



# InterRidge News

Initiative for international cooperation in ridge-crest studies

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France  
Japan  
United Kingdom  
United States

## Associate Members

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Germany  
Italy  
India  
Korea  
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South Africa  
Spain  
Sweden  
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## Contents

### InterRidge Office Updates

The InterRidge Wish List.....	3
Coordinator Update.....	4
InterRidge Publications.....	6
InterRidge Web Page Overview.....	7

### InterRidge Projects

Overview of InterRidge Working Groups.....	8
Global Distribution of Hydrothermal Activity Working Group.....	9
Monitoring and Observatories Working Group.....	10

### Reports and announcements

89 <sup>th</sup> Dahlem Workshop.....	11
Elizabeth Mann Borgese .....	11

### International Ridge-Crest Research

#### Biological Studies

MAR-ECO - "Patterns and Processes of the ecosystems of the Northern Mid-Atlantic"; an international project under the Census of Marine Life programme. <i>Bergstad O. A.</i> .....	12
Towards unravelling the enigma of vent mussel reproduction on the Mid Atlantic Ridge, or when ATOS met Cages. <i>Dixon D et al</i> .....	14

#### Island arc/BAB

Submarine Hydrothermal Mineralisations and Fluids off the Lesser Antilles Island Arc – Initial Results from the CARIBFLUX Cruise SO 154. <i>Halbach P. et al</i> .....	18
Geophysical Experiments in the Mariana Region: Report of the YK01-11 cruise. <i>Goto T. et al</i> .....	22

#### Ophiolites

How back-arc basins evolved: tholeiite associations in the Kudi ophiolite of western Kunlun Mountains, northwestern China. <i>Zhihong W.</i> .....	25
---	----

Continued over page ....

## Contents continued...

### International Ridge-Crest Research cont ...

#### Pacific-Antarctic Ridge

Widespread Silicic Volcanism and Hydrothermal Activity on the Northern Pacific – Antarctic Ridge. <i>Stoffers P. et al.</i> .....	30
---	----

#### Mid-Ocean Ridge

Isotope provinces of mid-ocean ridges. <i>Pustovoy A.A. et al.</i> .....	33
--	----

#### Mid-Atlantic Ridge

New data on hydrothermal activity in the area of 12°57'N, MAR: initial results of the <i>R/V Professor Logatchev</i> cruise 20. <i>Bel'tenev V.Ye. et al.</i> .....	38
Sulphide mineralization, volcanic and tectonic activity of the MAR near Sierra Leone F.Z.: 10 cruise R/V “Akademik Ioffe” (preliminary results). <i>Skolotnev S. et al.</i> .....	41

#### Indian Ridge

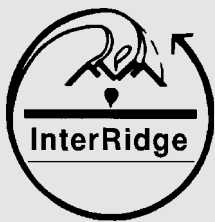
Preliminary results of a recent cruise to the Northern Central Indian Ridge. <i>Drobia R.K. et al.</i> .....	43
--	----

<b>World Ridge Cruise Map and Schedule, 2002</b> .....	47
--	----

<b>National News</b> .....	52
----------------------------	----

<b>Calendar and Upcoming Meetings</b> .....	58
---	----

<b>National Correspondents and Steering Committee Members</b> .....	63
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## InterRidge Mailing List

Sign up on the web at:

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

You can use the online form to join our regular mailing list to receive *InterRidge News*, or to be placed on our electronic mailing list, or 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. We are constantly adding new entries to the electronic directory, which 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.

## The InterRidge *Wishhhhhh* List....

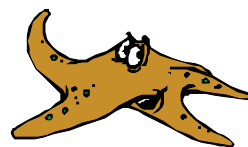
On suggestion of the IR Steering Committee, we have opened the InterRidge *Wishhhhhh* list to facilitate and promote sample exchange between ridge scientists. Please submit requests for samples, to the IR Office. I would like to encourage all ridge scientist to check the *Wishhhh* list and share samples 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: CHIMINEY 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>



### SEARCHFORGRAPHITE

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>

### ROCKSAMPLES

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!

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



## Coordinator's Update

### Member Nations

The number of nations involved in InterRidge activities continues to grow. This year, Mauritius has joined InterRidge as a Corresponding Member nation. We welcome Dr. Daniel P. E. Marie from the Mauritius Oceanography Institute is the National Correspondent for Mauritius. This brings the total number of InterRidge member countries to twenty eight.

### Upcoming InterRidge meetings

This year is a very busy one for IR meetings, there is something for everyone! An ever increasing demand to pool resources and expertise, on an international level, in order to maximise research scope, quality and output, and at the same time minimise costs for individual nations is the driving force for organising more international meetings.

#### *IR Steering Committee meeting*

The next IR Steering Committee meeting will be hosted by Dr Riccardo Tribuzio, 13-14<sup>th</sup> September 2002, Sestri Levante, Italy.

#### *InterRidge MOMAR II Workshop*

The 2<sup>nd</sup> MOMAR workshop will take place 15-17<sup>th</sup> June 2002, Horta, Azores (Portugal). The main goals of this workshop are to:

- 1) establish a plan for the development and installation of an ocean-bottom observatory along the Mid Atlantic Ridge south of the Azores, and
- 2) to identify the required scientific and technical support required to operate and manage the projects, data and instruments involved in the MOMAR observatory. The latest information about this workshop can be obtained from the IR website.

#### *SWIR Workshop*

A workshop to synthesise current knowledge and identify areas, both disciplinarily and geographically that

require investigation and decide on future direction of research in this area is scheduled for 17-20<sup>th</sup> April, 2002, at SOC, UK. The workshop is set to be a great success with over 70 delegates from 13 countries registering to participate. A proceedings volume from the meeting will be published as a "Theme" in the electronic journal, G-cube (G3 <http://g-cubed.org/>). InterRidge is offering the "Outstanding student award" for the best student presentation at this workshop. The winner will be announced in the next issue of IR news!

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

The first IRTI will be held 9-13 September 2002, at the University of Pavia, Italy. The IRTI is being jointly organized by the Hotspot-Ridge Interactions working group and the Global Distribution of Hydrothermal Activity Working Group. The Institute will take place over 4 1/2 days, and will comprise of:

- 1) a short course component, which will focus on the modelling aspects of the dynamics of hydrothermal circulation in the crust,
- 2) a one day field excursion to study hydrothermal alteration in the northern Apennine ophiolites and
- 3) a workshop component to synthesize the current models, debate controversies, and outline the future directions for collaborative research. For more information see the back of this issue of IR news or look on the IR website.

#### *Next Decade Workshop*

The Next Decade Workshop will be held 10-12<sup>th</sup> June 2002, Bremen, Germany. The current InterRidge programme will come to an end of its 10 year plan at the end of 2003. Thus, it is time for the international ridge com-

munity to convene together and share their ideas about the direction of future ridge research. The aim of this workshop will be to exchange and propose ideas for a new InterRidge Science plan for the next decade of international and multidisciplinary research.

Representatives from Principal and Associate member nations will develop the "Next Decade Project Plan" for InterRidge, based on the discussions during the workshop. 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 is expected to be of direct benefit to individual scientists and national programmes for the nations involved. At the same time the "Project plan" will provide opportunities for the involvement of other nations.

All of the International Ridge Community is encouraged to submit white papers, ideas and opinions to the InterRidge Office ([intridge@ori.u-tokyo.ac.jp](mailto:intridge@ori.u-tokyo.ac.jp)) with their views about the "Next Decade" of international Ridge research. For details about what the white papers should contain please refer to the IR website: <http://www.intridge.org/ndir.htm>

#### **The InterRidge office**

The original IR Science Programme plan will be finishing at the end of 2003. The IR office will remain in Tokyo until the end of the duration of the current Programme in 2003. From 2004 the IR office will move to a new Host country under the appointment of a new Chair. Thus, at the end of this year, the IR office will be sending out a request for bids to host the next IR office and for nominations for

## InterRidge Office Updates

the new IR Chair. The period of tenure of the Chair is not precisely defined, but is normally expected to be three years. The final decision on the bids will be made during the InterRidge Steering Committee meeting in 2002.

The Next Decade workshop (see above) will be a crucial part of the office change over since the aim of the workshop will be to create a document outlining the Science plan for IR for the next decade. Input from the entire IR community is requested. See the IR website for more information:

<http://www.intridge.org/ndir.htm>

### IR Steering Committee members

Thank you to Kantaro Fujioka (Japan), Chris German (UK), Dave Kadko (USA), and Ranadhir Mukhopadhyay (India) who have finished their term as national representatives on the IR Steering Committee. This year we welcome Chuck Fisher, Chair of the USA R2K program as a new USA representative, Masataka Kinoshita from JAMSTEC, Japan and Abhay Mudholkar as the new Indian representative. The new national representative for UK will be announced later this year.

Additionally, thanks go to Chris Fox who has finished his term as the Chair of the Event Detection and Response and Observatories Working Group last year. We welcome two new *ad hoc* steering committee members; Javier Escartin (France) and Ricardo Santos (Azores, Portugal), as the new co-chairs of the "Monitoring and Observations Working Group".

### Working Groups

The SWIR workshop (see above) is the last action of the SWIR working group. The SWIR workshop will end with a morning devoted to discussion and debate about the future of research on the Indian ridge. After the publication of the proceedings from the SWIR workshop this working group will be dissolved. The outcomes of the discussions during

this workshop will be announced in the next issue of IR news and on the IR website.

Past and current information about IR working groups and projects can be found on the IR website:

<http://www.intridge.org/act2.html>

### IR Outstanding Student Presentation

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. This year the IR Student Awards will be handed out during the upcoming SWIR workshop (UK) and the IRTI (Italy). Background about students that receive the IR award and abstracts of their presentations will appear in the next issue of IR news. Students from all countries are encouraged to participate in IR meetings and to present their work!

### InterRidge home page

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 IR 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 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

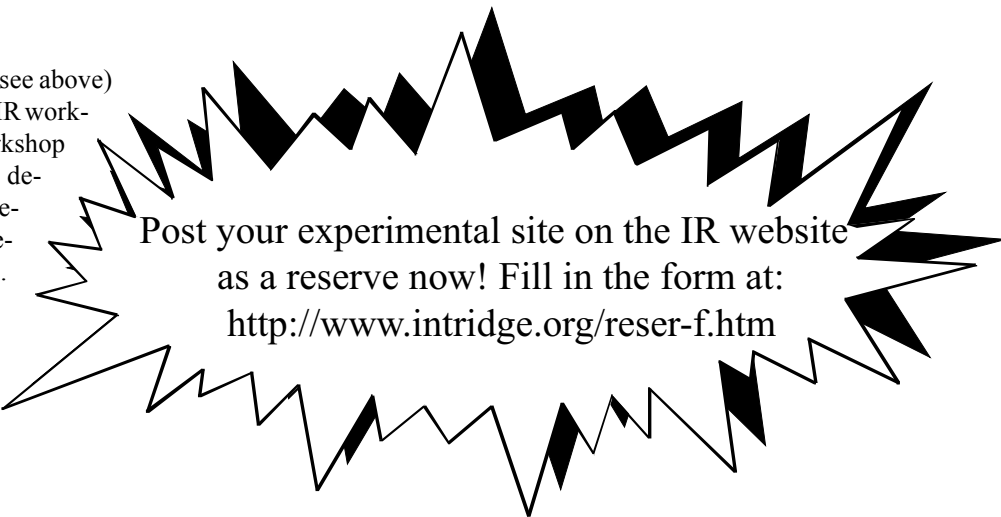
found there is available on page 7 of this issue.

