fig.1). For comparison of sampled rocks with recent volcanic unites the dragged material from station H13-43 located in central part of Vanuatu arc was used. The major oxides were determined by XRF. For dating, the K-Ar method was used. Measurements were carried out using a mass-spectrometer, MI1201. All analytical procedures were performed at the United Institute of Geology, Geophysics and Mineralogy SB RAS. All rocks were divided into groups using cluster analysis with the tree-ring reconstruction. Euclidian distances were used for the construction of dendrogramms. The optimal distance function was calculated on the basis of oxide content difference between the nearest points. The square root of mean-square difference of concentration between nearest points was taken as a metric coefficient for every component. The total information about the collection used is available from the following web site URL: http://www.uiggm.nsc.ru/geodynam/lab820/index.html or it may be received by e-mail: kolobov@uiggm.nsc.ru.

The geochemical surveys show that there are two magmatic series in the area of New Hebrides trench: tholeiitic and subalkaline. At Vanuatu arc the island arc tholeiitic and calc-alkaline series are present, the later being more widespread. Statistical analysis allows to divide the rocks of New Hebrides trench into 5 groups (Table 1). The only group of rocks from New Hebrides trench belongs to the tholeiitic series (group 1). The compositional characteristics of this group are akin to BABB at the main North Fiji basin. The basalts of this type have the most ancient age (27.4 - 17.0 Ma). Among the subalkaline basalts there are sodium and potassium unites. The sodium basalts are more differentiated and they include three groups. (groups 2, 3 and 4). Group 2 is more plentiful but, nevertheless, has respectively a narrower time interval (17.2 - 14.0 Ma). Subalkaline basalts of groups 3 and 4 were found only in the southern part of New Hebrides trench. They cover the older time interval of origination (20.8 - 18.0 Ma). Among themselves all these groups differ in contents of Al_2O_3, FeO* and CaO. The sodium subalkaline basalts have affinity with OIB. The presence of potassium subalkaline basalts in the New Hebrides trench (group 5) is most remarkable because the shoshonitic-latitic series is formed exclusively in the rear of the active well-developed continental margins and in continental rifts. The majority of these rocks are the usual shoshonites with high contents of K_2O, Rb, Sr, Li and Ba. The age of these rocks varies from 5.5 to 5.4 Ma.

Calc-alkaline basalts predominate at the station H13-43 located in the northern part of the Vanuatu arc. Statistically, the rocks from this station can be divided into two groups (6 and 7). The former corresponds to magnesia island-arc tholeiites, the later to calc-alkaline basalts of islands and submarine volcanoes from Vanuatu arc formed in the Pliocene-Pleistocene age. Our data show the age of these basalts to be 4.5 - 3.6

Table 1. Chemical composition and K-Ar age of volcanic rock groups from New Hebrides trench and Vanuatu arc.

Region	New Hebrides trench										Vanuatu Arc			
Cluster	BBAB (1)		OIB (2)		OIB (3)		OIB (4)		SHB (5)		IAT (6)		CAB (7)	
Oxides	x	σ	x	σ	x	σ	x	σ	x	σ	x	σ	x	σ
SiO_2	49,41	0,90	49,42	0,98	48,51	0,90	48,48	1,39	47,96	1,18	47,75	0,65	50,35	1,72
TiO_2	1,29	0,13	2,05	0,28	2,53	0,39	1,97	0,24	0,90	0,14	0,86	0,09	0,79	0,14
Al_2O_3	15,07	0,70	14,69	0,46	15,22	0,71	16,14	0,86	16,96	0,93	14,58	0,61	18,06	1,23
FeO*	9,70	1,00	10,33	1,10	11,33	0,99	9,53	0,93	9,46	0,71	9,45	0,28	8,40	0,82
MnO	0,18	0,03	0,19	0,03	0,18	0,02	0,16	0,03	0,20	0,05	0,14	0,00	0,13	0,03
MgO	7,22	0,62	5,94	0,75	3,89	0,76	3,78	0,55	4,65	0,63	10,14	0,54	4,46	1,21
CaO	11,98	0,72	10,73	0,80	8,61	0,85	10,55	0,78	10,23	1,06	12,03	0,73	9,81	1,31
Na_2O	2,26	0,27	2,96	0,33	4,05	0,33	3,93	0,44	2,82	0,37	1,95	0,13	2,94	0,37
K_2O	0,38	0,11	0,54	0,16	1,05	0,31	0,86	0,18	2,96	0,41	0,87	0,06	1,54	0,42
P_2O_5	0,25	0,07	0,38	0,09	0,48	0,08	0,48	0,09	0,44	0,10	0,29	0,12	0,35	0,13
П.П.П.	1,45	0,99	1,91	0,86	3,01	0,65	3,11	1,33	2,46	1,61	1,60	1,17	2,44	0,98
n	50		62		31		9		32		3		17	
Age interval (Ma)	27.4-17.0		17.2-14.0		20.8-18.0				5.5-5.4		3.6		4.5-3.9	

x – arithmetic mean content; σ - mean-square deviation; n – number of analysis; * - ferum content calculated for FeO. Abbreviations: BABB– Back Arc Basin Basalts, OIB – Ocean Island Basalts, SHB – Shoshonite, IAT – Island Arc Tholeiites, CAB – Calc-Alkaline Basalts.

Ma, which is consistent with the period of early island arc volcanism in this area.

Tomography code

Understanding of the mechanisms driving the geological evolution in a region is impossible without reliable data on its upper mantle structure, for which seismic tomography is a most powerful tool. Here we apply our tomographic code to get the 3D seismic structure beneath the Tonga-New-Hebrides region down to the depth of 650 km.

The upper mantle structure was studied using the Inverse Teleseismic Scheme. The main idea is to use teleseismic rays from earthquakes in a region recorded by the worldwide seismological network (Koulakov, 1998), whereby the deep structure of any active seismic area can be imaged without data of regional networks. In this research, we used about 800 000 P teleseismic rays (epicentral distances from 20° to 91°) from over 20000 shallow (<50 km) earthquakes that occurred in the Tonga-New-Hebrides region and were recorded by more than 2000 stations of the worldwide seismological network. The information was taken from the ISC catalogues for the period from 1964 to 1996. The procedure of travel time processing for this code was described in detail in (Koulakov, 1998). The tomographic inversion is based on node parameterization, in which velocity parameters are computed in the nodes of a 3D grid, and the velocity pattern between the nodes is approximated continuously (constant velocity gradient).

The ITS code is applied to a number of overlapping fragments of the study region, which is a way to test the stability of the results by their comparison in the overlap areas on the one hand, and, on the other hand, a way to avoid the effect of lower mantle anomalies due to the small size of the fragments. In this context, the best for teleseismic approximation is the aspect ratio of a scanned region within 1.4 – 1.8. The results for different fragments were compared, averaged, and summed up. The general result of this research has been computed on the basis of five fragments located along the highest seismicity zone. In each fragment the grid was installed on seven depth levels: 50, 150, 250, 350, 450, 550, and 650 km, with 60 nodes on each level, distributed according to the ray density.

The tomographic results are presented in a horizontal section at a depth of 150 km and three vertical sections (Fig. 2). Hatched fields mark negative seismic anomalies (low-velocity zones) and unhatched fields mark positive seismic anomalies (high-velocity zones), most often interpreted as cooler mantle fields. Black dots on the vertical sections show the hypocenters of deep earthquakes located near the section plane (± 50 km).

Discussion

The tomographic images of the Tonga-New-Hebrides region we obtained clearly show subduction zones traceable as boundaries of cool slabs whose penetration into the mantle depends on the duration of subduction. The upper mantle structure beneath the Tonga trench is consistent with the tomographic model by R. van der Hilst (1995) which shows the position of the Pacific slab down to 1400 km. From the observed rate of subduction of ~8 cm/year, its duration in the Tonga trench can be estimated at 30-35 Ma, which coincides with the geological reconstruction by J. Daniel et al. (1977). It was shown that in the Eocene the convergence of Pacific and Australian plates occurred between New Caledonia and Loyalty islands, with subduction of the Australian plate under the Pacific one. About the Eocene/Oligocene boundary, the subduction changed polarity and the subduction zone moved to the Lau islands and the Vitiaz trench. So during the Miocene the Pacific plate subducted beneath the Australian plate along the eastern foot of the Lau-Colville ridge and Vitiaz trench. The effusions of BABB (group 1) relate to this period of geodynamic evolution of New Hebrides region. As the spreding zones opened, the deeper parts of mantle began to melt forming basaltic series with subalkaline geochemical profile. Thus, the subalkaline basalts of OIB type (groups 2, 3 and 4) are formed here. Their age is younger, corresponding to the second half of the Miocene.

There is a knee of the Pacific plate slab under the Tonga trench at a depth of 400-700 km (van der Hilst, 1995). The width of the horizontal segment of the slab depends on the convergence rate increasing towards the equator and coincides with the magnitude of displacement of the trench axis from its Miocene position. Between 5 and 6 Ma, calc-alkaline island-arc volcanism in Fiji islands gave way to the shoshonitic series typical of back-arc environments, and the subduction zone moved to its present position located along the Tonga islands.

As is seen in the tomographic sections, the slab of the Australian plate under the New-Hebrides trenches has its lower end at 300-400 km. With the convergence rate in this area of 8-10 cm/year, subduction has continued for less than 4-5 Ma, which is consistent with other geological and geophysical evidence. The absence of sediments in the New-Hebrides trenches and the symmetrical distribution of volcanites of similar age and composition on both sides of the trenches attest to a relatively short duration of subduction. Moreover, 5.5 – 5.4 Ma shoshonites (group 5) sampled on both sides of the trenches indicate that this region was then the back area of a mature island arc. Compositional similarity of those shoshonoites with post-Miocene shoshonites in Fiji islands proves that in the Miocene, the New-Hebrides, Fiji, and Lau islands composed a single island-arc system that extended along the Tonga and Vitiaz trenches (Taylor et al., 2000).

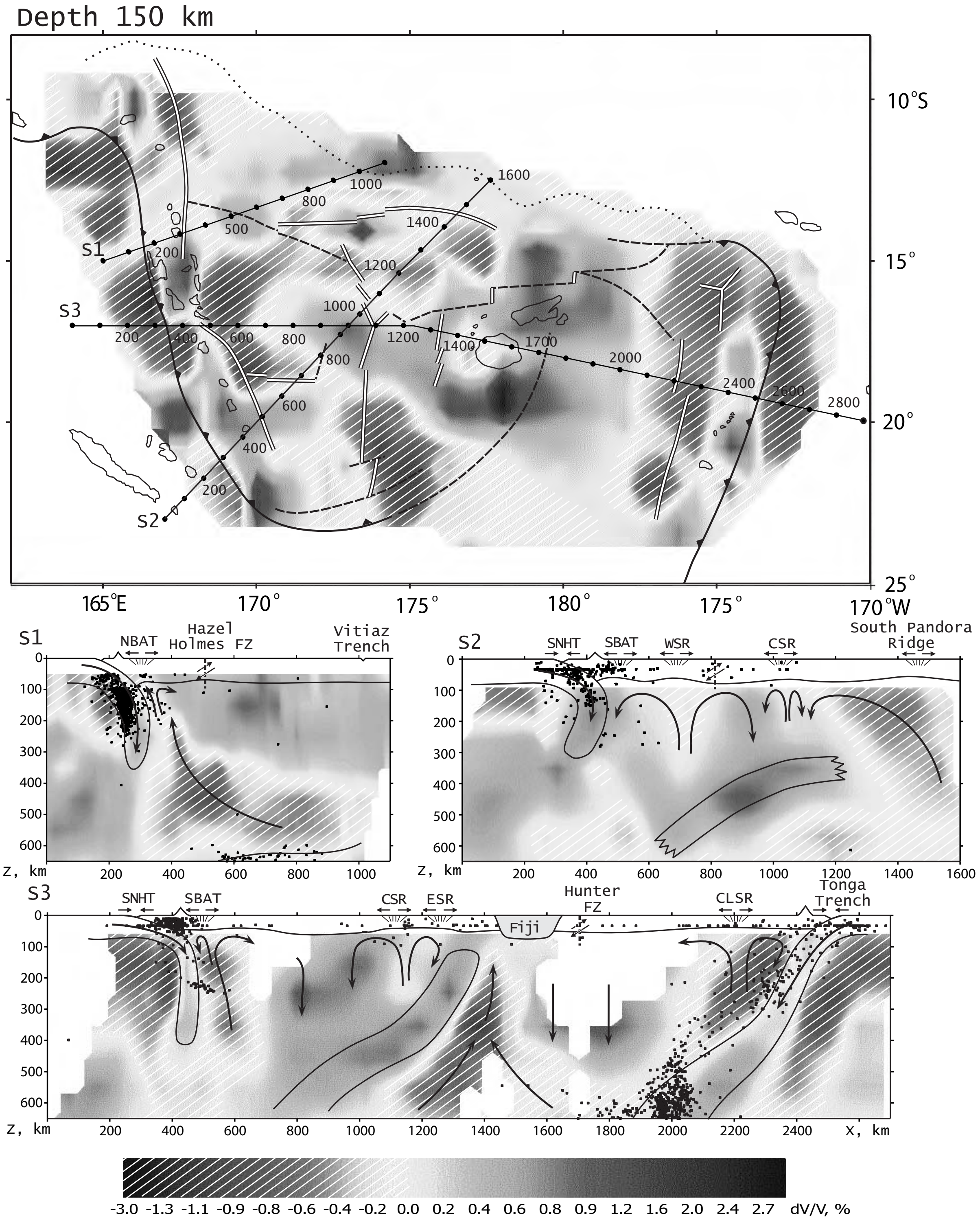

Figure 2. Results of Inverse Tomographic Scheme of New Hebrides region. Horizontal section at 150 km (above). Three vertical tomographic section with depth intervals from 50-100 to 650 km (below). Locations of earthquake hypocenters are shown with filled dots on vertical sections (50 km). Arrows show presumable direction of uppermantle heat and mass transfer. Z - depth (km). X - distance from the initial point of section (km). Other symbols are as in Fig. 1.