We have an alias for our website to make the IR URL easy to remember, you can access the InterRidge home page by simply typing: <http://www.intridge.org>

The IR databases are unique, they provide an international pool of information about all manner of issues related to mid ocean ridges. The "Global hydrothermal vents database" as well as the "Ridge-Hot Spot Interaction Reference Database" can be searched by conventional method, by typing in search words in any of the fields but also these two databases contain interactive area maps to make searches easier. Thus, you can do your search by location just by clicking on the different areas on the globe. The databases take a lot of work to maintain but we rely on your input to keep them up to date!

We are very pleased to see that the use of the InterRidge website continues to increase. 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. A brief summary of what can be found on the InterRidge website is also available at <http://www.intridge.org/latest.htm>

Agnieszka Adamczewska  
InterRidge Coordinator  
April 2002



Post your experimental site on the IR website  
as a reserve now! Fill in the form at:  
<http://www.intridge.org/reser-f.htm>

## 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](mailto:intridge@ori.u-tokyo.ac.jp).

### InterRidge News:

Past issues of InterRidge News, are available 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:

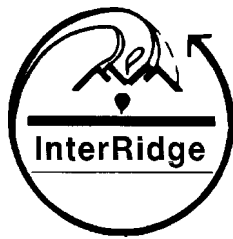
- IR MOMAR (*MONitoring the Mid-Atlantic Ridge*) workshop report, April, 1999.
- IR **Mapping and Sampling the Arctic Ridges: A Project Plan**, pp. 25, December 1998.
- ODP-IR -IAVCEI Workshop Rep.: **The Oceanic Lithosphere and Scientific Drilling into the 21st Century**, pp. 89.
- IR Global Working Group Workshop Report: **Arctic Ridges: Results and Planning**, pp. 78, October 1997.
- IR **SWIR Project Plan**, pp. 21, October 1997 (revised version).
- IR Meso-Scale Workshop Report: Quantification of Fluxes at Mid-Ocean Ridges: **Design/Planning for the Segment Scale Box Experiment**, pp. 20, March 1996.
- IR Active Processes Working Group Workshop Report: **Event Detection and Response & A Ridge Crest Observatory**, pp. 61, December 1996.
- IR Biological *Ad Hoc* Committee Workshop Report: **Biological Studies at the Mid-Ocean Ridge Crest**, pp. 21, August 1996.
- IR Meso-Scale Workshop Report: **4-D Architecture of the Oceanic Lithosphere**, pp. 15, May 1995.
- IR 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.
- IR Global Working Group Report 1993: **Investigation of the Global System of Mid-Ocean Ridges**, pp. 40, July 1994.
- IR Global Working Group Report 1994: **Indian Ocean Planning Meeting Report**, pp. 3, 1994.
- IR 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-IR -IAVCEI Workshop: **The Oceanic Lithosphere and Scientific Drilling into the 21st Century**, pp. 126, 1996.

### Steering Committee and Program Plan Reports:

- |   |  |
|---|--|
| <ul style="list-style-type: none"> <li>IR STCOM Meeting Report, Kobe, Japan, 2001.</li> <li>IR STCOM Meeting Report, WHOI, USA, 2000.</li> <li>IR STCOM Meeting Report, Bergen, Norway, 1999.</li> <li>IR STCOM Meeting Report, Barcelona, Spain, 1998.</li> <li>IR STCOM Meeting Report, Paris, France, 1997.</li> <li>IR STCOM Meeting Report, Estoril, Portugal, 1996.</li> <li>IR STCOM Meeting Report, Kiel, Germany, pp. 22, 1995.</li> <li>IR STCOM Meeting Report, San Francisco, USA, 1994.</li> <li>IR STCOM Meeting Report, Tokyo, Japan, 1994.</li> </ul> | <ul style="list-style-type: none"> <li>IR STCOM Meeting Report, Seattle, USA, pp. 6, 1993.</li> <li>IR Meeting Report, York, UK, 1992.</li> <li>IR Meeting Report, Brest, France, pp. 39, 1990.</li> <li>IR Program Plan Addendum 1997, pp. 10, Jan. 1998.</li> <li>IR Program Plan Addendum 1996, pp. 10, April 1997.</li> <li>IR Program Plan Addendum 1995, pp.10, 1996.</li> <li>IR Program Plan Addendum 1994, pp.15, 1995.</li> <li>IR Program Plan Addendum 1993, pp. 9, 1994.</li> <li>IR Program Plan, pp. 26, 1994.</li> </ul> |
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# 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 InterRidge 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 suggestions are always welcome.

The alias for the IR website makes the URL easy to remember, you can now access the InterRidge home page 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 'Activities' 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 with updates of

their activities can be found 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 the 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 research. 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 sign up form.

Furthermore, there is a neat little program, which you can use to 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.intrridge.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.

*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).

### Biological Studies

*Objectives:* Objectives of the New biology WG are outlined on the IR website.

*Chairs:* F. Gaill (France) and S.K. Juniper (Canada).

*WG members:* M. Bischoito (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 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).

### 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 Sept. 2002.

*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).

### HotSpot-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 Activities:* The agenda for this new WG is being developed.

*Chair:* J. Lin (USA)

*WG members:* R.K. Drolia (India), J.

Dyment (France), J. Escartin (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 Activities:* Organisation of the second MOMAR workshop. Objectives of the workshop are listed on the InterRidge website.

*Chairs:* J. Escartin (France) and R. Santos (Azores, Portugal)

*WG members:* Chris Fox (USA), K. Mitsuzawa (Japan), Pierre-Marie Sarradin (France), Adam Schultz (UK), Paul Snelgrove (USA), Paul Tyler (UK).

### 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).



## Global Distribution of Hydrothermal Activity Working Group

Chris German

*Challenger Division for Seafloor Processes, Southampton Oceanography Centre, UK*

This is the first update for two years from this working group, first established in late 1997. There is a reason for the lack of an annual update last year – I was at sea for 70 days in the Indian Ocean helping identify new sites of venting along the Central Indian Ridge and wasn't around to coordinate our Working Group's input!!!

### InterRidge Theoretical Institute

The first item to bring to your attention in this issue is the imminent demise of the Working Group in 2002. This is in keeping with InterRidge directives on WGs and their lifetimes – but fear not! We shall be bowing out not with a whimper, but a bang. Specifically, joint with the now-defunct 4-D architecture working group, we shall be co-hosting the first ever InterRidge Theoretical Institute to be held in Pavia, Italy, September 9-13, 2002: "Thermal Structure of the Ocean Crust and Dynamics of Hydrothermal Circulation". The meeting will comprise a 2-day shortcourse - with invited keynote papers plus ample time for discussions and contributed poster presentations - followed by a field-trip to local hydrothermally altered ophiolites and finishing with a 2 day workshop identifying future directions for coordinated InterRidge research. From this WG's perspective, a clear objective will be to improve our understanding of the geological controls of seafloor hydrothermal venting.

Full details are available on the InterRidge web-site:

<http://www.intridge.org/irti.htm>

### Global Distribution of Hydrothermal Activity

It has always been the objective that ANY InterRidge Working Group should be able to make a significant contribution to its chosen area of focus within the space of ca. 5 years. I

am pleased to report that ours has been no exception.

### Hydrothermal Exploration

Highlights of field programmes since early 2000 have included discovery of new hydrothermal fields along three separate sections of ultra-slow spreading ridge-crest –

**1)** the Atlantic portion of the SWIR (to be reported by Bach *et al.* at the InterRidge SWIR workshop in April 2002 – but look out, too, for the paper in *G<sup>3</sup>* any week now!); **2)** the Knipovich Ridge (see, *e.g.*, Tamaki, Cherkashov *et al.* (*IRNews* 10.1 pp 48-51, 2001); Connelly & German. *EOS Trans AGU* 83, OS205-206, 2002); **3)** most recently, the exciting discovery of abundant hydrothermal signals along the Gakkel Ridge in the Arctic Ocean (see, *e.g.*, Edmonds *et al.*, *EOS Trans AGU* 82, F647, 2001). In parallel, a UK cruise to the southern Mid-Atlantic Ridge in late 2001 identified clear suspended particulate and dissolved Mn anomalies at a range of sites between 2 and 14 degrees South (C.R. German, unpubl. data) while there have already been wide-ranging reports of the discoveries of first sites of venting in the Indian Ocean during 2000-2001 (Hashimoto *et al.*, *InterRidge News* 10 (1) pp. 21-22; Van Dover *et al.*, *Science* 294, 818-821, 2001). In concert, this makes for **at least one vent-site now known to exist in every major ocean basin**, worldwide, as well as clear demonstration that hydrothermal activity occurs in abundance along even the slowest spreading ridges as well as along the fast and medium-fast.

### Global Vents Data-Base, On-Line

Another important achievement of the WG, early on, was the establishment of a readily-updated electronic data-base of every known hydrothermal field – whether visited and sam-

pled on the seabed or just identified from water column anomalies. Both the data-base and the update forms can be accessed directly from :

<http://www.intridge/vent.htm>

**Only time will tell whether this valuable legacy is used to full advantage by you, the user!!**

### Vent Biogeography

Finally, as well as the IRTI leaving the geological aspects of this Working Group in good order (we have also had a very favourable initial response from AGU about publishing a Geophysical Monograph arising from the proceedings) the biogeographic aspects of our work have also progressed well and will be left in good health as the Working Group itself is wound up. WG member Cindy van Dover recently published an invited review article in *Science* (together with WG co-members Kevin Speer & Chris German, among others): "Evolution and biogeography of deep-sea vent and seep invertebrates" *Science* 295, 1253-1257. That paper took the opportunity to identify a range of key targets for future investigation, selecting specific regions of the mid-ocean ridge-crest where discovery and biological characterisation of new vent-sites would be of particular benefit. Faster than the current InterRidge WG can disband, therefore, I am pleased to report the establishment of a new related initiative supported by the Sloan Foundation as part of the Census of Marine Life programme. From Summer 2002, Profs. Paul Tyler and Chris German at SOC, UK, will co-host the international pilot office for a new programme, ChEss (Chemosynthetic Ecosystem Studies) dedicated to designing and initiating surveys of life in vent and seep communities on the ocean floor. Funding is for three years, in the first instance; contact Paul Tyler ([pat8@soc.soton.ac.uk](mailto:pat8@soc.soton.ac.uk)) for details.