The inclined positive seismic anomaly in the central parts of S2 and S3 (Fig 2) may be a fragment of the ancient Pacific slab subducted along the Vitiaz trench in pre-Pliocene time. The anomaly is more pronounced in section S2, possibly, because of partial destruction of the slab by the mantle plume seen in the right side of S2. The slab plays a role of a "heat screen" as hot material from the transition zone and from the lower mantle ascends along its bottom. The absence of deep seismicity along the detached slab is evidence of slow sinking, probably at a rate under 1 cm/year, as it sinks merely by negative buoyancy without pushing from the Pacific plate. Hence, for the last 5 Ma after detachment the slab has sunk as shallow as 50 km. During the same time span, active back-arc spreading caused significant north-eastward displacement (600 - 800 km) of the Vitiaz trench off the detached slab.

The new tomographic data, along with paleomagnetism and geochronology call for some revision in the existing ideas of the geodynamic evolution of the Tonga-New Hebrides region (Carney et al., 1985). Namely, we suggest that a significant reorganization of the geodynamic regime occurred 5 Ma ago, at the Miocene/Pliocene boundary. Before that time, the Pacific plate subducted in the east-west direction along the Lau-Colville subduction zone and the Vitiaz trench. Since the earliest Pliocene, the New Hebrides island arc sprung up to the west, together with the opening North Fiji basin. The Pacific – Australian plate convergence boundary moved to the present New Hebrides trench, whereby the Australian plate started an eastward subduction beneath the Pacific plate. Based on the rate of plate motion (Pelletier et al., 1998) and the depth of the Australian slab (400 km), the duration of the Vanuatu subduction may be estimated at 4 - 4.5 Ma. This is consistent with the 4.1 - 3.9 Ma K-Ar ages of island arc tholeiitic and calc-alkaline basalts (groups 6 and 7 respectively) that erupted at the early stage of the island-arc evolution. About the same time (early Pliocene), the subduction zone in the southern New Hebrides region moved to the east, from the foot of the Lau-Colville ridge to the Tonga-Kermadec trench, but the subduction preserved its westward polarity.

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The articles appearing in InterRidge News are intended to disseminate as quickly as possible preliminary results on recent mid-ocean ridge and back arc ocean cruises. Articles are not peer-reviewed and should not be cited as peer reviewed articles. The InterRidge office does edit the articles and strives to correct any grievous errors however all responsibility for scientific accuracy rests with the authors. Comments on articles that have appeared in InterRidge News are always welcome.

Agnieszka Adamczewska
InterRidge Coordinator

International Ridge-Crest Research: Mid-Ocean Ridge

New Program by KORDI Focuses on the Geological and Biological Issues of Hydrothermal Systems on Active Plate Boundaries in the Western Pacific

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In February 2000, Korea Ocean Research and Development Institute (KORDI) launched a new program to investigate active hydrothermal vent fields in the western Pacific. This new program, referred to as "Daeyang" (meaning a large open ocean in Korean), is an initiative by KORDI to expand its marine scientific effort in the Pacific and to provide new platform for the Korean scientists to collaborate with scientists from other countries, which are leading research activities on mid-ocean ridges. Since its start two years ago, the program has paved the way for the Earth scientists, physical oceanographers, chemists and biologists to conduct joint research projects in the western Pacific.

Brief History

KORDI's interest in the Pacific Ocean can be traced back to the late 80s starting with the investigation of manganese nodules in the central Pacific. Since the mid-70s, many countries have explored the seafloor in the east and central Pacific between the Clipperton and Clarion Fracture Zones, and in the early 90s Korea became the latest member to join the list. Domestically, an important turning point was reached in 1992 with the launch of Onnuri, a 1500-ton research vessel. KORDI's activity in the Pacific grew and diversified with the addition of this new research vessel. In 1995, a program was initiated to investigate manganese crust that formed around the rims of old Cretaceous and Jurassic seamounts in the western Pacific. From 1998 to 2000, three reconnaissance surveys were conducted in the western and equatorial Pacific to assess the economic feasibility of sulfide deposits. During this period, the surveys were conducted around the Yap trench and arc region in 1998, in the Manus Basin, Papua New Guinea in 1999 and in the Woodlark Basin in the Solomon Islands in 2000. The Daeyang Program differs from these early mineral reconnaissance surveys in that its main focus lies on building a basic scientific foundation. The Daeyang Program is entering its second phase. The first phase of the Daeyang Program was conducted in 2000 and 2001. During the first phase, scientists conducted, for the first time, an extensive geological survey of the Ayu Trough, the southernmost sector of the Philippine Sea.

The First Phase

Background

The Ayu Trough was chosen as the study area because it is the only margin along the Philippine Sea Plate (PSP) that is not a subduction zone (Fig.1). For example, the Izu-Bonin-Mariana subduction system and the Yap and Palau Trenches comprise the eastern boundary of the PSP, and the Nankai Trough and Ryukyu and Manila and Philippine Trenches the western boundary. Some of the trenches are very active subduction zones, whereas others are significantly less active, as demonstrated by the present-day seismicity data and the presence of active volcanoes.

Although scientists generally agree about the large northward movement of the PSP during the Tertiary, there is a debate regarding the rotational history of the PSP. For example, Rangin et al. (1990) and Hall et al. (1995) argue that the PSP has undergone a major clockwise rotation in the last 50-60 Ma. On the other hand, Daly et al. (1991) and Lee and Lawver (1994) disagree with the clockwise rotation of the PSP. One of sources for the controversy lie in the fact that there is very little reliable paleomagnetic information, in particular, regarding the declination of the PSP. Some investigators have used the paleomagnetic measurements taken from the island arc region. However, many island arcs lie too close of convergent boundary and therefore the declination may be affected by local deformation of the islands and not represent the motion of the PSP. Presently, much of the useable information on the declination of the PSP comes from paleomagnetic observations made on land at the southern end of the PSP such as those from Halmahera (Hall et al., 1995).

The plate motions are in general determined by taking magnetic anomaly pairs across the spreading axis and deducing the rate of opening and direction from them. As a result, accretionary boundaries are where the relative velocity of the plate can be derived. In the case of the PSP, however, the resolution of plate velocity is difficult because it is almost entirely surrounded by subduction zones, except for a few places, including the Ayu Trough.

The Ayu Trough has been considered as a possible site where magnetic analyses might provide an important constraint on the relative motion of PSP. However, the conventional methods of measuring magnetic field and subsequent analysis pose a problem because the Ayu Trough is close to the magnetic equator and the general direction of spreading is east and west. The conventional means of measuring magnetic field is to measure the scalar total field values using proton precession magnetometer. However, a simple geometric consideration will show that a mid-ocean ridge located at the magnetic equator and spreading east-west will have a greatly subdued total field anomaly. Another factor which may hinder this effort is that, on the basis of bathymetric information from earlier investigations, Ayu Trough appears to be spreading at a very low rate. If so, the discrimination of different anomalies may be quite difficult.

Despite its significance, only a handful of surveys have been made in the Ayu Trough to date. An early notable work on the Ayu Trough was by Weissel and Anderson (1978) who examined the boundaries of the Caroline Plate including Ayu and Sorol Troughs. On the basis of sediment thickness observed along seismic profiles and sedimentation rates derived from nearby DSDP site 62, they inferred that the Ayu Trough began opening during the mid-Miocene, perhaps 10-12 Ma. However, this is a rough estimate and further studies are needed including age dating on rock samples to validate the timing of opening. Another question regarding the Ayu Trough is whether it is actively spreading at the moment or not. According to Weissel and Anderson (1978), the spreading of the Ayu Trough appears to have slowed down or even halted since 6 Ma. Until high-resolution near-bottom magnetic vector field measurements are obtained, however, a direct estimation of spreading rate may also be quite difficult. More recently, a survey of the Ayu Trough was carried out in 1992 by the University of Tokyo onboard R/V Hakuho-Maru (Segawa, 1993). The survey performed a multidisciplinary geological investigation of the western Pacific which included the Ayu Trough and collected underway geophysics and multibeam bathymetric survey north of 3°25'N at the Ayu Trough. However, the primary focus of this investigation was to document the crustal accretionary processes at the axis, and therefore the ship track lines of this survey did not extend far from the axis to address the opening history of the basin.

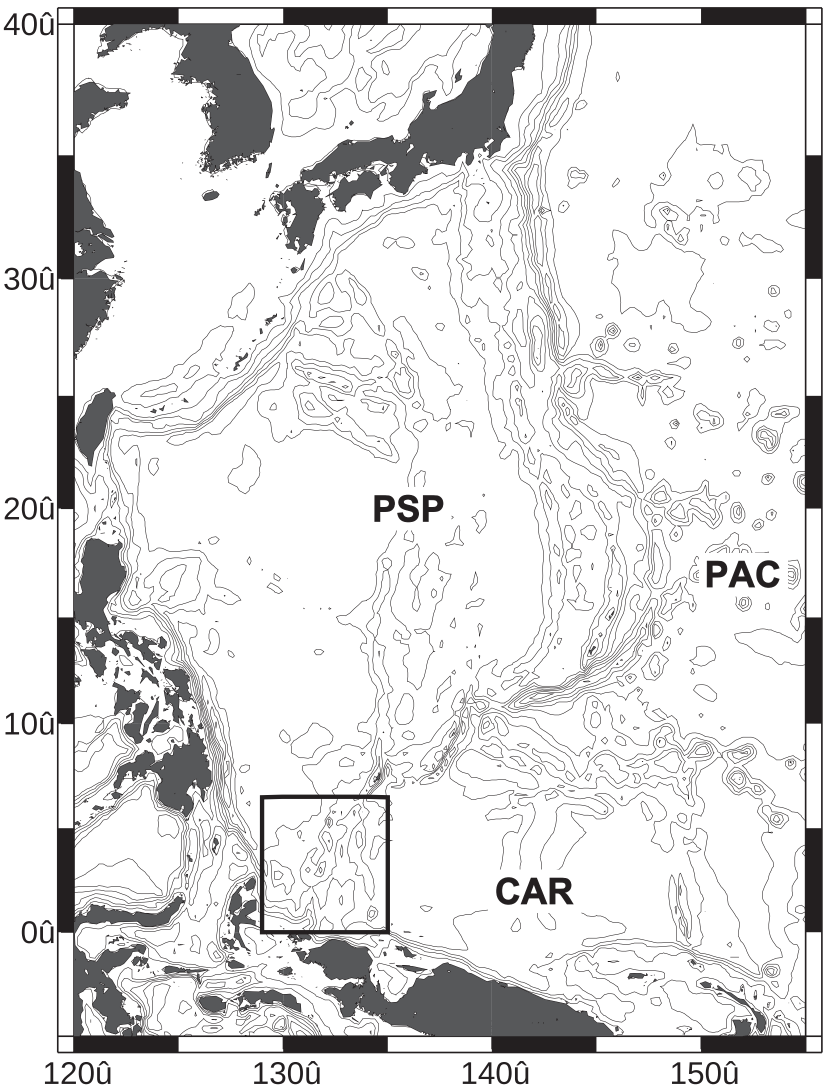

Figure 1. Location of the Ayu Trough at the southern end of the Philippine Sea Plate. Determining the motion of the Philippine Sea Plate remains controversial because it is surrounded by trenches expect along the Ayu Trough (shown in box), which is a divergent margin. The Philippine Sea Plate is denoted as PSP, Caroline Plate as CAR, and Pacific Plate as PAC. The contours represent bathymetry at 200-m interval.

KORDI's Investigation

The morphology of Ayu Trough at first hand in plan view resembles a triangle or reversed fan with Tobi and Mapia Ridges forming the outer rims of the Ayu Trough. This observation led Weissel and Anderson (1978) to postulate that the Euler pole of the Ayu Trough is located just south of the Palau Island near 7°N and 133°E. However, it is impor-

International Ridge-Crest Research: Mid-Ocean Ridge: Lee, cont...

tant to recognize that this argument is based on general morphological trends and not on geophysical evidence. The exact pole of rotation between the Philippine Sea and Caroline Plates therefore remains an open question.

KORDI's investigation of the Ayu Trough was performed in two stages. In May 2000, R/V Onnuri conducted multibeam bathymetric mapping and gravity and magnetic survey of the Ayu Trough between 3°30'N and 2°N. This was a short survey with 6-7 days of ship time. In May 2001, KORDI scientists returned to the Ayu Trough. This time, during 15 days at the site, we covered the area south of 2°N all the way down to the equator. In addition to the standard underway geophysical measurements and multibeam bathymetric mapping, the survey performed three multichannel seismic profiles, 9 dredge samplings, numerous CTD measurements, two piston cores and three multiple cores, which sampled the upper few tens of centimeters. In both 2000 and 2001, in addition to the total field measurements, shipboard vector magnetic fields were also measured. Figure 2 is a bathymetric map of the Ayu Trough between the Palau Island and the equator. It was produced by combining multibeam bathymetric data collected by KORDI in 2000-2001 and University of Tokyo from 1992 cruise (Fujiwara et al., 1995). The multibeam system used by KORDI represents an upgraded 121-beam system, providing cross-track coverage of 3.5 times the water depth, whereas that of University of Tokyo at the time was a 16-beam system, which provides a narrower coverage. The location of dredge sites and multichannel seismic profiles are presented in Figure 2.

An important observation of our study is that, on the basis of multibeam bathymetric data (Fig. 2), the Ayu Trough reveals evidence of oblique spreading rather than fan-shaped opening as previously suggested. A detailed study is underway to determine the exact pole of rotation and its implications for the motion of PSP.

One of the tasks performed by KORDI scientists was to look for possible hydrothermal plumes. Numerous CTD measurements were made along the axis in 2001. The CTD was lowered to within a hundred meters from the seafloor for this purpose. In spite of our efforts, no direct evidence for hydrothermal venting was found at this time. Instead, only a minor anomaly in water temperature at greater than 4 km was observed along the axis to the south. This is attributed to increasing heat flux at the axis as one approached the south.