## Updates on InterRidge Projects

## Monitoring and Observatories Working Group

### Expanded Acoustic Monitoring of the Mid-Atlantic Ridge

Chris Fox

*NOAA/PMEL/VENTS Program, Newport, USA*

Monitoring of low-level seismicity on the Mid-Atlantic Ridge (MAR) using autonomous underwater hydrophones will be continued and expanded in the coming years. The initial effort, consisting of six hydrophones moored in the region of 15°-35° N (see InterRidge News 8.1, March, 1999), was deployed in March 1999 by Debbie Smith (WHOI), Maya Tolstoy (LDEO) and Chris Fox (NOAA/PMEL) and funded by USRIDGE for two years of data collection. After extending this initial effort to a third year, US RIDGE recently agreed to fund four additional years of monitoring in a more operational mode, with routine posting of derived seis-

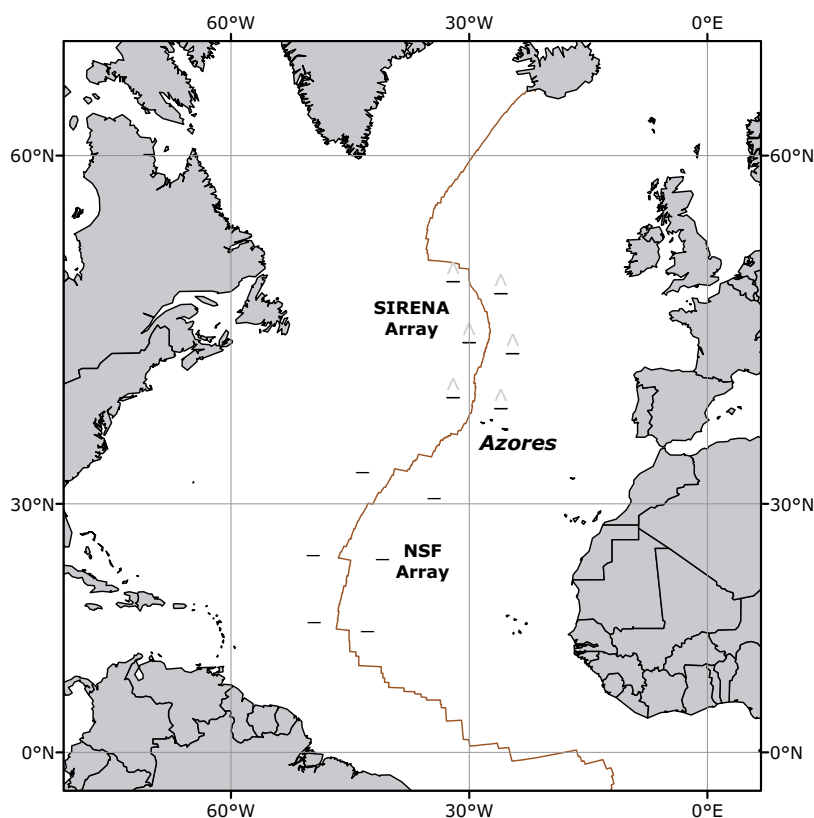
mic source locations posted on the world wide web and raw hydrophone signals to be made available to the scientific community *via* FTP. PIs on the extended effort are Bob Dziak (OSU), Haru Matsumoto (OSU), Debbie Smith (WHOI), and Chris Fox (NOAA/PMEL). The existing array provides excellent coverage of the MAR from the equatorial region to the Azores, but bathymetric shadowing of the acoustic signals have not allowed monitoring of the MAR north of the Azores.

In May 2002, a French expedition (SIRENA) on the French research vessel *Le Suroit* will deploy a new array of six hydrophones around the

MAR between the Azores and the Gibbs Fracture Zone (Fig. 1). The PIs for this experiment are Jean Goslin (CNRS, Brest) and Chris Fox (NOAA/PMEL). The experiment is jointly funded by the French government and US NOAA. The array is only planned for a one-year deployment but every attempt will be made to maintain the array long-term, similar to the USRIDGE array to the south. Although the sensors will be located south of Gibbs, they should be able to routinely detect activity from the Reykjanes Ridge south of Iceland. This new data set, combined with data from the southern array, will provide excellent coverage of the Azores platform and can be combined with seismic sensors on the Azores for a more complete picture of the seismicity of the hotspot. The first data set will be recovered in summer 2003.

Planning is underway to deploy additional acoustic sensors at other locations in the Atlantic and other ocean areas by the Sound in the Sea project of NOAA's Ocean Exploration Programme (PI: C. Fox). One possible target area is along the equator in the Atlantic in conjunction with the existing PIRATA array of surface weather buoys. The acoustic data sets described, while being collected for ridge crest studies, provide valuable data to researchers studying the distribution of large marine mammals in the open ocean and the impact of manmade and natural noise on marine life. Further information on these experiments, access to seismic source information, and access to raw data (still under development) can be found at:

<http://www.pmel.noaa.gov/vents/acoustics.html>. All of these topics will be discussed in detail at the upcoming MOMAR-II workshop June 15-17 in Horta, Azores.



**Figure 1.** Plot of the planned hydrophone deployment, along with the existing array.

Reports and announcements

## 89<sup>th</sup> Dahlem Workshop update

Chris German

*Southampton Oceanography Centre, UK*

What happens to the heat released when magma rises from within the Earth to generate new mid-ocean ridge crust – a fundamental component of plate tectonics? How does seawater transport this heat to the oceans? How deep does water penetrate beneath the seafloor; under what range of pressure and temperature conditions does it react; and with which rock types? How do the resulting fluids rise to the surface and what range of mineral deposits do they produce? How do the resultant fluxes of energy – both thermal and chemical – serve to support unique deep-sea hydrothermal ecosystems? Is there a valid link to the origin of life? What impact do hydrothermal fluxes have on the chemical balance of the oceans and what is the fate of the materials they produce? Does a predicted ~100km-wide high-productivity corridor – a larval superhighway – exist

along ridge-crests? Can we identify hydrothermal signatures in the geological (including paleontological) record; where do 100 million tonne ore deposits form in the modern day; and have hydrothermal sediments played an important role, throughout Earth history, in the transfer of material from the mantle to the continental crust?

These are just some of the questions highlighted during a week-long meeting of 38 international scientists at the 89<sup>th</sup> Dahlem Workshop held at the Freie Universität in Berlin, Oct. 15-19, “Energy & Mass Transfer in Marine Hydrothermal Systems”. The ethos of the Dahlem Workshops is unique – not to present what is already known, but to highlight what we do not yet know, what we need to know, and why. The list, above, just skims the surface of the many new ideas that were generated recently when the field’s top researchers were

compressed together under the pressure-cooker conditions of an isolated retreat. Full discourse of the various subjects highlighted above – including four completely new articles written during the course of the week’s proceedings – will be published in June 2002\*. As a more immediate result, however, consensus has already been reached on a new multi-branched and interlinking process-flow model – *the Dahlem Hydrothermal Reference Model (DaHRM)* – which will be taken forward as the new international state-of-the-art for hydrothermal fluxes at mid-ocean ridges, within the broader whole-Earth *Geochemical Earth Reference Model (GERM)*.

\* *Energy and Mass Transfer in Marine Hydrothermal Systems*, ed. P. Halbach, V. Tunnicliffe, and J. Hein. Berlin: Dahlem University Press.

## Elizabeth Mann Borgese

Ecologist Elisabeth Mann Borgese died at 83 Geneva, Switzerland — Elisabeth Mann Borgese, an activist for protecting the world’s oceans and the last surviving child of German literary giant Thomas Mann, died of a respiratory infection in the early morning hours of 8<sup>th</sup> February 2002 in Samedan, Switzerland, near St. Moritz. Swiss press reports said she skied the day before she died in spite of her pneumonia. Her father, the German essayist, cultural critic, and novelist, was awarded the Nobel Prize for Literature in 1929.

Ms. Mann Borgese was an ecologist

who fought for the preservation of the oceans, wrote numerous papers and books and contributed to conferences on maritime issues. She had been dubbed “ambassador of the oceans.” She also was a university professor in Halifax, Nova Scotia, Canada; the founder of the International Ocean Institute in Malta; and one of the founders of the Club of Rome, a group of scientists focusing on worldwide environmental problems. In 1970, she organized a pioneering conference, *Peace in the Oceans*, concerning the Law of the Sea. Since then, 30 similar confer-

ences have taken place worldwide. She is credited with helping bring about a 1982 UN treaty on the Law of the Sea after more than a decade of negotiation. A Canadian later by choice, Ms. Mann Borgese was born in Munich, the second youngest of Mann’s six children. When she was 15, she and her family left Nazi Germany for Switzerland, where she trained as a concert pianist. She came to the United States in 1938 with her parents and, a year later, married Giuseppe Antonio Borgese, a writer and art historian who had fled Fascist Italy. He died in 1952.

International Research: **Biological Studies**

## MAR-ECO - “Patterns and Processes of the ecosystems of the Northern Mid-Atlantic”; an international project under the Census of Marine Life programme