The Next Phase

The second phase of Daeyang Program is expected to be a five-year program from 2002 to 2006. During this period, a greater emphasis will be given to geological and biological studies of active hydrothermal vent fields and the basins that contain them. Some of the target areas that are being considered for 2002 include the New Ireland forearc basins, the eastern Manus Basin and previously unsurveyed areas in the western Bismark Sea in Papua New Guinea. The New Ireland Forearc basin hosts a group of Pliocene to Recent alkaline volcanoes, which represent the Tabar-Lihir-Tanga-Feni island

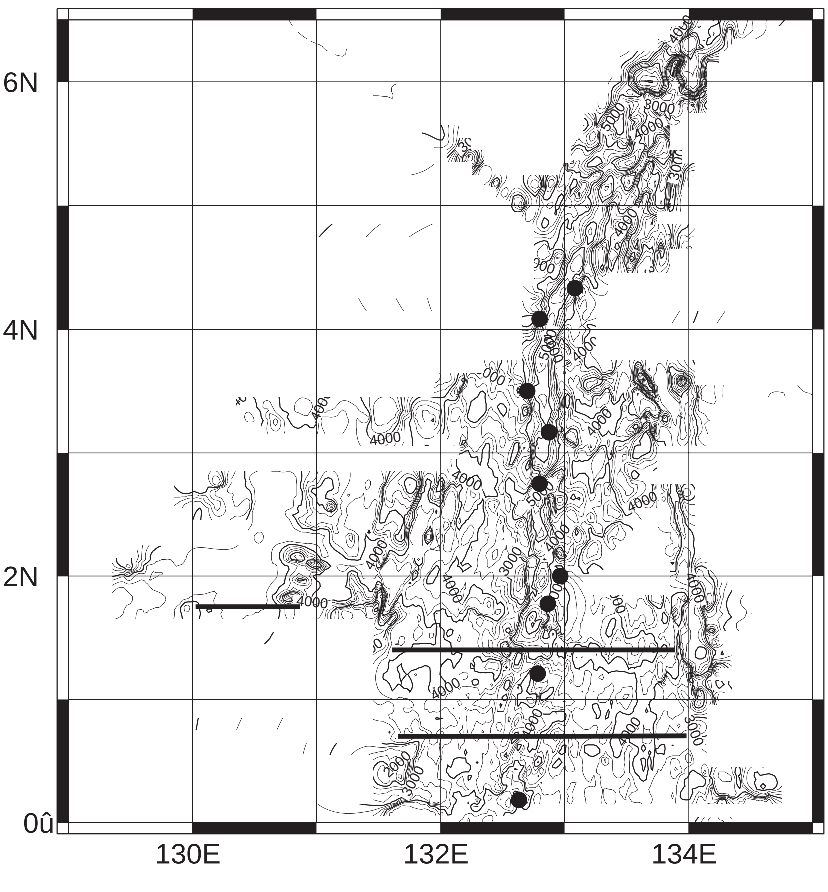

Figure 2. Bathymetric map of the Ayu Trough compiled from different sources. The multibeam bathymetric data to the north of 3°30'N are from 1992 survey by the University of Tokyo [Segawa, 1993] (courtesy of Toshiya Fujiwara). The bathymetric data south of 3°30'N were collected by this study in 2000 and 2001. The solid lines represent multichannel seismic profiles and the solid circles the location of dredge rock sampling during 2001 survey. The bathymetric contours are at 250-m interval.

chain. One of the islands in the chain, Lihir, is a locus of one of the largest epithermal gold deposits known currently. In 1994 a survey by scientists mainly from University of Freiberg, Germany discovered a number of seamounts between Lihir and New Ireland, including the Conical, Edison and TUBAF Seamounts. Several pieces of evidence suggest that magmatic activity in the forearc basin is controlled by lithosphere extensions which generally strike north-south. However, the nature of such north-south trending tectonic features is poorly understood. One of the objectives of KORDI's cruise in 2002 is to document tectonic structures in the forearc basin using a combination of bathymetric and seismic methods. In addition, biological sampling is planned at the Edison seamount and eastern Manus Basin.

Another area that is being considered is the Sorol Trough. The Sorol Trough is tectonically similar to the Ayu Trough in many ways. Previous studies suggest that the Sorol Trough represents a transtensional boundary between the Caroline and Pacific Plate and that the Caroline Plate is undergoing counterclockwise. If so, the spreading at the Ayu Trough will also affect the plate motion along the Sorol Trough. Therefore, in order to determine the motion of the Caroline Plate, we can not consider the two troughs separately.

In 2003 and beyond, Daeyang Program plans to extend its operation beyond the western Pacific. One scenario is to explore the hydrothermal vent fields in the northern East Pacific Rise and around the Galapagos Islands. In order to conduct an effective vent biological study, it is important to have access to tools for taking biological samples from the deep seafloor. This will require employment of a deep-sea submersible or remotely operated vehicle (ROV). At present, KORDI does not own either of these tools. A project is underway within the engineering division of KORDI to build a ROV that is fitted for a full-ocean-depth survey and sampling. However, the vehicle will not be ready until 2004. In the meantime, alternative ways are being sought to sample biological materials from the vent sites. This may be accomplished through cooperation with countries that have access to or by hiring of submersibles and ROVs.

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International Ridge-Crest Research: Ophiolites

Preliminary Geochemical and Mineral Data from the Isabela-Aurora Ophiolite, Northeastern Luzon, Philippines

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Introduction

The Huatung basin, east of Taiwan, is underlain by Early Cretaceous (115-131 Ma) oceanic crust (Deschamps et al. 2000). This conclusion was based on paleontological dating of cherts and radiometric dating of gabbros collected from Lanyu Island and the submarine Gagua ridge, respectively, as well as the evaluation of marine paleomagnetic lineations (Deschamps et al. 2000). The crust of the Huatung basin could extend even farther to the south, possibly as far as the basement of Luzon island (insert in Fig. 1, Deschamps et al. 2000). Among several exposures of oceanic crust-mantle sequences in Luzon, those found in its north-eastern portion are actually directly south of the Huatung basin and separated from the WPB (West Philippine Basin) by the East Luzon Trough (insert in Fig. 1). In this short communication, we present preliminary geochemical data from representative crust and mantle rocks collected from the Isabela-Aurora coastline, north-eastern Luzon during the summer 2000 campaign of the Philippine-France Cooperative Project in Geosciences (Magmatism and related mineralizations).

Geology and age of the ophiolite

The basement of north-eastern Luzon is composed of dismembered fragments of peridotites, gabbros, basalts and minor pelagic sedimentary sequences, which we collectively refer to as the Isabela-Aurora ophiolite (Fig. 1). The peridotites include lherzolites (AU06 and AU08), harzburgites (AU05) and dunites (AU04). The dunites exhibit transitional contacts with the harzburgites. These peridotites commonly display textural features suggesting plastic and brittle deformations similar to those recorded by uppermantle peridotites. We there-

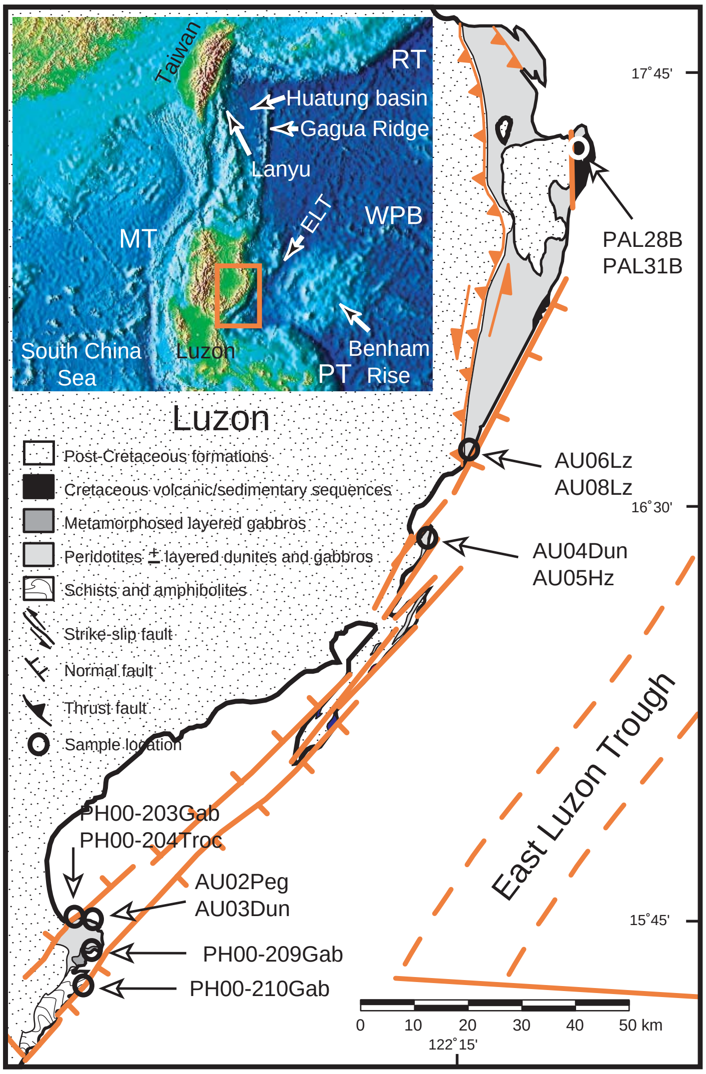

Figure 1. Simplified geological map of north-eastern Luzon and sample collection locations. Inset shows tectonic features discussed in the text. West Philippine Basin (WPB); East Luzon Trough (ELT); Philippine Trench (PT); Manila Trench (MT); Ryukyus Trench (RT).

fore believe that they represent residual mantle rocks.

The layered mafic-ultramafic rock complex is composed of, from bottom to top, dunites (AU03), pyroxenites and gabbros (PH00-203, PH00-204, PH00-209 and PH00-210). In general, the layered complex dips towards the east (i.e., the direction of the Huatung and the WPB).

The volcanic unit of the ophiolite outcrops in the northern portion along with voluminous residual peridotites (Fig. 1). It is dominantly composed of pillow basalts (PAL28B and PAL31B), which are in structural contact with the underlying peridotites and overlain by sedimentary beds of pelagic provenance. Cherts from these sedimentary deposits have yielded Early Cretaceous radiolarian assemblages (Okamura, 1986 in Billedo et al., 1996). In addition, rare outcrops of intercalated calcareous and siliceous sediments overlying pillow basalts also yielded Late Cretaceous faunas (Billedo et al., 1996). On the one hand, radiometric dating of a pillow basalt (PAL28B) using the K-Ar isotopic method gave an age of 87.15 ± 5.82 Ma, while amphibole separates from an amphibolite collected from the layered ultramafic-mafic rock complex depicted in the southwest portion of Fig. 1 yielded an age of 92 ± 0.5 Ma (Billedo et al., 1996).

Volcano-sedimentary formations, the oldest of which is dated to Middle to Late Eocene, are either in structural contact or unconformably overlie the ophiolite (Billedo et al., 1996), (Fig. 1). Plutons dated to Middle to Late Eocene and Early Oligocene to Early Miocene also intrude the basement complex.

Geochemical data

The entire data set is available from the first author upon request. Representative compositions of olivines, orthopyroxenes and spinels from the upper mantle peridotites are given in Fig. 2. The plots of orthopyroxene (OPX) Al_2O_3 (wt%) contents show a negative correlation with the X_{Mg} ($Mg/Mg+Fe^{total}$) of olivines (OL) from the lherzolites to the harzburgite, which is consistent with higher degrees of mantle melting for the latter (Fig. 2a). The mineralogical compositions displayed by the lherzolites are similar to those of peridotites collected from slow-spreading mid-oceanic ridge (MOR) environments (Dick, 1989), whereas

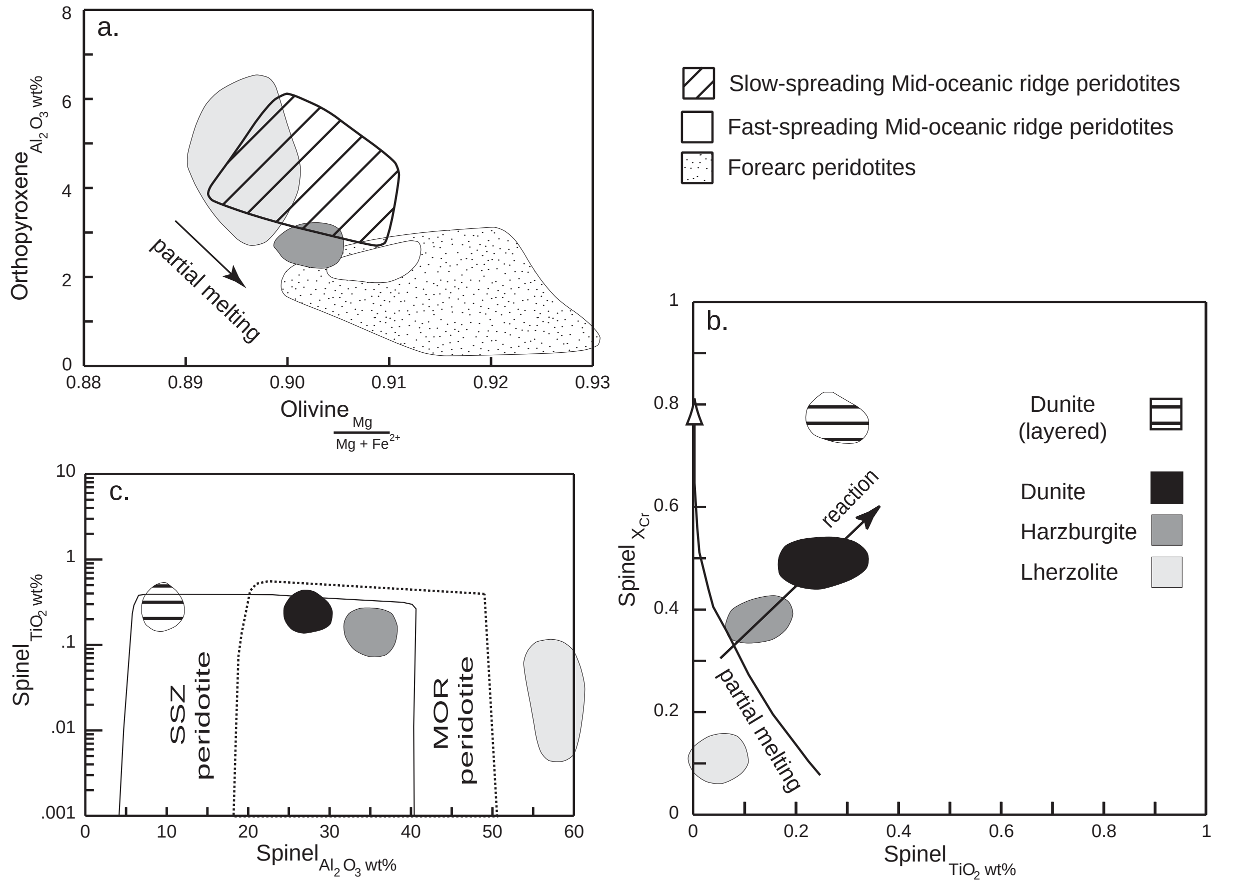

Figure 2. Major mineral compositions of peridotites from the Isabela-Aurora ophiolite. (A) X_{Mg} olivine versus Al_2O_3 (wt%) orthopyroxene. (B) TiO_2 (wt%) spinel versus X_{Cr} spinel. (C) Al_2O_3 (wt%) spinel versus TiO_2 (wt%) spinel. Data sources for fields of peridotites from different modern geodynamic settings are given in the text.