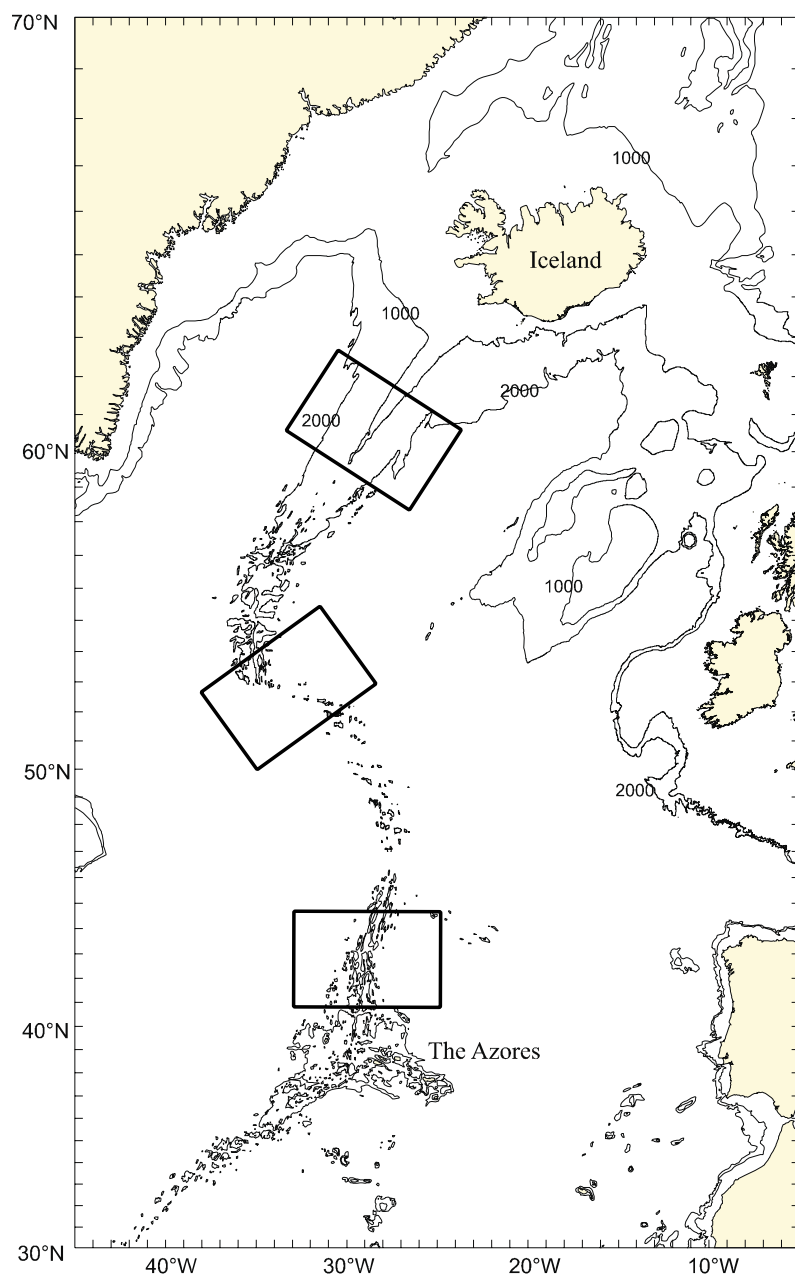
Odd Aksel Bergstad

*Institute of Marine Research, Flødevigen Marine Research Station, N-4817 His, Norway*

### MAR-ECO—a North Atlantic biodiversity study

Despite the wide distribution and extensive area of mid-ocean ridges (e.g. Garrison 1993), relatively few previous investigations have been dedicated to the study of the animal communities inhabiting these vast areas of the world ocean. Ridges may have characteristic faunas, but they may also significantly influence the processes affecting the slope and shelf biota such as intercontinental migration and dispersion. On this background, the project MAR-ECO (<http://www.mar-eco.no/>), focussing on the macrofaunal communities associated with the Mid-Atlantic Ridge (MAR) between Iceland and the Azores, has recently been established as an international ecosystem study under the Census of Marine Life (CoML, <http://www.coml.org>) programme. MAR-ECO targets classical food-chain organisms but works in parallel with ChESs (<http://www.wm.edu/com1/>), a CoML project studying chemosynthetic systems.

The overriding aim of MAR-ECO is to describe and understand the patterns of distribution, abundance and trophic relationships of the organisms inhabiting the mid-oceanic North Atlantic (Fig. 1), and identify and model ecological processes that cause variability in these patterns. Fish, crustaceans, cephalopods, and gelatinous plankton and nekton have the highest priority in the study, but there will also be some effort devoted to epibenthic communities. The project will be carried out as a multi-



**Figure 1.** The Mar-Eco area with sub-areas selected for detailed studies. The exact locations are to be decided during the planning phase.

International Research: **Biological Studies:** Bergstad, cont...

ship operation in 2003-2005, with most activity in 2004 centred around a two-month cruise on the Norwegian *R/V G.O.Sars*.

**Science Plan, tasks and hypotheses**

The Science Plan now available (*e.g.* on the website <http://www.mar-eco.no/>) presents the three central tasks of MAR-ECO and a compilation of hypotheses and suggestions resulting from discussions during and after an initial workshop held in Bergen 12-13 February 2001:

**Task 1:** Mapping of species composition and distribution patterns.

*Theme 1:* Identity and distribution patterns of macrofauna.

*Theme 2:* Population genetics and dispersion studies.

**Task 2:** Identification of trophic interrelationships and modelling of food web patterns

**Task 3:** Analyses of life history strategies

The three tasks are obviously inter-related. Also, all the tasks rely on a thorough understanding of the abiotic environment (bathymetry, watermass properties and distributions, circulation). A major challenge of the project is to overcome observation difficulties at large depths and in rugged terrain. A central aim is thus to utilise modern remote sensing technology (acoustics, optics) using advanced instrument carriers (*e.g.*, towed vehicles, ROVs, AUVs etc.), in addition to more traditional samplers and observation methods.

Some basic overall hypotheses or questions to be addressed are:

- 1) Are the MAR communities extensions of the communities inhabiting the North Atlantic continental slope regions?
- 2) Is the MAR a barrier between the pelagic fauna of the east and west North Atlantic basins? Is there a difference in species occurrence either side of the MAR?
- 3) Do circulation features, *e.g.* the Gulf Stream, act as barriers between the northern and southern fauna? In the region of the Gulf Stream, what is the effect of eastward drift and

import of material from the west?

- 4) What is the significance of seamounts within the ridge system?
- 5) Is the trophic structure of the northern mid-Atlantic ecosystem similar to that on the slope regions of the eastern and western sides of the Atlantic?

**Organisation and schedule**

The International Steering Group organises and oversees the planning, financing, and implementation of the project. Members of the group are:

Dr. Odd Aksel Bergstad, IMR, Norway (chairman)

Prof. Peter Boyle, Univ. Aberdeen, UK

Dr. Olafur S. Astthorsson, MRI, Iceland

Dr. Ricardo S. Santos, Univ. Azores, Portugal

Dr. Uwe Piatkowski, Univ. Kiel, Germany

Prof. Michael Vecchione, NOAA, NMFS, USA

Dr. E.M. Burreson, Virginia Institute of Marine Science (VIMS), USA

Prof. Ulf Båmstedt, University of Bergen, Norway

Dr Pascal Lorance, IFREMER, France

Norway has taken on the secretarial duties for the project, and the responsible institution will be the Institute of Marine Research (IMR) in collaboration with the University of Bergen. The new Norwegian research vessel *R/V G.O. Sars* will be at the disposal of the project activities in 2004, and may form a central focus of international multi-vessel operations.

The schedule and phases of MAR-ECO are the following:

Planning phase: 2001-2003

Field phase: 2003-2005

Analysis, synthesis: 2004-2008

Incorp. in OBIS: 2005-2008

**Current status**

The status of MAR-ECO is that the planning phase has been initiated and a formal organisational structure has been set up. A planning grant recently awarded enables the

International Steering Group to stimulate the network of experts to formulate component projects.

A first planning workshop was held in the Alfred Wegener Institut für Meeresforschung in Bremerhaven in early January 2002 to facilitate presentation of the project and co-ordination of the component project building. Some 45 experts from around the North Atlantic gathered to focus on component project formulation. The following is a list of the working titles of MAR-ECO studies now being formulated, and full outlines and updates will be presented on the website in due course:

*Zooplankton studies:*

Distribution, abundance and species composition of zooplankton in cross-frontal and cross-ridge transects of the Mid Atlantic Ridge. PI: Webjørn Melle, The Institute of Marine Research, Norway.

Feeding behaviour and swimming mode of gelatinous zooplankton and nekton. PI: Ulf Båmstedt, the University of Bergen, Norway.

Time-scale distribution and trophic structure of deep-water gelatinous zooplankton and nekton. PI: Marsh Youngbluth, The Harbor Branch Laboratory, USA.

Trophic structure of major copepods, euphausiids and fish larvae across the Mid Atlantic Ridge. PI: Astthor Gislason, Marine Research Institute, Iceland.

*Pelagic nekton:*

Longitudinal and latitudinal changes in mesopelagic/ bathypelagic nektonic fauna (fish, cephalopods and crustaceans) along MAR. PIs: Mike Vecchione, Kir Nesis, Sergey Evseenko, Peter Boyle, Martin Collins, Von Westerhagen, Christian Pusch, Uwe Piatkowski, Filipe Porteiro, Ricardo Santos, João Pereira.

Interactions of mesopelagic and bathypelagic fauna with the benthopelagic community associated with MAR seamounts/ slopes. PI: Bernd Christiansen, Univ. of Hamburg, Germany.

## International Research: **Biological Studies: Bergstad, cont...**

Effects of the Sub-polar Front on MAR pelagic communities. PIs: Peter Boyle, Martin Collins, University of Aberdeen, UK.

Life cycle strategies of selected species living in different water masses. PIs: Roger Villaneuva, Peter Boyle, Christian Pusch.

Fertilisation experiments with fish and cephalopods for egg and larvae description/ recognition. PI: Sergey Evseenko, Shirshov Institute of Oceanology, Moscow.

Evaluation of global changes comparing catch of historical cruises with present day. PI: Filipe Porteiro, Ricardo S. Santos, DOP, Horta, Portugal.

### *Demersal nekton studies*

Distribution patterns and species composition of demersal fishes

in relation to habitat variability on the Mid-Atlantic Ridge. PI: Franz Uiblein, Univ. of Salzburg, Austria.

Spatial genetic structure of commercially valuable deep-sea fish from the North Atlantic. PI: Rus Hoelzel, Univ. Of Durham, UK.


Epibenthic and Benthopelagic (Demersal) Invertebrate communities, distribution and ecology. PI: David Billett, SOC, UK

Life history studies of demersal fishes. PI: Maurice Clarke, Marine Fisheries Service, Ireland

### **The Mar-Eco vision**

The MAR-ECO vision is that, following the 2001-2008 project period, the identity, distribution patterns, food-webs, and life history patterns of the macrofaunal commu-

nities of the northern Mid-Atlantic Ridge and its flanks will be understood and well known both to the scientific community and the interested public.

The website <http://www.mar-eco.no/> is the main source of updates, contact information, and documents relevant to the project. 



## **Towards unravelling the enigma of vent mussel reproduction on the Mid Atlantic Ridge, or when ATOS met Cages!**

David R. Dixon<sup>1</sup>, P.M. Sarradin<sup>2</sup>, L.R.J. Dixon<sup>1</sup>, A. Khripounoff<sup>2</sup>, A. Colaço and R. Serrao Santos<sup>3</sup>

<sup>1</sup> Southampton Oceanography Centre, United Kingdom

<sup>2</sup> IFREMER Centre de Brest, France

<sup>3</sup> IMAR, University of the Azores, Horta, Portugal

During the recent EU-funded ATOS cruise (*R/VL Atalante*, ROV Victor, June 22<sup>nd</sup> – July 21<sup>st</sup> 2001) to active vent sites south-west of the Azores, two distinct yet complementary types of benthic apparatus were deployed to tackle the question of the timing of reproduction in the vent mussel *Bathymodiolus azoricus*. The first were sediment traps of the type used previously during the EU-funded MARVEL cruise in August and September 1997 to trap settlement stage (prodissoconch II) larvae of *B. azoricus* at the Rainbow and Menez Gwen vent sites (Comtet *et al.*, 1998). The second were acoustically retrievable cages described recently in IR news. Something of a

mystery surrounds the reproductive behaviour of this dominant vent species since cruise collected samples have so far failed to yield any evidence of significant gonad development, which contrasts with expectations based on the belief that vents are aseasonal and therefore able to provide a virtually unlimited food supply for the indigenous vent fauna (from bacterial chemosynthesis). Thus, given the high abundance of the species, particularly in the Azores region, the reproductive behaviour of the Atlantic mussel remains something of an enigma. One supplementary aim of the EU-funded VENTOX cage study was to sample mussels outside the usual

cruise period, which is limited by the summer weather window, so that their gonad condition during the winter months could be assessed using histological methods.

### **Sediment traps**

As part of the ATOS cruise objectives, measurements were carried out of particulate and biological fluxes produced at two hydrothermal sites (Rainbow and Lucky Strike) located within the MAR segment. The experiment consisted of mooring two sediment traps (1 m<sup>2</sup>) close to the vents for 1 year's duration in order to follow the fluctuations in the frequency of mussel larval settlement and general particulate emis-



sions close to these two hydrothermal sources. A third sediment trap was deployed at a distance away from any hydrothermal source to obtain a measurement of the background pelagic flux to use as a reference for the Azores region. As with the cages, the design of the sediment traps was modified to facilitate deployment using the French ROV Victor 6000. Each trap unit (Fig. 1) consists of a PPS5 trap (©Technicap) modified by the addition of 7 syntactic foam floats (©Euroshore). The dimensions of each trap are: 215 cm height and 205 cm in diameter. The weight in air is 446kg with a positive buoyancy of 144kg. An acoustic release (Posidonia type) which can be located by the ROV navigation, is attached to the frame. A surface location system, consisting of an Argos beacon, flasher and radio beacons, was also fixed to the top of the trap to aid recovery.

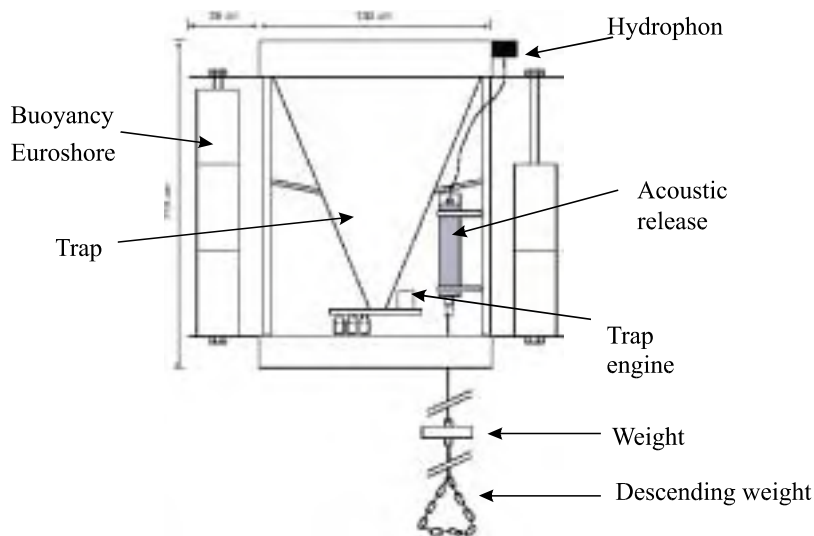
The two vent-located traps were deployed close to the F5 marker at Rainbow and Sintra at Lucky Strike, respectively. The position of the reference pelagic trap was N36° 13.30, W 33° 52.7. The Portuguese *R/V Arquipélago* is scheduled to recover all three traps in summer 2002.

### Mytilid reproduction

In common with other mytilids, *B. azoricus* lacks a true gonad and produces gametes in a fleshy multi-purpose tissue, the mantle, which lines the shell valves (Fig. 2). In other mytilids, apart from acting as a gonad, this tissue is also used to store food reserves (lipid and glycogen) outside the breeding season, which are then used for the manufacture of gametes later in the year. The sexes are normally separate in mytilids. In the best-studied mytilid species, the blue mussel *Mytilus edulis*, by the time that spawning takes place, in the spring, the mantle tissues are completely transformed into mature gamete, sperms or oocytes, with very little or no evidence of any storage tissue (viz. adipogranular cells) remaining. The fact that gamete mother cells are produced *de novo* each season is another reason why the mantle is considered not to be a true gonad; unlike the situation in mammals where in females a finite number of oocytes is laid down at the embryo stage. Taken together this alternating pattern of tissue activity in the mantle underpins a *seasonal reproductive cycle*, something that is typ-

ical of species living in environments where food supply and/or other environmental factors vary markedly over the year, something that is not normally associated with hydrothermal vents.

In common with *M. edulis*, *B. azoricus* undoubtedly produces vast numbers of gametes that are released prior to fertilisation into the vent plankton (Fig. 2). However, examination of several hundred adult mussels during three EU-funded summer cruises (MARVEL, PICO and ATOS) failed to reveal any evidence of ripe or, for that matter, discernible gametes in mantle squashes (D. Dixon, unpublished data,) which conflicts with the expected pattern if the Atlantic vent mussels were spawning continuously (at least at the population level; Tyler and Young, 1999). A previous sediment trap study revealed that larval settlement occurred between 24 August and 5 September 1997 (Comtet *et al.*, 1999). Loading a proportion of the collecting buckets with a special high salt buffer allowed DNA confirmation of the identity of these larvae (Dixon & Dixon, 1998; Comtet *et al.*, 1999). Previous histological evidence also points to episodic spawning behaviour in *B. azoricus* (Comtet & Desbruyères, 1999). Clearly, this contrasts with our expectations for a species living in a supposedly aseasonal deep-sea vent environment, which is the reason why our aim now is to accumulate additional histological evidence of gonad condition in the winter period using the acoustically retrievable cages and sediment traps. The cage study will focus in particular on the winter period when there is an expectation that a high proportion of individuals will contain developing and/or ripe gametes. Tissue samples from the recent ATOS cruise and follow-up cage recovery study are currently undergoing histological analysis and these have provided additional supporting evidence of a seasonal reproductive cycle in this species (Dixon, Lowe, Villemin & Dixon, in preparation). The close-



**Figure 1.** Diagram showing the design of the sediment trap described in this article.

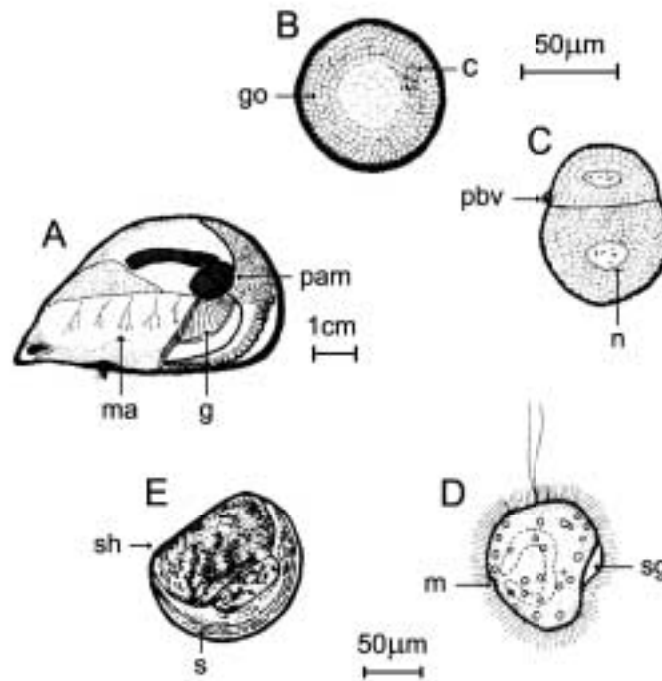
International Research: **Biological Studies:** Dixon *et al.*, cont...

ly related *Bathymodiolus thermophilus* from Pacific vents appears to exhibit continuous reproduction, with a range of reproductive stages being present in the gonadal tissues between May and December (Maria Baker, SOC, pers. com.).

### What is the reason for this apparent seasonality?

It remains to be seen which ecological driver is responsible for the unexpected occurrence of seasonal reproduction in *B. azoricus*, but a likely candidate is the need for a particulate food supply during the larval dispersal phase. While the nutrition of the adult mussel appears fully catered for by the sulphide and methane in the vent emissions, its planktotrophic mussel larvae require a dependable source of particulate organic material to sustain them during the weeks or months while they are dispersing as part of the plankton (Fig. 2). Since the surface waters over the MAR are generally considered to be oligotrophic, it seems likely that the survival of these microscopic larvae will depend to a large extent on the small but nonetheless significant peak in primary production that takes place in the surface waters over the ridge in the early spring (Fig. 3). It is our belief that it is only those larvae that are released around the time of this spring peak that stand any chance of completing their larval development and thus successfully recruiting back into the adult populations. Natural selection acting through the larval phase (something that tends to be treated as a black box in ecological and evolutionary studies) is likely to be the reason why reproductive periodicity has been selected for in at least one dominant MAR vent species, *B. azoricus*.

Previous work on seasonal reproduction in the deep sea has emphasised the role of phytodetritus on the feeding energetics of deep-sea benthic organisms, resulting in the synchronisation of reproductive activity (*e.g.* Tyler *et al.*, 1982). It has



**Figure 2.** Basic mytilid life-history pattern proposed for *Bathymodiolus azoricus*.

This consists of a sedentary adult phase (A), external fertilisation (B), planktotrophic development (C), appearing in this case to be dependent upon the spring bloom in primary production, and larval settlement (D) shown to take place in the summer months leading to clearly recognisable adult size/age cohorts, evidence of a discontinuous recruitment pattern (Van Dover *et al.*, 1996; Comtet & Desbruyères, 1998).

already been demonstrated that surface-derived particulate matter reaches the vent environment on the MAR (Dixon *et al.*, 1995), and there remains the possibility that qualitative differences in the nutritional content of this photosynthetic versus the locally-produced, chemosynthetic-derived food source could provide the signal that ensures the synchronisation of reproductive development in the adult populations. Other evidence also suggests that surface-derived materials can enter the deep-sea vent environment, sometimes in a largely unmodified form (Fileman *et al.*, 1998). Interestingly, in the Pacific (EPR) where Maria Baker conducted her studies on *B. thermophilus*, there is no evidence for a marked, seasonal peak in phytodetrital flux, which probably explains the lack of reproductive synchrony in this species (M. Baker, pers. com.)

This proposed link between the reproductive behaviour of a dominant MAR vent organism and fluctuations in the levels of primary production in the surface waters conflicts with the commonly stated belief that hydrothermal vents are an isolated, self-contained environment, which was thought to be largely independent of processes going on elsewhere in the rest of the ocean. The existence of seasonal reproduction, if confirmed, in at least one dominant member of the Atlantic vent fauna, will force us to reconsider how we view metazoan life in these islands of chemosynthetic productivity in the deep ocean. Clearly, while vent bacteria may tell us something about life on Mars, vent metazoans have their feet (byssus!) firmly anchored here on Earth!