International Ridge-Crest Research: Ophiolites: Tamayo et al., cont...

that of the harzburgite is equivocal between MOR and arc-related environments (Dick and Natland, 1996; Parkinson and Pearce, 1998).

Spinels (SP) display increasing X_{Cr} (Cr/Cr+Al) from the lherzolites to the harzburgite, in agreement with the partial melting trend exhibited by the OPX and the OL (Fig. 2b). However, the X_{Cr} plots of SP from the dunites appear similar to the signatures of reactions between mantle rocks and ascending basaltic magmas. Comparison of the Al_2O_3 (wt%) and TiO_2 (wt%) contents of SP from the Isabela-Aurora peridotites with the compilation of the SP compositions shown by MOR and suprasubduction related peridotites (Kamenetsky et al., 2001) suggest that such compositions can exist in both of these geodynamic settings (Fig. 2c).

Multi-element spectra normalized to the Primitive Mantle values of Sun and McDonough (1989) of representative samples from the crustal sequence are presented in Fig 3. The basalts display relatively flat patterns, essentially similar to the spectra shown by normal mid-oceanic ridge basalts (N-MORB). The gabbros also exhibit the same smooth flat multi-element patterns, often broken by a negative anomaly in Nb but not in Ti. Common accessory phases in these gabbros are aluminous spinel containing essentially no Ti (PH00-204) and rare opaques. There are no obvious features that would relate the decoupling of Ti from Nb to the accumulation of Ti-rich phases from post-cumulus interstitial fluids. Rare amounts of amphiboles in these rocks are alteration products and, thus, are unlikely sources of dramatic changes in magmatic signatures. The Nb anomaly could be a fractionation rather than a source geochemical feature.

A preliminary conclusion from the patterns of the spectra would be that the gabbros mirror those of the associated basalts and, thus, suggest their derivation from liquids with MORB-like compositions rather than supra-subduction related magmas since, the latter, normally display clear negative anomalies in both Nb and Ti.

Interestingly, coexisting clinopyroxenes and plagioclases from these gabbros display relatively high X_{Mg} (Mg/Mg+Fe^{2+}) values and An (Ca/Ca+Na+K) contents, respectively (insert in Fig. 3). These compositions are unlike those shown by gabbros collected from slow-spreading MOR systems such as the Southwest Indian Ridge, nor those sampled from the Mariana Trough (Meyer et al., 1989; Bloomer et al., 1995). Instead, they are similar to the plots displayed by some Hess Deep (East Pacific Rise; Dick and Natland, 1996) and Mariana arc-forearc gabbros (Bloomer et al., 1995). Although the Hess Deep and Mariana samples originate from very different geodynamic settings, they both appear to be derived from liquids whose upper mantle sources have undergone either relatively high degrees of partial melting or several melting episodes on the basis of clinopyroxene and plagioclase compositions.

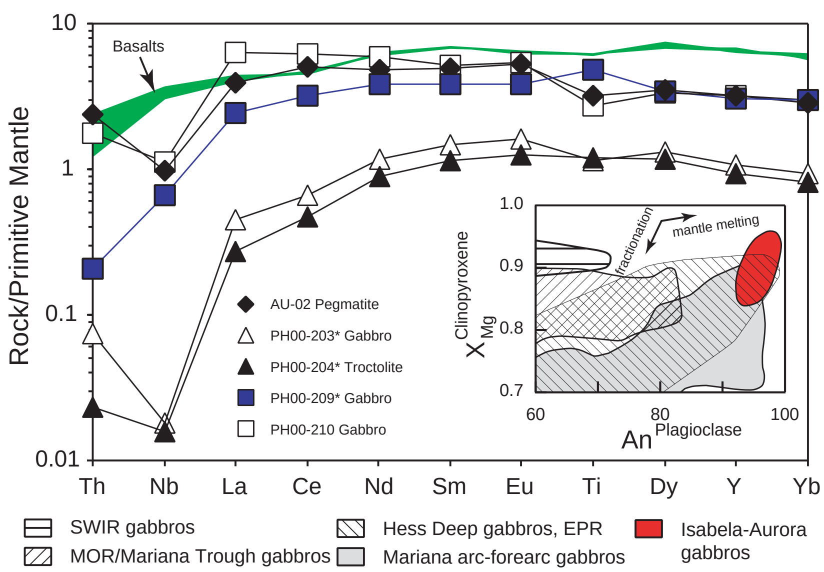

Figure 3. Multi-element plots of samples from the crustal sequence of the Isabela-Aurora ophiolite. Inset shows An versus X_{Mg} of coexisting plagioclases and clinopyroxenes, respectively, from gabbros. Data sources for fields of gabbros from different modern geodynamic settings are given in the text.

Preliminary observations and their implications

Our preliminary results suggest that the Isabela-Aurora ophiolite includes:

1) a volcanic unit with N-MORB affinity;
2) a layered ultramafic-mafic complex derived from basaltic melts originating from a highly depleted mantle source;
3) a residual upper mantle sequence displaying mineral compositions similar to mantle peridotites underlying modern MOR environments.

Therefore, if the Luzon basement were an extension of the Huatung basin as suggested by their similarity in age and their spatial proximity, then, the preliminary geochemical data from the Isabela-Aurora ophiolite would suggest that the Huatung and the ophiolite basement of, at least, north-eastern Luzon were part of a larger Cretaceous Oceanic Basin, which displays geochemical signatures similar to those shown by rocks collected from modern MOR environments.

Acknowledgements

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A SPECIAL ISSUE ON ANCIENT AND MODERN SEAFLOOR VOLCANOGENIC MASSIVE SULFIDE DEPOSITS

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Peter A. Rona and Zengqian Hou, Guest Editors

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International Ridge-Crest Research: Arctic Ridges

Crustal accretion, hydrothermal activity and microbial colonization along the Mohns and the Knipovich ridges: Preliminary results from the SUBMAR-2000 and 2001 cruises

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Crustal accretion

The Mohns and the Knipovich ridges are characterized by oblique and ultraslow spreading. En échelon volcanic ridges have been demonstrated to occupy parts of the rift valley of Mohns ridge (Geli et al., 1994). During the last two years, multibeam mapping of the entire Mohns ridge (Fig. 1) has been carried out by the Norwegian Petroleum Directorate in cooperation with the SUBMAR program (SUbsurface Biosphere, hydrothermal and Magmatic activity along the Arctic Ridges). The multibeam data demonstrate that en échelon volcanic ridges occupy the rift valley of the entire ridge. The en échelon ridges are typically 20-30 km long and approximately 20 degrees oblique to the general trend of the rift valley. The distance between the volcanic ridges increases northeastwards from 10 km in a region 100-200 km north of the Jan Mayen fracture zone, to 30-50 km in the northeastern part of the ridge. This is accompanied by a general northeastward increase in the water depth from around 2000 to around 3000 meters. Further north along the Knipovich ridge, the spacing between oblique volcanic ridges increases to around 100 km - again accompanied by a further increase in water depth. The increase in the distance between the oblique volcanic ridges may be related to a general northward decrease in the magmatic productivity of these ridges. This is currently being tested by basalt geochemistry and geophysical studies.

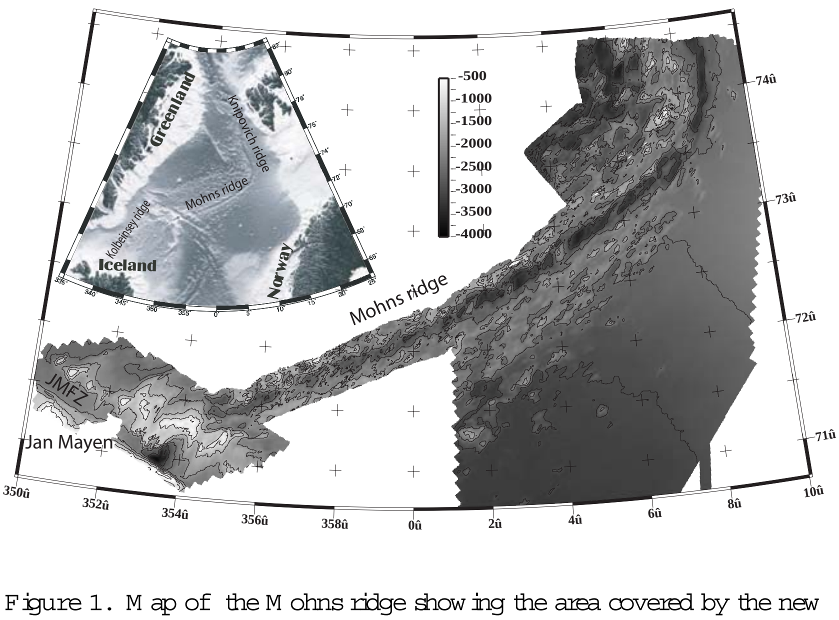

Figure 1. Map of the Mohns ridge showing the area covered by the new multibeam data.

The location of the southwesternmost segment of the Mohns ridge has been poorly defined. Multibeam mapping combined with dredge sampling and ROV studies suggest that the neovolcanic zone intersects the Jan Mayen fracture zone about 60 km east of Jan Mayen. This volcanic island, therefore, does not define the southernmost tip of the Mohns ridge. The southwesternmost segment is markedly different from other Mohns ridge segments. It is longer (approximately 80 km), shows no well-developed rift valley, and the water depth over the middle part of the segment is very shallow - only around 500 meters. We are presently evaluating whether these features may be related to ridge-transform or hotspot-ridge interactions.

A particularly shallow northern flank is another characteristic feature of the Mohns ridge. Some of the marginal highs and ridges are only 600 meters below sea level, towering almost 3000 meters above the deepest parts of the adjacent rift valley floor. ROV dives to a marginal high at 72°40'95N, 2°50'83E demonstrated that pillow lavas are exposed on the top. These lavas are compositionally similar to the rift valley lavas, showing that the very shallow flank region is composed of uplifted axis crust. Other shallow regions of the flank also yielded basaltic dredge samples with compositions similar to the axis lavas. No ultramafic or gabbroic rocks have yet been recovered from the Mohns ridge. This may be an artifact of incomplete sampling, or it may reflect that the oblique spreading and non-transform character of this ridge disfavor extensive tectonic exposure of the lower crust and uppermantle.

A detailed sampling program of the Mohns ridge and the submarine parts of Jan Mayen was carried out during the two cruises. Ongoing elemental and isotope analyses of the samples will hopefully cast light on hot spot-ridge interactions and crustal accretion processes along the Arctic ridges. Some of the basalts recovered are extraordinarily rich in plagioclase phenocrysts. Samples with up to 40% plagioclase phenocrysts and with crystal sizes up to 4 cm were recovered. Individual crystals show multiple growth/dissolution features, and complex compositional zoning, with An-contents ranging from An_{89} to An_{77}. Single crystals contain several melt-inclusion rich bands that show distinctly lower An-contents. These features are compatible with formation of the bands during periods of strong undercooling. Single samples contain plagioclase crystals that, despite being similar in size, appear to have contrasting growth/dissolution histories, indicating extensive crystal mixing. The large plagioclase phenocrysts, crystal dissolution and renewed growth textures, multiple melt-inclusion bands, and crystal populations with different growth/dissolution histories, witness a dynamic magmatic system and that magma may reside for considerable time within the magmatic plumbing system below ultraslow spreading ridges.

Hydrothermal activity

Only a few hydrothermal fields have been found along the Arctic spreading ridges. Two active fields are located in shallow waters just north of Iceland, close to the Kolbeinsey and Grimsey islands (Olafsson et al., 1989, Hannington et al., in press). An extinct hydrothermal field with numerous sulfide chimneys was recently discovered on a flat-topped volcano at around 1200 meters water depth on the Kolbeinsey ridge (Pedersen et al., 1989). Another inactive field with chimneys of yet unknown compositions was discovered this year in the middle of the southernmost segment of the Mohns ridge in 500 meters water depth.

During the SUBMAR-2000 cruise, heavily sulfide-mineralized fault breccias were recovered at 72° 39'33N; 2°40'87E by dredging up a bounding fault wall of the Mohns ridge. The breccias consist of fine-grained basaltic clasts, with fracture and cavity fillings dominated by quartz, pyrite and chalcopyrite. The mineralized breccias must have formed by high-temperature hydrothermal circulation along a major fault, and give hope that deep water hydrothermal venting may eventually be discovered along the Arctic spreading ridges.

Microbial colonization

An important aim of the SUBMAR project is to assess the overall microbial diversity at oceanic spreading ridges. While much attention has been focused on microbial life associated with hydrothermal venting, little is known about the microbial diversity of the cold, non-hydrothermal environment at oceanic ridges. Microbes seem to play an important role in the degradation of ocean-floor basaltic glass, and traces of a deep biosphere have been documented to several hundred meters depth in the crust by means of glass alteration/dissolution textures, DNA-staining experiments, and carbon isotope ratios from various ODP holes (Thorseth et al., 1995, Torsvik et al., 1998). So far, little is known about the nature of these organisms, and how and at what stage a deep biosphere is established. A deep biosphere may develop simply by gradual burial of colonized surface lava flows, and knowledge of the biodiversity and colonization rates of basaltic lava flows are important for understanding the microbial colonization of new crust that apparently takes place at spreading ridges.

During the SUBMAR-2000 and 2001 cruises, basalts dredged and sampled by ROV from the Mohns and the Knipovich ridges were incubated by a team of microbiologist soon after the samples were recovered. A few samples taken by ROV were placed in a pressure-releasing container at the sea floor to avoid contamination en route to the surface. Sediment and seawater samples that were treated in the same manner as the basalts served as controls. Samples of basaltic glass and associated palagonite were transferred to bottles with media to which various carbon and energy sources were added. The cultures were incubated either aerobically or anaerobically. The aerobic cultures were made to enrich for iron- and manganese-oxidizing bacteria, methanotrophic and methylotrophic bacteria, sulphur oxidizers and general aerobic bacteria. The anaerobic cultures were made to enrich for iron and sulphate reducing bacteria and for methanogenic Archaea. All cultures were incubated at 4°C. Samples were also fixed in ethanol for later analysis by electron microscopy, epifluorescence microscopy and for DNA/RNA extraction for PCR, DGGE, sequencing and slot blot hybridisation analysis. In addition, aliquots of unfixed samples were centrifuged on board ship and the pellets stored in a freezer for later whole-cell PCR DNA amplification.