It is intended to deploy the cages again this summer (2002) in collaboration with colleagues at IMAR/



International Research: **Biological Studies:** Dixon *et al*, cont...

DOP and other Portuguese laboratories. The plan is to recover them at intervals into the next winter period, something that can only be achieved using a small vessel, *R/V Arquipélago*, operating opportunistically out of Horta with respect to the mid Atlantic winter weather conditions.

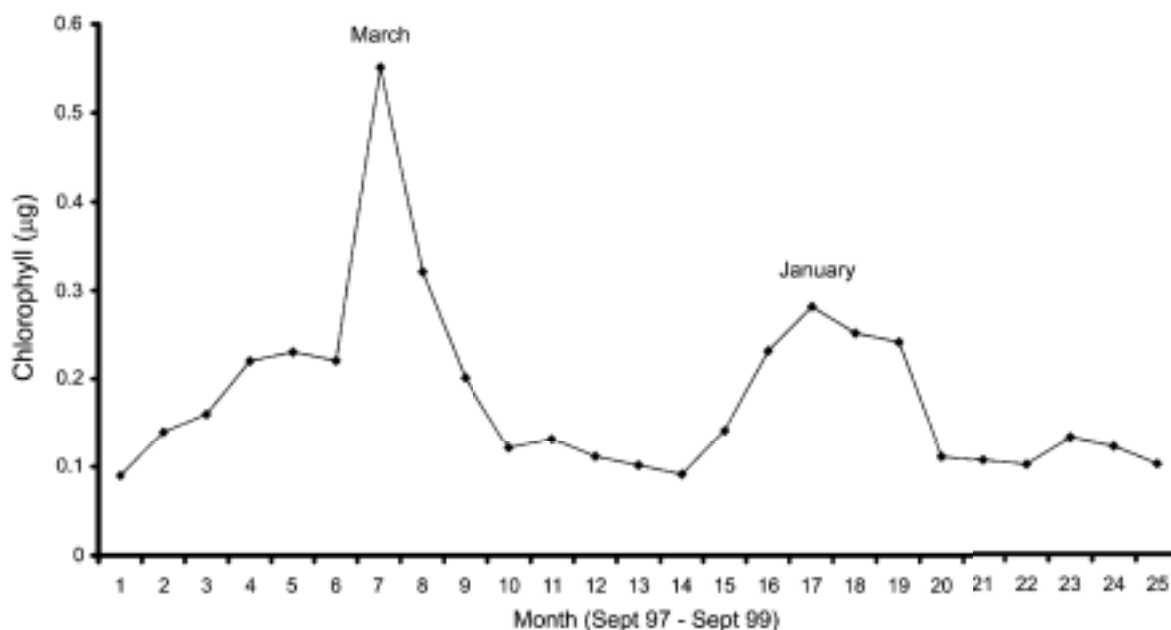
#### Acknowledgements

We are extremely grateful to Simon Partridge (Sonardyne International Ltd.) for generously offering to provide acoustic releases for this summer's cage study. This work represents part of the research programme of the EU-funded VENTOX project (EVK3CT1999-00003) and is funded in part by the UK Natural Environment Research Council. We are also extremely grateful for funds provided previously by the EU AMORES project (MAS3-CT95-0040; co-ordinator Dr Daniel Desbruyères). Finally, we wish to express our grateful thanks to the Cap-

tains and crews of the *R/Vl'Atalante* and the *R/V Arquipélago*, and to the pilots and technicians of ROV Victor, without whom none of this work would have been possible.

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**Figure 3.** Monthly chlorophyll levels in the surface waters above the mid-Atlantic Ridge at 37°N 31°W derived from satellite imagery (data supplied by Prof. Robin Pingree, University of Plymouth). It is clear that in the two years, Sept 1997-Sept 1999, there was a peak in primary production in the surface waters in the early spring that exceeded the winter background levels by between three and six-fold.

## Submarine Hydrothermal Mineralisations and Fluids off the Lesser Antilles Island Arc – Initial Results from the CARIBFLUX Cruise SO 154

P. Halbach<sup>1</sup>, H. Marbler<sup>1</sup>, D.S. Cronan<sup>2</sup>, A. Koschinsky<sup>1</sup>, E. Rahders<sup>1</sup> and R. Seifert<sup>3</sup>

<sup>1</sup> Freie University of Berlin, Department Geochemistry, Hydrogeology, Mineralogy, Berlin, Germany

<sup>2</sup> T.H. School of Environment, Earth Sci. and Eng., Imperial College of Sci., Tech. and Med., London, UK

<sup>3</sup> University of Hamburg, Institute of Biogeochemistry and Marine Chemistry, Hamburg, German

### Introduction

In comparison with other island arcs such as those in the Mediterranean Sea and SW Pacific, there have been only few studies of submarine hydrothermal mineralisations in the Caribbean island arcs. Kang (1984) described some hydrothermal manganese deposits from the region and Polyak *et al.* (1992) reported on a hydrothermal water column anomaly between Montserrat and Guadeloupe. More recently, Johnson & Cronan (2001) have reported considerable metal enrichments in hydrothermal fluids and metalliferous sediments off the central Lesser Antilles volcanic arc. The elements variably enriched in the fluids as a result of the hydrothermal activity are Fe, Mn, As, Si, B, Li and in the sediments are Fe, P, Mo, As, Sb, Hg, Cu and Pb. Variations in the concentrations of these elements in both fluids and sediments along the arc were thought to result from a number of factors, the most important of which is the stage that each island's volcano has reached in its eruptive cycle.

In order to investigate submarine hydrothermal mineralisation off the Lesser Antilles in more detail, a research cruise (CARIBFLUX) was carried out from January 15 to February 8, 2001, with the German research vessel "R/V Sonne" (SO 154). The main objectives of this cruise were to carry out measurements and water sampling in the water column and the near-bottom water layer as well as the study of local tectonics and the recovery of hard rock and sed-

iment samples to look for indications of recent to subrecent submarine hydrothermal activity in the area of the Lesser Antilles island arc. The western slope of the arc was selected as the main target area since this area has many nearshore shallow water thermal springs (Johnson and

Cronan, 2001).

Major target areas were the Kahouanne Basin and the Montserrat Ridge S and SW of the island of Montserrat, the area W of Dominica, St. Lucia and the Kick'em Jenny submarine volcano NW of Grenada (Fig. 1).

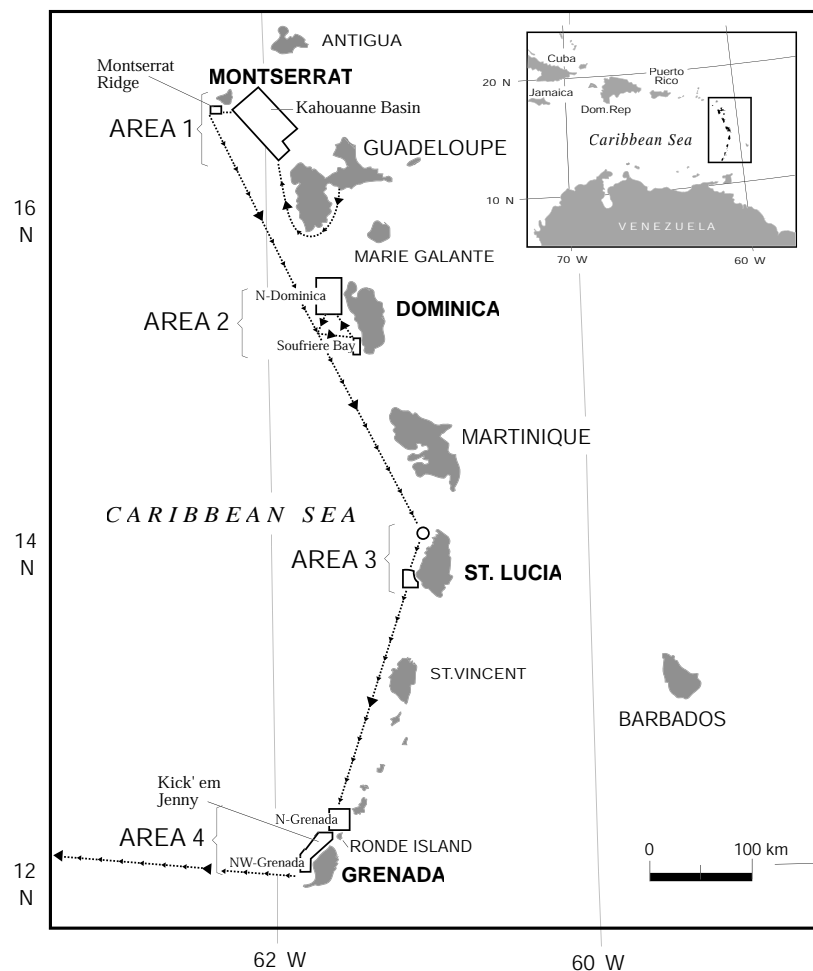


Figure 1. Map of the Lesser Antilles with cruise track and target areas.

### Kahouanne Basin

Sample locations in the deepest part of the Kahouanne Basin and close to the Shoe-Rock-Spur (SRS) fault zone (western margin of the basin) were chosen. Methane concentrations in water samples in that area were generally below  $3.5 \text{ nmol l}^{-1}$ , and values exceeding  $1.5 \text{ nmol l}^{-1}$  were restricted to the upper 400 m of the water column. Anomalous Zn concentrations in the lower water column (earlier described by Polyak *et al.*, 1992) could not be confirmed.

Sediments contained a few pyrite and chalcopyrite grains, rarely nontronite was found in the southern Kahouanne Basin, and in one dredge haul Mn-crusts of thicknesses up to 6 cm were sampled. This pointed to subrecent hydrothermal activity in this region: further dredge sampling led to the discovery of an inactive hydrothermal site on a small plateau in the upper part of the SRS fault zone. These observations and samplings suggest that a young massive sulphide deposit may exist beneath the sea floor. The post-cruise detailed geochemical and mineralogical studies of the manganese crusts, the nontronite samples and the gossan fragments support this in certain respects (*e.g.* high Pb-values in certain Mn-oxide-layers of the crusts).

The nontronite fragments are of dark greenish to orange/reddish colour (in the upper oxidised part) with thicknesses up to 10 cm. Beside the predominant iron clay mineral nontronite occur illite, muscovite and small amounts of calcite. The content of total Fe (bulk) is up to 18 wt.% with depleted Mg, Ca and Al contents.

In the "gossan" fragments the values of total Fe reaches 17 wt.%. The Mn contents are up to 6.5 wt.%, which is relatively high for this type of rocks. Values of trace metals including Ni, Pb, Zn and V are relatively low and range from 160 up to 300 ppm. The mineral composition of these samples includes iron minerals such as goethite (also a small amount of hematite), nontronite,

aragonite and a low content of quartz and manganese oxides. No secondary Cu or Pb minerals were determined.

### Montserrat Ridge

At the Montserrat Ridge, again no clear indications of present hydrothermal activity were found in the water column. Hydrothermal Mn crusts up to 27 cm thickness were dredged, and Mn-cemented ashes are abundant along the ridge. The crusts from the Montserrat Ridge are unique and are described here for the first time from this part of the Lesser Antilles Island arc. They might have the function of a cap rock above a sulphide deposit.

Within the Mn crusts massive layers occur which show very heterogeneous mineralogical compositions. Manganese minerals including todorokite, birnessite and psilomelane occur as thin layers (up to 7 mm) alternating with layers (up to 2.5 cm) of light calcitic and aragonitic sediments and layers of sediments (up to 1.5 cm) with a manganese cement in the outer parts. Within the

crusts appear metasomatic replacements of the limestone, including abundant fossil shells as well as irregular enrichments of nontronite and other clay minerals. The Mn contents for single layers can reach 55 wt.%. The Mn/Fe ratio is very high (up to 118) suggesting little or no input from normal seawater. The contents of most trace metals (Ni, Zn, Pb and Co) are very low (Table 1) and the concentrations of the rare earth elements are less than 10 ppm. The outer layers and some internal layers of the crusts with distinct petrographical and geochemical compositions indicate that the crusts precipitated from distinct hydrothermal episodes and are not a product of continuous deposition.

### West of Dominica

Near-shore investigations of Soufriere Bay at the southern tip of Dominica showed that a supposed water-covered continuation of a hydrothermally active caldera, which occurs on land, does not exist. Off NW Dominica, five seamounts were investigated. The older ones are

**Table 1.** Chemical composition of manganese crusts

sample		18cd	52cd-a	52cd-b	83cd
<b>W.depth</b>	m	1144	950	950	1252
<b>Fe</b>	wt%	5,15	0,64	3,82	8,15
<b>Mn</b>	wt%	40,8	55,3	29	23,6
<b>Al<sub>2</sub>O<sub>3</sub></b>	wt%	5,76	1,98	2,44	8,3
<b>MgO</b>	wt%	1,58	3,42	3,23	3,95
<b>CaO</b>	wt%	2,15	6,7	7,67	6,07
<b>Cr</b>	ppm	9	13	4	19
<b>Cu</b>	ppm	59	114	149	226
<b>Ni</b>	ppm	57	308	714	657
<b>Zn</b>	ppm	53	197	271	298
<b>Ti</b>	ppm	864	457	1140	1830
<b>Co</b>	ppm	21	26	345	67
<b>Mo</b>	ppm	53	360	317	350
<b>Li</b>	ppm	17	66	-	250
<b>Pb</b>	ppm	140	11	1420	9

**Sample description.** **18cd:** manganese cemented sediments (Kahouanne Basin); **52cd:** massive crust, **-a:** inner Mn oxide-layer, **-b:** outer Mn oxide-layer (Montserrat Ridge); **83cd:** incrustation of volcanic rock (north of Dominica). Data from XRD and ICP-OES

International Research: Island arc/BAB: Halbach *et al.*, cont...

covered by Mn-oxides, and brecciated material often contained barite. Of particular interest are andesitic breccias cemented by hydrothermal manganese-oxyhydroxides. Methane concentrations in the water column were below  $3.0 \text{ nmol l}^{-1}$ , with highest concentrations in the biologically influenced upper water body, while in deeper water  $1 \text{ nmol l}^{-1}$  was not surpassed. However, further water analyses indicated local enrichments of reduced Cr species and Zn, which may indicate hydrothermal contributions. The highly sensitive determination of Cr species has been shown to be an effective means to trace hydrothermal sources (Sander and Koschinsky, 2000) because the hydrothermal Cr(III) signal is stable in the water column. However, the various measurements revealed a strong variability, probably caused by strong local variabilities in oceanographic parameters and possibly several small hydrothermal sources. As hot springs are known to exist along the coast and offshore Dominica (John-

son and Cronan, 2001), we assume that the signals we identified are derived from various fluid sources at different water depths off Dominica.

#### West of St. Lucia

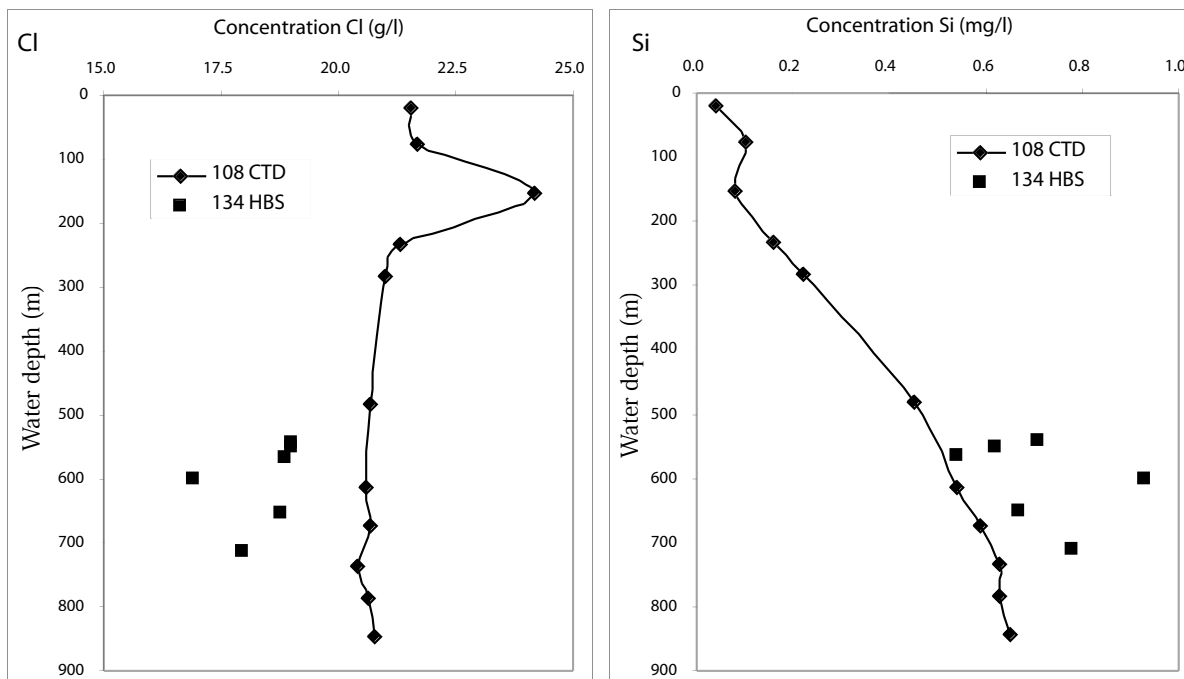
Enhanced methane concentrations up to  $13.8 \text{ nmol l}^{-1}$  were found in the St. Lucia Bay at water depths between 50 and 100 m. Methane data correlate with a similar depth profile of Cr(III) and a maximum of Cr(III) at the same depth. This input of reducing waters can probably be related to the hydrothermal springs at the coast of the bay. No hydrothermal solid samples were recovered.

#### Kick'em Jenny

Enrichments of reduced Cr species and of zinc were identified in many water column profiles throughout the area; these enrichments mostly coincide with maxima of methane and can be attributed to the influence of submarine hydrothermal springs. The valley south of the volcano contains small, step-like normal faults. Fluids with methane

contents about 5-fold the background concentration (about  $14 \text{ nmol l}^{-1}$  compared to  $2\text{--}3 \text{ nmol l}^{-1}$ ) as well as positive anomalies of Zn (up to  $120 \text{ nmol l}^{-1}$  in unfiltered samples) were discovered in about 600 m water depth, indicating that low-temperature hydrothermal fluids are emanating from the faults. High resolutions of the CTD sensor profiles revealed small negative salinity anomalies at various depths; however, temperature anomalies could not be identified clearly.

Unfortunately, we had no permission to sample the crater of the volcano. Six water samples were taken directly at the seafloor on the flanks of the volcano with the Hydro Bottom Station (HBS) which is an instrument especially designed to sample diffuse hydrothermal fluids (Halbach *et al.*, 2001). These samples showed increased concentrations of Si (up to  $33 \text{ } \mu\text{mol l}^{-1}$  compared to a background of  $18 \text{ } \mu\text{mol l}^{-1}$ ), methane (up to  $22 \text{ nmol l}^{-1}$ ), and of several trace metals such as Zn, Cu and Ni. There is a significant deple-



**Figure 2.** Chloride and silica concentrations in the water column profile of station 108 CTD and in the bottom water samples of station 134 HBS at the southern flank of the Kick'em Jenny submarine volcano.

International Research: Island arc/BAB: Halbach *et al.*, cont...

tion in Cl ( $0.48 \text{ mol l}^{-1}$  compared to the background of  $0.59 \text{ mol l}^{-1}$ ), sulphate, Na, K and Mg compared to the ambient bottom water. Very small chemical signals were also visible in the water column profiles at this depth range (Fig. 2). As mixing of seawater with meteoric water can largely be excluded, the reduced chlorinity of the samples may indicate boiling and phase separation in the subseafloor. Boiling in hydrothermal systems produces a vapor phase that is enriched in gases but depleted in chloride and metal ions and a brine phase that is highly saline and metal-rich (*e.g.*, Butterfield *et al.*, 1990). Accordingly, our samples would represent a condensed vapor phase. Measurements of stable isotopes support this theory.

### Discussion

Although hydrothermal mineralisation on the sea floor close to the islands is only low grade, it is hypothesised that phase separation in the hydrothermal fluids at depth could be leading to higher grade mineralisation below the vent fields or the discharge of metal rich brines on the lower flanks of the volcanic islands.