Enrichment cultures, chemical analysis of metabolic products, PCR, DGGE and 16S-rDNA sequencing have so far shown the presence of iron- and manganese-oxidizing and

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reducing bacteria, methanotrophic bacteria and methanogenic Archaea in the basalt samples. Sulphate-reducing bacteria were rare in the basalt samples, but were common in the seawater and sediment samples.

Electron microscopy of the basaltic glass on which biomolecular methods were applied, revealed successive stages from incipient microbial colonization to well-developed biofilms along variably-altered fracture surfaces (see Thorseth et al., in press). Filamentous, coccoidal, oval, rod-shaped and stalked microbial morphologies were observed (Fig. 2). Precipitation of alteration products around microbes has developed hollow subspherical and filamentous structures. The precipitates are often enriched in Fe and Mn indicating that these elements are utilized in metabolic processes, in accordance with our biomolecular results.

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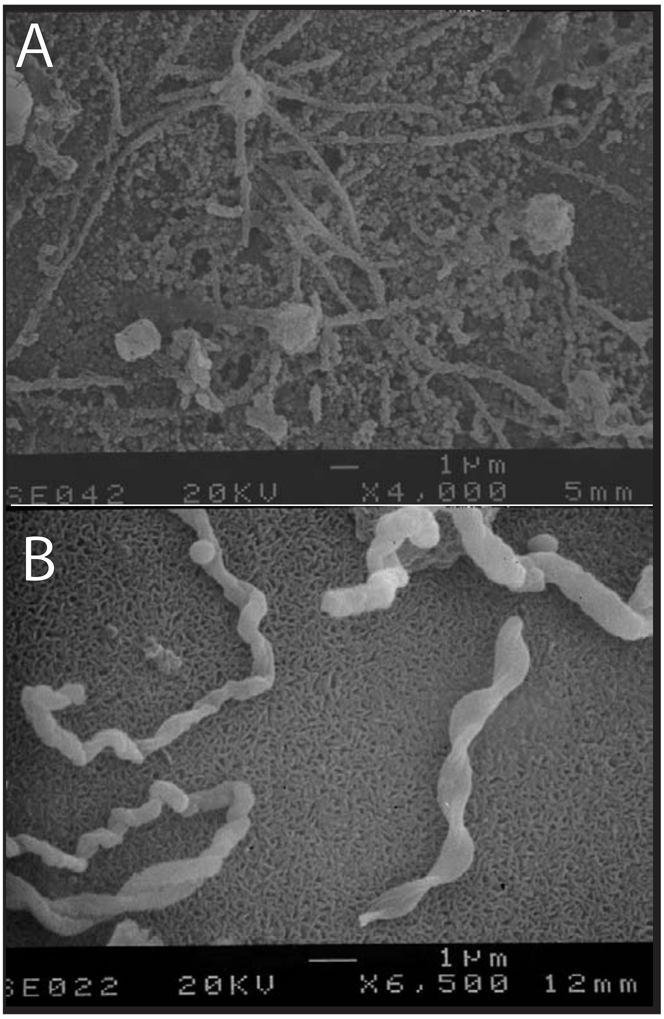

Figure 2. Back scatter images of fracture surfaces from the glassy margin of basalts sampled from the Mohns and the Knipovich ridges. The fracture surfaces are often heavily colonised by microbes that contribute to the degradation of the basaltic glass and the formation of palagonite. A) Star-shaped stalked microbe on an ultra-thin alteration layer developed along a fracture. The cells are heavily encrusted with Fe-rich precipitate. B) Fe-and Si-encrusted and unencrusted branching, twisted stalks on a thin alteration layer. The cells resemble the iron oxidising Gallionella.

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Results of the Arctic Mid-Ocean Ridge Expedition - AMORE 2001 - Seafloor Spreading at the Top of the World

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Overview

The Arctic Mid-Ocean Ridge Expedition (AMORE 2001) returned in early October 2001 after an incredibly successful nine-week study of Gakkel Ridge and its surrounding basins in the high Arctic. AMORE 2001 was an international effort involving two icebreakers: PFS Polarstern, from the Alfred Wegener Institute in Bremerhaven, Germany, and the new U.S. icebreaker, USCGC Healy. It was Healy's maiden scientific voyage, and she proved to be an excellent icebreaker and scientific platform. This historic and highly successful expedition far exceeded anyone's expectations and went well beyond the goals set forth by InterRidge in charting and sampling Gakkel Ridge. Some of the highlights of the expedition are:

- Basalts and peridotites were recovered from over 200 sites within and near the axis of Gakkel Ridge, about three times as many sites as were planned.
- Hydrothermal plumes were discovered and sampled along this ultraslow spreading ridge.
- A high-resolution, well-navigated map of the ridge was unexpectedly produced using the hull-mounted multibeam sonar systems, which worked far better in the ice than anticipated.
- Successful seismic measurements showed that crustal thickness varies strongly along the axis of Gakkel Ridge, most likely according to distinct volcanic centers.
- The crustal thickness in the Nansen Basin does not follow theoretical models, which predict thin crust at slow spreading rates. The crust thickens towards the Gakkel Ridge.

Introduction

Gakkel Ridge is an end-member of the global spectrum of mid-ocean ridges in many respects, and offers a unique combination of characteristics (e.g. spreading rate, geographical location, obliquity, segmentation) which may control the composition of the erupted magmas, the crustal thickness and the presence of hydrothermal activity. Its spreading rate is by far the slowest of any mid-ocean ridge and varies by a factor of two along its length. AMORE 2001 has thus greatly extended the range of values over which we can investigate the relationships between ridge properties and spreading rate. Gakkel Ridge has an exceptionally deep rift valley, and the thinnest known crust for a normal ridge (<4 km). It has no large offsets, so it allows examination of the roles of ridge obliquity (transform faults) versus mantle upwelling in causing ridge segmentation. Gakkel Ridge is far from the Indian Ocean, and therefore allows separation of the effects of spreading rate from the anomalous Indian Ocean mantle source in the geochemistry of basalts. Analysis of a few small basalt and peridotite samples from Gakkel Ridge suggests the extents of melting may be very low (Mühe et al., 1997; Hellebrand et al., in press). This has implications for the ratio of peridotite to basaltic crust that may be present in the ridge axis.

While so far there is little doubt on the existence of thin crust in the rift valley, the situation off-axis is different. Past observations and a recent study (Weigelt & Jokat, 2001) indicate that there might be no simple relation between spreading velocity and crustal thickness away from the Gakkel rift valley. Although spreading velocity decreases, sparse seismic refraction data and gravity modeling suggest a thickening of the oceanic crust. It is not clear whether this observation is typical or if it represents only local variations in the composition of the oceanic crust. In any case it challenges currently accepted theoretical models. Maybe Gakkel Ridge represents a threshold spreading environment, where existing global models fail in general.

How the mantle beneath the Arctic Ocean is related to the mantle beneath the northernmost Atlantic Ocean and the rest of the planet, and how it may have been influenced by the nearby continents are additional basic questions that will be addressed by geochemical study of the igneous rocks. Gakkel Ridge is our sole opportunity to sample this portion of the earth's interior.

Gakkel Ridge

Gakkel Ridge stretches 1800 km across the Eurasian Basin of the Arctic Ocean, all of it beneath Arctic sea ice (Fig. 1). It is the most remote and slowest spreading portion of the global mid-ocean ridge system. To the west it passes via Lena Trough and the Molloy Fracture Zone into Knipovich Ridge, the most northern part of the MAR. Its eastern end runs into the continental margin of the Laptev Sea, where rifting continues (Drachev et al., 1998). Spreading rates decrease from 1.33 cm/yr (full rate) at the western end to 0.63 cm/yr at the eastern end in the Laptev Sea. Spreading is nearly orthogonal to the strike of the ridge and there is only one major offset in the ridge axis at about 60°E (Kovacs et. al., 1985).

Cruise Operation

The ships left Tromsø July 31 and approached Gakkel Ridge from east of Svalbard at about 15°E (Fig. 1). The ships first joined Gakkel Ridge at 20°E after the seismic reflection survey crossing the entire Nansen Basin. Both ships then traveled westward along the axis to 8°W performing bathymetric mapping and sampling and acquiring seismic refraction data along axis between the sampling stations. The ships then sampled the rift axis and walls intensively as they returned eastward to 20°E, operating somewhat independently because of favorable ice conditions. The northern and southern walls of the rift valley were mapped during this return. During all seismic reflection experiments in the Nansen and Amundsen basins as well as the seismic refraction profiles along the Gakkel Ridge, both ships operated jointly. Here, Healy led the convoy to break ice for Polarstern that towed the streamer and the airguns (Fig. 1). For both transects in the Nansen and Amundsen basins this setup was critical for the excellent data quality achieved. Because of ice conditions, the latter transect took place at 72°E instead of the primary geographical objective which was to have been a long transect perpendicular to the ridge at 85°E. At the end of the survey, both ships visited the North Pole, where a brief celebration was held. USCGC Healy returned to Gakkel Ridge at 87°E for intensive sampling of a recent lava flow (Edwards et al., 2001) while Polarstern returned to Gakkel Ridge along the seismic survey's path to the west and occupied heat flow stations in the basin. The ships rejoined on Gakkel Ridge at 72°E for the return trip westward along the ridge that involved intensive sampling and more bathymetric mapping, with a wide angle seismic study carried out concurrently. Ice and fog conditions worsened around September 11, so sampling became more difficult and some targets were forsaken. Still, Healy and Polarstern sampled and mapped somewhat independently but in a coordinated program until the time at which they left the ice around 24°E on September 27, 2001. USCGC Healy returned to Tromsø on October 2, 2001

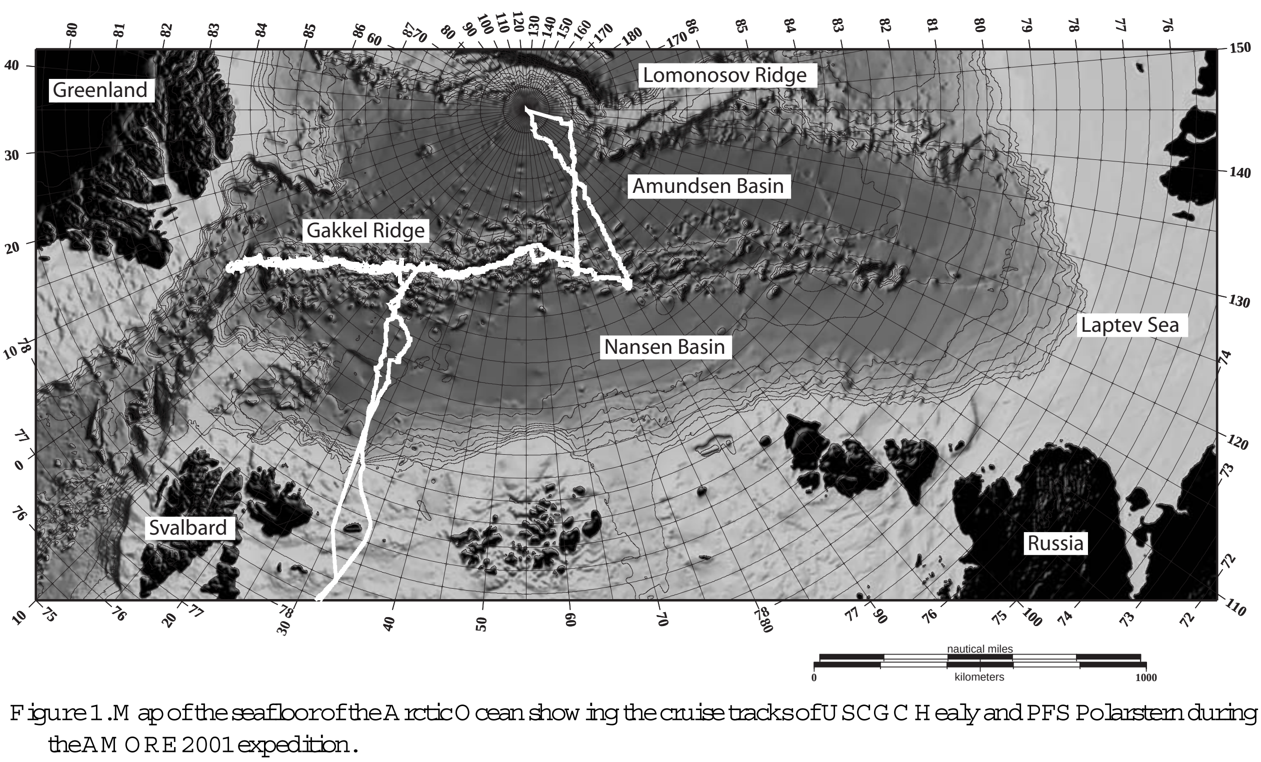

Figure 1. Map of the seafloor of the Arctic Ocean showing the cruise tracks of USCGC Healy and PFS Polarstern during the AMORE 2001 expedition.

while Polarstern went to Bremerhaven on October 7.

New bathymetric map of Gakkel Ridge produced

Surprisingly, the ships' bottom mapping sonar systems (Seabeam 2112 on Healy and Hydrosweep on Polarstern) were able to generate superb maps of the seafloor even while the ships were breaking ice. The bathymetric results far exceeded our expectations. The total surveyed region covers ~1000 km of the axis from 8°W (Lena Trough) to 88°E, providing the first data for the western Gakkel Ridge. The resolution of these data is significantly better than previously existing bathymetry from SCICEX (Cochran et al., in prep.) and reveals geologic detail critical to understanding the segmentation and volcanic and tectonic processes of this ultra-slow spreading MOR. The new bathymetry data show three distinct magmatic-tectonic regions within the area mapped.

Rock recoveries

There was some doubt about whether we would be able to dredge in ice covered waters. After a steep learning curve, the success rate for dredging was fairly high. Flexibility in choosing targets was important, and in a few cases, large ice floes kept us away from entire regions. Each dredge operation had to be carefully set up and planned, using leads through the ice pack and taking into account ice drift velocities. In addition to dredges on both ships, USCGC Healy employed wax cores to recover glass and PFS Polarstern had a TV-Grab. These methods required less open water to succeed. Rock samples were recovered from more than 200 sites along the axis and flanks of Gakkel Ridge, mostly by dredging.

More than 120 basalt glass samples were analyzed on board USCGC Healy for major elements, Sr and Ba by direct current plasma spectrometry. Because the cruise track encompassed a double-pass along most of the ridge, the onboard data permitted testing of hypotheses formulated on the first pass by further sampling on the second pass. Models for the effect of decreasing spreading rate on melt composition that predicted progressively smaller extents of melting at greater depths eastward along the ridge will be tested using these data.

Forty-six thin sections and hundreds of hand samples of mantle peridotites were examined during the course of the expedition. Most of these peridotites are altered 60-90%, like most abyssal peridotites. Some however are stunningly fresh, containing no detectable serpentine in thin section. The distribution of mantle rock types is similar to that from other mid-ocean ridges, but peridotites from Gakkel Ridge seem to have undergone low degrees of partial melting in accordance with theoretical predictions.

Hydrothermal activity along Gakkel Ridge

Miniature Autonomous Plume Recorders from Ed Baker of NOAA PMEL were used on dredges and rock cores to identify sites of hydrothermal venting through light scattering and temperature anomalies associated with hydrothermal plumes. In all, there were 118 MAPR deployments from Healy and 19 from Polarstern. Several plumes were found, and several had corresponding temperature anomalies. On board analysis and interpretation of the MAPR data were used to target CTD/rosette deployments, which were collected from Healy at six stations along the Gakkel Ridge. Plume water samples were collected for Mn, methane, and ^{3}He to confirm the hydrothermal nature of the light scattering anomalies and provide some estimate of source strength. Unweathered hydrothermal sulfide chimneys were dredged at one site. In addition, a potential fossil hydrothermal upflow zone as evidenced by abundant epidosite rocks was also dredged from a tectonically uplifted portion of the ridge flank.

Biological specimens

Many of the 98 recovered dredges by USCGC Healy contained biological samples from the benthos and water column. Animals, mollusk shells, fossils, associated rocks, and all other evidence of biological activity were collected. Organisms were preserved using multiple methods for planned morphological and genetic studies. A surprising number of dredges yielded sponges and shrimp. Though the sampling was not biologically targeted, the recovered animals are uniquely valuable to science. Sessile species hold clues to the minimum age of recent lava flows and sulfide deposits. If the organisms are hydrothermally associated, their distributions will indicate or confirm active venting areas along the ridge, and could extend biogeographic inferences into another ocean basin. Pending funding, complete taxonomic sorting of samples and species identifications will be conducted, new species will be fully described, and correlations between biological distributions and extant venting will be investigated.

Geophysical Experiments

To provide a consistent geophysical/petrological model for the super-slow Gakkel Ridge, sufficient information on the crustal thickness and the composition of the upper mantle beneath the rift valley and its flanks is required. Several different geophysical methods were applied to meet these objectives. Both conventional ship-based experiments like seismic reflection experiments as well as measurements located on drifting ice floes were conducted. The results are briefly reviewed here.

Seismic Reflection Experiments. To determine the crustal structure of the Eurasian Basin north and south of Gakkel Ridge, two long seismic transects in Amundsen and Nansen basins were acquired. A 24 l airgun cluster in combination with a 300 m long streamer (48 channels, 6.25 m group spacing) was used. In addition, 36 sonobuoys were deployed in order to provide information on sediment and crustal velocities for a depth conversion of the seismic data. All three profiles provided excellent data and most of the oceanic basement was

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clearly imaged after processing. The sonobuoys provided signals from even deeper levels of the oceanic crust and in a few cases, signals from the Moho are visible. This allowed a minimum estimate of the crustal thickness. Gravity modeling of the transects will provide more reliable crustal models than in the past.

Seismic Refraction Experiments. To investigate the crustal thickness along the rift valley of Gakkel Ridge both ships had to work together. For this type of reconnaissance survey, only a few stations were deployed along each profile. In case of reverse shooting at maximum two seismic data acquisition units were deployed on ice floes to record the airgun signals. During profiling, USGCC Healy led the convoy, while RV Polarstern towed an airgun array (in total 24-l) to generate the acoustic signals. Crustal thickness was measured at 18 different locations. All stations worked without problems. Most of the record sections show clear Pn arrivals from the crust/mantle boundaries with velocities between 7.8 and 7.9 km/s. The crustal thickness along the rift valley varies between 2 and 6 km.

Gravity measurements. A fixed mounted gravity meter KSS31 onboard the FS POLARSTERN gathered gravity data during the entire cruise. The instrument worked without any problems during the entire cruise. Harbor values were taken in Tromsø and Bremerhaven.

Helicopter based Magnetics. This program intended to fly a detailed magnetic survey across the rift valley of Gakkel Ridge. Unfortunately most of the planned survey could not be conducted, due to constantly foggy weather conditions. Measurements were performed during only 14 days of the cruise. Magnetic data were gathered for a total flight time of 56 hours (4480 nm) with a line spacing of 2 km across the ridge. The data are of good quality and were flown across prominent bathymetric features, so a contribution towards better understanding of spreading processes along the Gakkel Ridge can be expected.

Heat Flow measurements. Thirty eight heat flow measurements were made at fourteen heat flow stations along the rift valley of Gakkel Ridge, and seven along an off-axis seismic transect into the Amundsen Basin. Here, good control for the sediment thickness was provided by the seismic reflection data acquired on the way to Lomonosov Ridge. In the rift valley, it was difficult to find sediment patches of a sufficient extent to perform the measurements. The Parasound data clearly showed that small volcanoes covered most of the seafloor with only a few sediments in between.

Remote Magnetotelluric Experiments and Seismological Array. The deployment of the seismological and magnetotelluric stations on the ice faced two problems. The constantly bad flight conditions in the beginning of the cruise in combination with the relatively fast sampling of the petrology program did not allow the stations to be deployed a reasonable distance to the ship. The risk involved in finding the stations after several days of deployment and with flight distances of more than 50 NM was too large. Secondly, the time of 3 hours plus limited flight windows needed to construct one MT station restricted the number of instruments.

Five MT-experiments were conducted along Gakkel Ridge to investigate the conductivity of the earth's crust and the mantle below this mid-ocean ridge. The stations were recovered after 3 - 9 days. Critical to the interpretation of these data is the rotation of the ice floe on which the instruments are located. Although the floes showed significant drift paths, their rotation was not so strong. So the instruments acquired reasonable data for most of the deployment periods.

While the crustal thickness along Gakkel Ridge was determined by seismic refraction experiments, seismological data are necessary to probe the upper mantle. For this experiment a mobile network consisting of 3-4 stations was deployed on an ice floe. The deployment of the array was mostly finished in three hours. The RefTek recording units had almost no failures during their deployment on the floes. A first view of the seismological data showed that teleseismic as well as local events were recorded. The most spectacular quakes were recorded from the Pacific-Antarctic ridge with sufficient S/N ratio. A careful data analysis will show to which extend local seismicity along the ridge was recorded.

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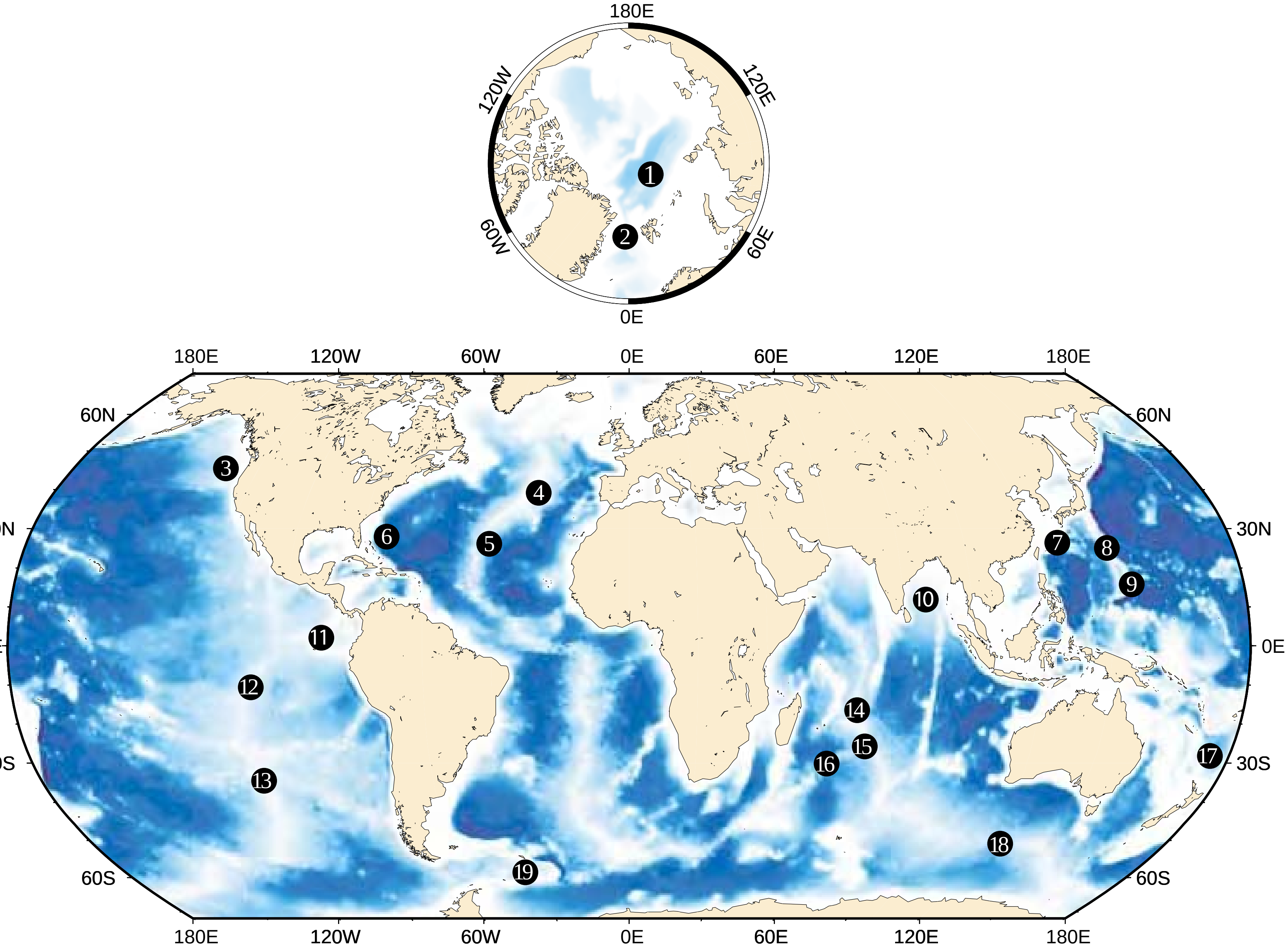

Ridge Cruises 2001 - 2002

Map No.	Country	PI	Institution	Cruise ID/Location	Research Objectives	Ship	Dates
3	Canada, USA	R.E.Thompson, M.Tilley, S.F.Mihaly	GSC	Endeavour Ridge	Middle vally rapid risponse, mooring recovery	J.P.Tully	2 Oct - 15 Oct '01
16	France, Denmark	E. Humler	U. France	SWIFT-SWIR 49-35E	Mapping and sampling of the west of SWIR	Marion Dufresne	Feb-Mar '01
4	France	Y. Fouquet	Ifremer	IRIS-Rainbow	Investigate biology and geoscience	L'Atalante ROV Victor	21 May- 08 Jun '01
4	France	P.M. Sarradin D. Dixon	Ifremer	ATOS-VENTOX project	Resarch into the specialised adaptations and processes in deep-sea hydrothermal vent fauna and microbinal populations	L'Atalante, ROV Victor	20 Jun- 21 July '01
12	France	F.Gaill N.Bris	U. Pierre	PHARE - EPR	In-situ experiments and biogeochemical interactions.	L'Atalante ROV Victor	May '02
4	France, USA, Portugal	J. Goslin	U. Brest	SIRENA-North Atlantic	Deployment of six moored autonomous hydrophones to monitor seismicity for a tomographic model.	Le Suroit	23 May - 10 Jun '02
19	Germany, Canada, USA	P. Herzig	Freiberg	HydroArc,Bransfield Strait- Antactic Peninsula	Investigation of hydrothermally active volcanoes in a sedimented marginal basin	SONNE	9 Feb - 28 Mar '01
13	Germany, France, Canada	P. Stoffers, P. Herzig	Kiel U.	SO157-FOUNDATION 3, Pacific-Antarctic spreading axis near 38S	Detailed dredge sampling of the spreading axis close to Foundation hotspot	SONNE	15 Jun - 14 July '01
11	Germany	K.Hoernle, F.Hauff	Kiel U.	SO 158, North of Galapagos platform and Galapagos Spreading Center, 3S-2N,85W-95W	Sampling of volcanic rocks,sulfide and manganese deposits, and deep-sea fauna along the GSC and of seamount volcanoes.	SONNE	15 July - 20 Aug. '01
1	Germany, USA	P. Michael, C. Devey, J. Wilfried	U.Tulsa	Gakkel Ridge	First ever geophysical and petrological investigation of the Gakkel spreading axis between 0 and 90E	Healy, Polarstern	31 July- 7 Oct '01

11	Germany, USA	K. Haase, U. Tulsa, A. Dehghani	Institut fur Geo-wisenschaften	SO160-GARIMAG, fossil Galapagos Rise at about 11S,95W,SE Pacific	Bathymetric,gravimetric,and magnetic study and gredge sampling of a segment of the fossil Galapagos Rise spreading axis	SONNE	18 Sep-10 Oct '01
10	India	Damesh Raju, PS. Rao	NIO	Adaman Sea	Multibeam mapping,geophysics,sampling	Sagar Kanya	8 Jan-11 Feb '01
14	India	R.Mukhopadhyay	NIO	Central Indian Ridge	Multibeam mapping, geophysics sampling, CTD	Sagar Kanya	25 May-28 Jun '01
7	Japan	K.Takai	JAMSTEC	Okinawa Trough	Sediments and microbio sampling at the hydrothermal area	Kairei	27 Jun.-17 July '01
7	Japan	K. Tamaki	ORI	Southern Okinawa Trough	Deep tow sidescan sonar survey of the rift zone	Hakuho-maru	7 May - 24 Jun '02
8	Japan	M. Kinoshita	JAMSTEC	Ogasawara (Bonin) Arc	Shinkai 2000 submersible dive for installing monitoring instruments at the hydrothermal site	Natsushima	19 Aug - 17 Sep '01
8	Japan	A. Maruyama	JAMSTEC	Ogasawara (Bonin) Arc	Shinkai 2000 submersible dive for microbiological study at the hydrothermal site	Natsushima	5 Oct - 27 Oct '01
8	Japan	J. Ishibashi	Kyushu Univ.	Ogasawara (Bonin) Arc	Geochemical water sampling at the hydrothermal sites	Kairei	7 Dec - 27 Dec '01
16	Japan	E. Kikawa	JAMSTEC	SW Indian Ridge	Survey outcrops of lower oceanic crust	Kairei, ROV Kaikou	5-29 Sep '01
16	Japan	T. Matsumoto	JAMSTEC	SWIR-Atlantis II FZ	Shinkai 6500 submersible dives at lower crust and mantle outcrop	Yokosuka	21 Dec - 15 Jan '02
9	Japan	M. Arima	Yokohama National Univ.	Mariana Trough and Mariana Arc	Sediments and microbio sampling at the hydrothermal area	Kairei	08 Jan - 24 Feb '02

Map No.	Country	PI	Institution	Cruise ID/Location	Research Objectives	Ship	Dates
15	Japan	K. Takai	JAMSTEC	Rodriguez triple junction	Shinkai 6500 submersible dives at hydrothermal sites	Yokosuka	21 Jan - 24 Feb '02
18	Japan	M. Shinohara	ERI	Australia - Antarctic Discordance	OBS/OBM crustal structure, deep-tow magnetics, SeaBeam mapping	Hakuho- maru	27 Jan- 12 Feb '02
17	New Zealand	I.Wright	NIWA, U.Kiel VUW	Southern Kermadec arc,35-30S	multibeam mapping, rock dredging, seafloor photography, and epibenthic fauna sampling volcanoes of the arc front.	Tangaroa	24 May - 14 Jun '02
17	New Zealand	C.Ronde, G.Massoth	GNS, NOAA, U.Kiel, Kyushu U.	Southern Kermadec arc,35-30S	CTD and in site chemical mapping and fluid sampling of hydrothermal plume associated with active volcanoes.	Tangaroa	16 Jan - 29 Jun '02
2	Norway	R.Mjelde	U.Bergen	Svalbard 01, Knipovith ridge	Multichannel reflections seismics, gravity and magnetic measurements.	Haakon Mosby	9 Sept - 3Oct '01
5	Russia	M. Sorokin,	PMGE	MAR,10-30deg.N	Focused survey at four previously discovered hydrothermal sites	Logachev	Sep - Nov '01
14	UK	L. Parson, C. German, B. Murton	SOC	CD 127/ CIR,19-26S	Ridge-Hotspot Interaction & hydrothermal activity on the CIR	RRS Charles Darwin	22 April - 23 May '01
15	UK	P. Tyler, C. German	SOC	CD 128/ Rodrigues Triple Junction, 25-26S	Hydrothermal Plume Processes (Biogeochemistry) in the Indian Ocean	RRS Charles Darwin	27 May- 27 Jun '01
16	USA	H.Dick, J.Lin	WHOI	SWIR	Rock dredging and geophysical survey	Knorr	8 Dec. 21 Jan.'01
5	USA	D. Smith	WHOI	MAR	Mooring recovery	Atlantis	06 Mar- 01 Apr '01

5	USA, Russia	C. Van Dover, S. Sudarikov	W&M, U Miami, MBARI	MAR	Sampling of vent sites along MAR Exploration of a new vent field at 13N Bore-hole site data recovery	Atlantis	26 Jun - 30 July '01
5	USA	R. Lutz	Rutgers	MAR	imaging of hydrothermal vent and ambient environments by IMAX and HDTV systems	Atlantis, Alvin	03 Aug - 30 Aug '01
3	USA	P. Johnson	UW	Juan de Fuca	Hydrothermal system	Thompson	17 Jun - 03 July '01
3	USA, Canada	B. Emley	NOAA	Axial Volcano, Juan de Fuca Ridge centered at 46 deg.N; 130deg.W	Sampling of biology, chemistry and geology, mapping and recover and deploy instruments	Ron Brown	12 July - 30 July '01
3	USA	E. Baker	NOAA	Axial Volcano and southern Juan de Fuca Ridge	CTD plume mapping and sampling Mooring deployments and recoveries	Wecoma	16 July - 02 Aug '01
12	USA	C. Cary	W&M	EPR	Biological studies at EPR, sample collection	Atlantis, Alvin	15 Oct - 02 Nov '01
12	USA	H. Shouten	WHOI	EPR	Near-bottom mapping of CAMH on the EPR	Atlantis, Alvin, ABE	06 Nov - 05 Dec '01
12	USA	J. Childress, C. Van Dover	UCSB, W&M	EPR	Biological studies of vent communities	Atlantis, Alvin	09 Dec- 01 Jan '02
12	USA	K.Von Damm	U.New Hampshire	EPR	Alvin 5 dives at 21N and 20 dives in 5 areas between 9-52N.	Atlantis	6 Jan- 10 Feb '02
6	USA	C. Van Dover	W&M	Blake Ridge	Studies of divesity in mussel beds.	Atlantis	22 -30 Sep. '01

National News....

France: Dorsales

2001 budget

Dorsales is funded by CNRs (2/3) and IFREMER (1/3). The budget of 120 000 $ is used to pay the InterRidge contribution (20 000 $) and to support Dorsales workshops and participation to meetings, as well as a few selected scientific projects. Because of the limited budget, the call for proposals is always focused. Following two workshops organized in Januray 2001, in Roscoff, respectively by M. Maïa and J. Escartin in Paris, and D. Jollivet the following themes were chosen:

- ridge/hotspot interaction

- population genetics and evolutionary sciences in vent taxa

Dorsales Cruises in 2001

-SWIFT (PI: E. Humler) - Mapping and sampling the SWIR between 35 and 49°E, Feb - March 2001, R/V Marion Dufresne

- IRIS (PI: Y. Fouquet) - ROV Victor dives on Rainbow hydrothermal field, joined cruise investigating biology and geosciences.

-ATOS (PI: PM. Sarradin) - ROV Victor dives - biology. Partly EC funded cruise to the MAR, Lucky strike and Rainbow

Cruises in 2002

Scheduled

-SIRENA - PI: J. Goslin, monitoring seismicity of the MAR North of the Azores with autonomous hydrophones. Hydrophones provided by C. Fox

-PHARE - PI: F. Gaill and N. Le Brisbiology, EPR 9°N and 13°N, ROV Victor cruise

Well evaluated but not yet scheduled

-TOMSWIR - PI: D. Sauter, seismic tomography of a very cold portion of the SWIR (Jourdannes mountains). Look at the deep structure of the ridge

- PACANTARCTIC 2 - PI: L. Dosso and H. Ondreas. Mapping and sampling the Pacific-Antarctic ridge in the area of the geochemical boundary (39-52°S)

-LUCKY STAR - PI: J. Escartin and S. Singh. Deep structure of the Jussieu Plateau and of the Lucky Strike segment, MAR south of the Azores

Dorsales Digital database

The French site is developped at SISMER, under the responsability of C. Deplus (CNRS), together with E. Moussa (SISMER, IFREMER). Seven areas where bathymetric data collected wity French R/Vs are particularly dense have been selected for the database, which can be found at: http://www.ifremer.fr/sismer/program/dorsale/

Funding of OBSs

A project to acquire 25 OBSs has been funded by CNRS (PI: S. Singh). The instruments should be available by 2002. They will be available to the whole CNRS community in France and in particular to the Dorsales community.

More funds are being sought to increase the number of instruments during the next years.

New R/V

The replacement of the R/V NADIR has been approved by the Ministry. The NADIR will most likely end operations next year. The new ship will be a carrier for the submersible NAUTILE and ROV VICTOR. It will be shared with the Navy, and so will have constraints, as yet undermined. The ship should be ready by 2004.

Future of Dorsales

The Dorsales program was renewed in 1998 for four years. It is in its last year of funding and the funding agencies have specified that they will not renew it in its present form.

CNRS has started a new program on "Geomicrobiology in extreme environements" that covers parts of the present Dorsales program but not everything.

To discuss the actions that the Dorsales community wants to promote during the next decade, a workshop was organized in Roscoff (Oct 29-31) by J. Dyment, F. Gaill and C. Mével on "Long term observations at mid-ocean ridges". Fifty persons attended (half biologists, half earth scientists). The aim was to understand active processes at mid-ocean ridges, with a particular focus on the link between geoscience and biological processes. This requires repeated observations and measurements and possibly long term observatories. Identified targets are the MOMAR area (MAR south of the Azores) and the EPR at 13°N. A project plan will come out of this workshop and be distributed to funding agencies for evaluation. But it is also obvious that efforts for long term observation at mid ocean ridges should be coordinated at an international level and France wants to be active in the MOMAR project supported by IR.

If the funding agencies agree on the new program, it will not start before 2003. Meanwhile, CNRS has committed to pay the French InterRidge contribution.

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National News....

New Zealand

RIDGE science projects in New Zealand continue to focus on the Kermadec – Havre arc – back-arc system to understand processes of arc rifting and new oceanic crust accretion, hydrothermalism, including associated mineralisation and vent biology, and petrogenesis of arc and back-arc magmatism.

Much of the ongoing work has been further analysis and publication, in collaboration with French, German and US groups, of research results from the Yokosuka 1997, Sonne 1998, and Tangaroa 1999 cruises to the region. Some of the more recent results have been presented at the Intra-Oceanic Subduction Systems: Tectonic and Magmatic Processes meeting in the UK by Gary Massoth (GNS) and Ian Smith (Uni. Auckland).

A major new initiative has been the commencement of vent-biological studies at three known active hydrothermal systems on Rumble III and V, and Brothers caldera (see Clark and O'Shea, this issue). Cruises during November 2000 and May 2001 have begun to document a rich vent fauna using seafloor photography, video transects and epibenthic sledge tows. Rumble III and V represent shallow-water habitats (shoaling to 220 and 450 m, respectively) whereas the Brothers caldera, particularly the vents on the northern caldera wall, lie within water-depths of 1550–1800 m. Much of the recovered material is now being distributed to relevant taxonomic experts for identification, with the fauna comprising many new species and some new genera. Preliminary identifications have recognised a variety of vent fauna, including at least one species of Bathymodiolus, a large gastropod attributed to Gmynobela, and three separate species of the caridean Alvinocaris shrimp. Likewise, a galatheid fauna is recorded (13 species) that appears to be limited to vent and adjacent areas, whilst 12 barnacle species are recorded, including the vent-specific Neolepas from Brothers caldera. Similarly, the anomuran fauna of Paralomis is restricted to Brothers. Molluscan numerically dominate the recovered fauna. The available data also show species diversity, density and substrate type are highly variable and "patchy", both within and between volcanoes. Discovery of these vent-faunas will stimulate new avenues of research in vent faunal diversity, distribution, and colonisation. Related genetic research is currently planned.

Forthcoming New Zealand cruises will involve a consecutive two-voyage programme using RV Tangaroa during May – June 2002 to map the active Kermadec arc front and possible associated hydrothermalism between 30° and 35°S. The first cruise (PI: Ian Wright, NIWA) with collaboration of T. Worthington (Kiel University) and J. Gamble (VUW) will use the newly installed EM300 multi-beam system on Tangaroa to swath map 7-9 arc volcanoes indicated from satellite gravity data, with concurrent rock dredging sampling and seafloor photographic studies. The cruise will focus on documenting the petrogenesis and submarine volcanology of the arc front with particular emphasis on establishing the presence of silicic calderas. Benthic biologists from NIWA will also participate in this first cruise. The second cruise (PI's: Cornel de Ronde and Gary Massoth, GNS) with collaboration of E. Baker and J. Lupton (NOAA) and colleagues from Kiel and Kyushu universities will focus on mapping hydrothermal plumes using a continuous hydrographic, optical, and chemical profiling system along the same segment of Kermadec arc front using the swath mapping results from the first cruise. This cruise will be the maiden deployment of a new CTD/rosette/in-situ chemical sensing system designed by Gary Massoth and built at GNS. This cruise will extend northward the earlier plume mapping studies from south of 35° (de Ronde et al., 1999) and will hopefully discover a similar frequency and intensity of gas/particulate emissions (at least 55% of volcanoes surveyed to date) to that of the 37°-35°S segment (de Ronde et al., 2001, submitted). Further hydrothermal studies are being planned for 2002 in collaboration with German and Australian colleagues that include possible vent-specific sampling and further plume mapping along the arc north of 30°S.

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National News....

India: InRidge

The InRidge programme (India's Ridge Research initiative) aims to understand the tectonic and oceanic processes along the Carlsberg Ridge (CR), Central Indian Ridge (CIR) and the Andaman back-arc basins (ABAB). These areas were selected essentially to obtain sufficient data to fill in the knowledge gap. The research issues addressed included: tectonic architecture, ridge-transform interaction, incipient triple junction formation, relation of spreading kinematics with increased seismicity on the Indian Sub-continent, petrological variations, search for hydrothermal signatures and to develop a genetic model for hydrothermal processes and metallogenesis.

The year 2001 saw a spurt in ridge-related research endeavour in India. Eighty ship-days were allotted onboard R/V Sagar Kanya to survey the Northern Central Indian Ridge (NCIR) and the ABAB. In addition, a collaborative effort with Japan resulted in two Indian scientists participating onboard R/V Hakuho-maru during its traverse along the CR during Dec. 2000-Jan. 2001.

The NCIR was surveyed onboard R/V Sagar Kanya during May-July 2001. The main objective of the cruise was to acquire geological and geophysical data at the intersection of CIR with the Wide Deformation Zone (WDZ), located between 4°-8°S, to understand ridge axis magmatism and plate geometry. Also a study of the crustal fabric at the intersection between the ridge and transform was carried out.

The ABAB is a young basin. Its study is significant since the nature of rifting can be examined here in terms of juvenile spreading or transitional, from rift segmentation to spreading segmentation. We have also to address the issue of low temperature hydrothermal process giving rise to gold mineralisation in the Andaman region. At the time of communicating this update, a cruise onboard R/V Sagar Kanya is visiting the ABAB to detail the spreading segment characteristics and associated hydro-thermalism.

The Indian funding agencies have extended their support to InRidge by identifying it as a national thrust program that forms a part of the 10th five year plan (2002-2007).

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InterRidge - Japan

For the last 6 months, Archaean Park program, a comprehensive program to study active hydrothermal system, has been most active with three research cruises at the Izu-Ogasawara Arc and an additional cruise in December 2001. A workshop, the Second Archaean Park Project Workshop, was also held on November 16-18, 2001 at Shuzennji hotspa resort in Izu Peninsula to discuss the results of the four research cruises conducted at Suiyo Seamount, which is a dacitic arc volcano of the Izu-Bonin arc, western Pacific. The 3 day meeting was attended by 68 researchers including 28 graduate students.

The main topic was the BMS drilling which produced 7 cores/holes with average depth of 5 meters. Six holes show fluid discharge with temperatures ranging from 9°C to 308°C. The cores and fluids were sampled during the BMS/Hakurei #2, successive ROV Hakuyo 2000 cruise, and two Shinkai 2000 cruises for geological, geochemical and microbiological studies. We conducted long-term monitoring for temperature, heat flow, fluid velocity and chemical fluctuation besides in situ culture of microbes. We are planning to go back to the Suiyo Seamount to drill again by BMS in late July 2002, which will be followed by ROV Hakuyo 2000 cruises for sampling and long-term monitoring. The Archaean Park project will have a major review next autumn and will be continued for another two years, provided that the program is suc-

National News....

cessful in getting high scores.

Coming cruises of InterRidge Japan other than Archean Park are two Shinkai6500 submersible expeditions in the Indian Ocean; one is at Kairei and Edmond hydrothermal sites in the Central Indian Ridge (PI: K. Takai), and the other is at the Atlantis II Fracture Zone at the Southwestern Indian Ridge (PI: T. Matsumoto). An intensive high resolution deeptow survey (bathymetry, image, and magnetics) will be done at the active rifts in the southern Okinawa Trough by R/V Hakuho-maru in June 2002 (PIs: H. Tokuyama and K. Tamaki).

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Korea

In May and June 2001, Korea Ocean Research and Development Institute (KORDI) conducted a multidisciplinary survey of the Ayu Trough using R/V Onnuri under the Daeyang Program (PI: Sang-Mook Lee). The Ayu Trough is divided approximately in half, with respect to 2°N, between the Republics of Palau and Indonesia. The survey is a continuation of the last year's survey in which the area north of 2°N was studied. Last year's survey included multibeam bathymetric mapping, gravity and magnetic field measurements for 7 days. This year, in addition to mapping and conducting underway geophysics in the area south of 2°N, the survey performed three 12-channel seismic profiles, 9 dredge rock samplings along the trough axis, 2 piston corings, and numerous CTD profiles of the water column in search of hydrothermal plumes. Also multiple cores were used to take sediment for biological studies. The survey took more than 15 days. After making a port call at Biak, Indonesia, R/V Onnuri made a couple transects across the eastern boundary of the Caroline Plate, where the boundary with the Pacific Plate is not clear, during a physical oceanographic study to investigate small-scale mixing along the equator. Preliminary results of this work will be presented at the Korean Oceanographic Society semi-annual meeting (November 2-3, 2001) and the Fall AGU.

Currently, preparations are being made for the next year's survey. Some of the areas the Daeyang Program will focus on 2002 are the forearc basin of New Ireland and Manus backarc basin, Papua New Guinea. The survey of the New Ireland forearc basin will include multibeam bathymetric mapping, gravity and magnetic field measurements, dredging, CTD and, if possible, biological sampling at Edison seamount. The New Ireland survey will be held in collaboration with the University of Freiberg, Germany. One of our objectives in the Manus backarc basin is to conduct a near-bottom deep-tow magnetic survey over the ODP Leg 193 drill sites. There is also a plan to investigate parts of the Sorol Trough, a transtentional boundary between the Caroline and Pacific Plates.

This year KORDI has started a new program to build ocean bottom seismometers (OBS) for crustal and earthquake studies (PIs: Sang-Mook Lee and Sup Hong). Although there have been studies using OBSs in Korea in the past, this is the first time that OBSs are being built in Korea for scientific purpose. The plan is to build and upgrade a couple of OBSs each year and so after a few years KORDI will have its own set to conduct crustal and earthquake studies.

Recently KORDI has been granted funding from the Korean government (PI: Pan-Mook Lee) to build a remotely operated vehicle (ROV). The ROV will be fitted for full-ocean depth operation and will be an important tool for ridge-related studies after 2004.

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National News....

Austria

Austrian biological research at hydrothermal vents is concentrated, for the most part, on chemoautotrophic sulfur-oxidizing (thiotrophic) symbioses. The most relevant of our studies to InterRidge are those focusing on *Riftia pachyptila* (Vestimentifera), one of the most conspicuous and well-studied of thiotrophic symbioses from the East Pacific Rise, Galapagos Rift and Guyamas Basin. Similar to many invertebrates, the worm's life cycle is characterized by a pelagic larva and a benthic adult. These two phases are linked by a settlement event that triggers a major morphological transformation during metamorphosis. In *Riftia pachyptila*, this life cycle is additionally impacted by another event – the uptake of a specific symbiont in the early juvenile phase that triggers a transformation from a non-symbiotic, heterotrophic animal and a free-living, autotrophic microbe to a 'symbiotic entity'. This process builds the framework of our studies in which we attempt to directly follow adaptations and study interactions in order to gain insight in the evolution of this association.

In the past years we concentrated on nutritional interactions and studied some aspects of the carbon metabolism in *Riftia pachyptila* symbiosis. By pulse-chase experiments in high-pressure aquaria and calculations of carbon incorportion rates using ^{14}C bicarbonate autoradiography and of carbon storage rates by quantitative electron microscopy we found that translocation of organic carbon from the symbionts to the host is a very fast process and is mainly facilitated by release of low molecular weight products. The single microbial symbiont, morphologically variable in size and form, was found to behave differently physiologically with respect to carbon incorporation and storage according to its morphotypes (Bright et al., 2000, Sorgo et al., in press). These morphotypes are hypothesized to represent different stages in a complex microbial life and terminal differentiation cycle that might be an adaptive strategy to an endosymbiotic life style (Bright & Sorgo, in press).

Ongoing research focuses on the morphological and ultrastructural adaptations during the life cycle of the host from early non-symbiotic, sessile stages in the size rage of 250 µm to a symbiotic later stage already developed in 150 µm larger individuals. We are especially interested in the time frame and location as well as specificity of symbiont uptake.

This research at the East Pacific Rise has been made possible by extensive cooperations with USA (C.R. Fisher, H. Felbeck, L. Mullineaux, J.J. Childress) and France (F. Gaill), and findings from the Austrian Science Foundations (FWF H0087-BIO, P13762-BIO). Participation on several cruises during the last years, where collections of animals and experiments could be carried out, are greatly acknowledged. Currently, we are invited by C.R. Fisher to join a cruise to the East Pacific Rise in December, 2001 in order to continue our studies.

We would like to build a platform of Austrian scientists in order to unite researchers in any discipline of natural science involving ridge-crest studies for exchange and cooperations within Austria and with other members of InterRidge. We anticipate to strengthen our presence in the Austrian as well as international scientific community and become an active member in InterRidge.

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Previous updates from various Nations can be found on the IR web site under the menu "Member Nations" or by going directly to:

http://www.intridge.org/act4.html

Upcoming Meetings and Workshops

Calendar of MOR Research related events (2001)

More details about all of the following meetings can be found via the Meetings menu on the InterRidge homepage:

http://www.intridge.org/info3.html

10 - 15 June, 2001	10th Water-Rock Interaction Symposium. Sardinia, Italy
25 - 26 July, 2001	B-DEOS Town Meeting. Cardiff University, UK
18 - 24 August, 2001	Second International Conference of Comparative Physiology & Biochemistry in Africa. Chobe National Park, Botwana
25 - 27 August, 2001	Joint Geosciences Assembly (JGA). International Convention Center, Taipei, Taiwan
8 - 10 Sept., 2001	Symposium on the Icelandic Plume and Crust. Reykjanes Peninsula, Iceland
24 - 26 Sept., 2001	Endeavour Observatory Workshop/Results Symposium. Seattle, WA, USA
8 - 13 October, 2001	Second International Symposium on Deep-Sea Hydrothermal Vent Biology. Brest, France
28 Oct. - 3 Nov. 2001	International Tectonic Symposia. Moscow - St. Petersburg, Russia
31 Oct. - 3 Nov. 2001	The 31st Underwater Mining Institute Conference. Hilo, Hawai`i
10 - 14 December 2001	AGU 2001 Fall Meeting. San Francisco, CA, USA
11 - 15 February 2002	Ocean Sciences Meeting. Honolulu, Hawaii
5 - 8 March, 2002	Oceanology International 2002. London, UK
16 - 19 April, 2002	Underwater Technology 2002 International Symposium. Tokyo, Japan
17 - 19 April, 2002	SWIR Workshop. SOC, UK
20 - 25 April, 2002	"Minerals Of The Ocean" - International Conference. St. Petersburg, Russia
10 - 12 June 2002	IR Next Decade Workshop. Bremen, Germany\
June 2002	MOMAR Workshop, Horta (Azores, Portugal)
9 - 12 July, 2002	Western Pacific Geophysics Meeting. Wellington, New Zealand
4 - 7 September, 2002	Plume Magmatism. Petrozavodsk, Russia
13-14 September 2002	Steering Committee Meeting. Italy
9 - 13 September, 2002	InterRidge Theoretical Institute (IRTI) Thermal Regime of Ocean Ridges and Dynamics of Hydrothermal Circulation. University of Pavia, Italy.

Upcoming Meetings and Workshops

American Geophysical Union Fall Meeting

10-14 December 2001, San Francisco, CA, USA

http://www.agu.org/meetings/fm01top.html

Ridge related Sessions

1) "Hotspot-Ridge Interactions" (AGU T-Section)
2) "Structure and Evolution of the Galapagos Volcanic Province" (AGU T-Section)
3) "The Initiation and Early Evolution of Young Ocean Basins" (AGU T-Section)
4) "Ophiolites and Continental Margins of the Pacific Rim and the Caribbean Region" (AGU T-Section)
5) "Seismic and Hydro-acoustic Constraints on Ocean Crustal Dynamics, Volcanism and Hydrothermal Fluid Circulation in the NE Pacific" (AGU S-Section)
6) "The RIDGE Endeavour Segment Seafloor Observatory: Results of Coordinated Experiments" (AGU OS-Section)
7) "Hydrothermal Activity in Back-arc Basins" (AGU-OS Section)
8) "Pushing the Envelope: A Tribute to the Career and Accomplishments of John M. Edmond" (AGU-OS03)

South West Indian Ridge Workshop (SWIR)

17-19 April 2002

Southampton Oceanography Centre, UK

http://www.intridge.org/swirwksp.htm

15 January - deadline for abstract submission

Organizing Committee: C. Mével, Co-chair (mevel@ccr.jussieu.fr),
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Upcoming Meetings and Workshops

InterRidge Next Decade Workshop
Call for white papers!

10-12 June 2002, Bremen, Germany

http://www.intridge.org

Co Chairs: Colin Devey (Germany) and Kim Juniper (Canada)

All of the International Ridge Community is encouraged to submit white papers to the InterRidge Office (intridge@ori.u-tokyo.ac.jp) with their views about the next decade of international Ridge research.

The latest information about the registration for the workshop is available from the left hand panel of InterRidge website.

2nd MOMAR Workshop

June 2002, Horta (Azores, Portugal)

Towards planning of seafloor observatory programs for the MAR region

For the latest information go to: http://www.intridge.org

Convenors: Javier Escartin, France, (escartin@ccr.jussieu.fr)
Ricardo Serrão Santos, Azores, Portugal (ricardo@horta.uac.pt)

Workshop Objectives:

a) define the scientific objectives to be pursued in the next 5-10 years: integration of biological, volcanic, tectonic, hydrothermal and oceanographic processes in time and space
b) identify technologies/instrumentation available for observatory-related studies, and future developments required: AUVs, moorings, ROVs, submersibles, data collection/storage/transmission, etc.
c) define the type of experiments to carry out in the future and establish a realistic implementation plan based on the scientific goals, as well as technological and funding constrains
d) define the procedures for management and integration of scientific data
e) establish links with existing national and international observatory-related projects: data and connector standards, transfer of technology
f) discuss and evaluate management proposals of study sites, and aspects related with scientific interpretation and dissemination for the general public
g) discuss and evaluate possibilities and strategies for funding of the observatory

Upcoming Meetings and Workshops

1st InterRidge Theoretical Institute (IRTI)

Thermal Regime of Ocean Ridges and Dynamics of Hydrothermal Circulation

9-13 September 2002, University of Pavia, Italy

Latest information about registration can be found at:
http://www.intridge.org/irti.htm

Organising Committee: C. German (Co-Chair), J. Lin (Co-Chair), A. Fisher, M. Cannat, R. Tribuzio & A. Adamczewska

We are pleased to announce the first IRTI to be held in Italy in September 2002.
The principal objectives of this theoretical institute will be:

(1) To foster exchange of information on recent progress in observational, experimental, and modeling studies of hydrothermal circulation and their implications for thermal evolution of the oceanic lithosphere.
(2) To identify key scientific issues that could be addressed in coming years and discuss a general plan for more focused international collaboration in this important research field.
(3) To educate a broad spectrum of international researchers, post-docs, and graduate students on the state-of-the-art research approaches, especially experimental and theoretical modeling capabilities.

The Institute will take place over 4 1/2 days' duration comprising 2 days' short-course and one day's field excursion to study hydrothermal alteration in the northern Apennine ophiolites followed by a further 1 1/2 days' workshop for a subset of the short-course/field trip participants.

We have arranged for 19 Invited Speakers and Discussion Leaders from across the international community to lead the proposed short-course.

The short-course and workshop will be held in the historic lecture theatre of the University of Pavia, situated approximately 30miles/50km south of Milano. The field course will be to the northern Apennine ophiolites, where exceptional hydrothermal alteration exposures can be observed.

Participation: We anticipate 50-100 attendees for the short course and field excursion and about 30 attendees for the workshop. Because space is likely to be limited, those interested in participating, either to the short-course and field excursion or for the full duration of the whole IRTI, should register their interests with Agnieszka Adamczewska at (intridge@ori.u-tokyo.ac.jp).

We look forward to seeing you in Italy!
Chris German (cge@soc.soton.ac.uk) & Jian Lin (jlin@whoi.edu)

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