The widespread occurrence of manganese precipitates on the western side of the Lesser Antilles shows that a fractionation process producing low-temperature hydrothermal solutions enriched in manganese has taken place possibly at more or less the same geological time throughout the study area. Additional work on the manganese crusts has shown that ferromanganese precipitation took place along faults and fractures and on ridges, and was promoted by the mixing of modified sea water (in a small amount) with hydrothermal fluid. The very low trace metal concentrations lead to the conclusion, that the mineralising fluid was mainly of hydrothermal origin. In the ternary diagram after Usui *et al.*, 1992 (Fig. 3a) it is shown that due to the low concentration of Ni, Cu and Zn, most of the analysed samples plot in the hydrothermal

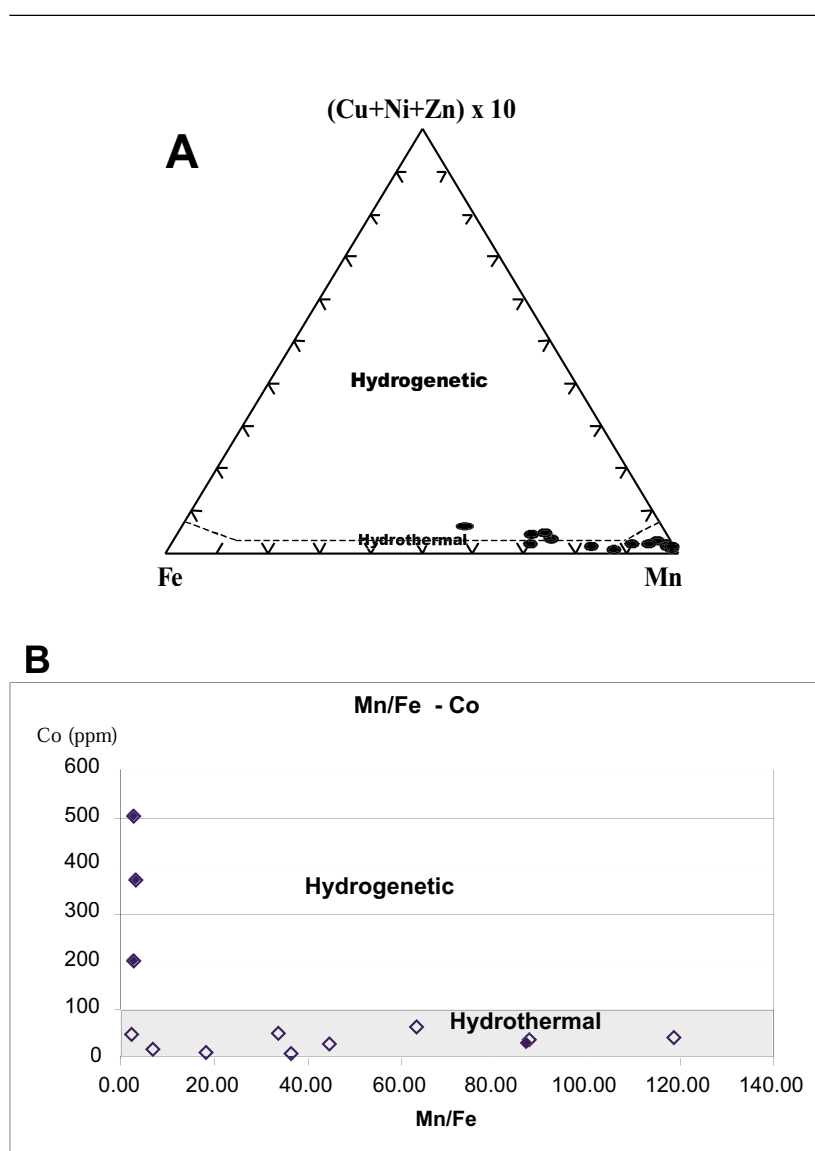
field. The diagram Mn/Fe vs. Co demonstrates that the hydrothermal samples are characterised by high Mn/Fe ratios and low Co concentrations (Fig. 3b); the three samples with higher Co concentrations indicate enhanced hydrogenetic input.

Because of the wide distribution of the manganese mineralisation in certain areas, it is thought to have been controlled by both focussed and diffuse hydrothermal flow. An additional but less important mechanism of mineralisation is a diagenetic remobilisation and concentra-

tion of manganese by pore fluid in the unconsolidated sediment.

It is clear from the above that the two main indicators of submarine hydrothermal activity in the region as a whole are manganese crusts and water column anomalies.

Other minerals of hydrothermal origin were only recovered between Guadeloupe and Montserrat, namely nontronite and sulphides. The nontronites indicate low-temperature hydrothermal activity whereas pyrite and chalcopyrite indicate higher temperature hydrothermal-



**Figure 3.** Elemental relationships of all Mn oxide samples recovered during cruise SO 154; (A) Ternary Diagram Fe– Mn (Cu+Ni+Zn) x 10 after Usui *et al.* (1992); (B) Co vs. Mn/Fe

International Research: Island arc/BAB: Halbach *et al.*, cont...

ism. Detailed geochemical analyses of the sediments have confirmed the enrichments.


Although the study area off the Lesser Antilles was sampled in detail in all likely hydrothermal locations, no massive sulphides were found on the sea floor. There are indications, however, that they may be present at shallow depth under the sea floor, beneath a cover of gossan or manganese crust. Nevertheless overall hydrothermal activity in the area appears to be less than, for example, in the western Pacific arcs.

#### Acknowledgements

Cruise SO 154 and the project CARIBFLUX (grant no. 03 G 0154) are funded by the German Federal Ministry of Education and Research (Bundesministerium für Bildung und Forschung BMBF). We thank the captain and crew of *R/V Sonne* for the skilled support

during the cruise.

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## Geophysical Experiments in the Mariana Region: Report of the YK01-11 cruise

T. Goto<sup>1</sup>, N. Seama<sup>2</sup>, H. Shiobara<sup>3</sup>, K. Baba<sup>4</sup>, M. Ichiki<sup>1</sup>, H. Iwamoto<sup>2</sup>, T. Matsuno<sup>2</sup>, K. Mochizuki<sup>3</sup>,  
Y. Nogi<sup>5</sup>, S. Oki<sup>3</sup>, K. Schwalenberg<sup>6</sup>, N. Tada<sup>2</sup>, K. Suyehiro<sup>1</sup>, H. Mikada<sup>1</sup>,  
T. Kanazawa<sup>3</sup>, Y. Fukao<sup>3</sup>, and H. Utada<sup>3</sup>

<sup>1</sup>JAMSTEC, 2-15, Natsushima, Yokosuka, Kanagawa 237-0061, Japan.

<sup>2</sup>Department of Earth and Planetary Sciences, Kobe University, Nada 657-8501, Kobe, Japan

<sup>3</sup>Earthquake Research Institute, University of Tokyo, Yayoi 1-1-1, Bunkyo-ku, Tokyo 113-0032, Japan

<sup>4</sup>Woods Hole Oceanographic Institution, Woods Hole, MA, 02543, USA

<sup>5</sup>National Institute of Polar Research, 1-9-10 Kaga, Itabashi, Tokyo 173-8515, Japan

<sup>6</sup>Department of Physics, University of Toronto, 60, St. George Street, Toronto, M5S 1A7, Canada

The Mariana region (Fig. 1), the eastern part of the Philippine Sea, is characterized by several tectonic features. The Mariana Trench is a result of downward going of the subducting Pacific plate. The Mariana Islands and the Mariana Trough are one of the typical island arc and backarc, respectively. The Mariana Trough is a present active backarc basin and the West Mariana Ridge is considered as a remnant island

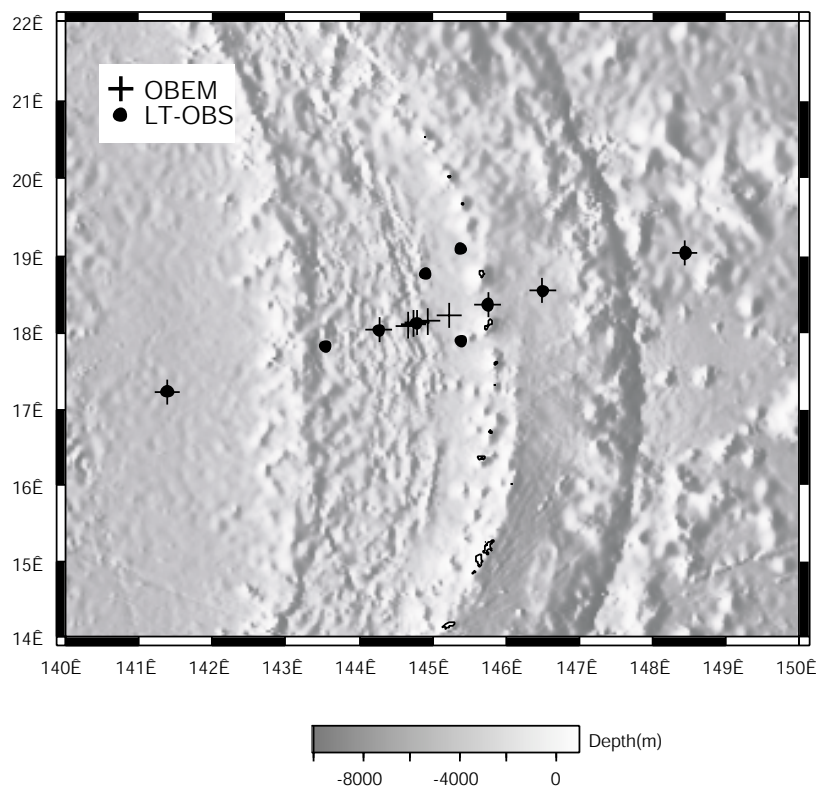
arc. In addition, serpentine seamounts formed by upwelling serpentine diapir are often found in the forearc area (*e.g.*, Stern and Smoot, 1998). Three upwellings from deep interior of the earth probably exist below this region; the Mariana Islands, Mariana Trough and the serpentine seamounts. These upwellings are related to create various tectonic features in the Mariana region. However, the dynamics of the

ocean bottom and the deep structure beneath this region are still unclear yet.

We conducted the YK01-11 research cruise by *R/V Yokosuka*, JAMSTEC in October 2001 to characterize tectonic features and to obtain a deep and dynamic image of the central Mariana region. Here, we briefly report the geophysical experiments in the YK01-11 cruise;

1) Surface geophysical surveys,





**Figure 1.** OBEM and LT-OBS positions deployed in the YK01-11 cruise. The bathymetry is based on a global database by Sandwell and Smith (1997) and Smith and Sandwell (1997).

- 2) long-term and semi-broadband ocean bottom seismometers (LT-OBSs) observation, and
- 3) ocean bottom electromagnetometers (OBEMs) observation.

Surface geophysical surveys are conducted to characterize the back-arc spreading evolution of the central Mariana Trough (16°N–19°N) and serpentine diapirs in the forearc (Fig. 2). Multi-narrow beam bathymetry, gravity field, and magnetic field data were collected. Gravity field data were obtained from the shipboard gravimeter. Magnetic field data are collected by the ship-towed proton precession magnetometer and the shipboard three-component magnetometers (STCMs: Isezaki, 1986), which can measure the vector of the geomagnetic field. The Mariana region is near the geomagnetic equator and total intensity anomaly amplitudes are often much reduced depending on the orientation of the ambient geomagnetic field and mag-

netic lineation (Isezaki, 1986). Therefore, the vector geomagnetic anomaly field is especially useful to understand its tectonics.

The morphology in the central Mariana Trough shows seven spreading axis segmentations on the basis of the present cruise and previous ones (KH92-1, YK96-13, and YK99-11). The non-transform offsets, that define the ridge segments, can be traced off-axis in the western side. The direction of the spreading fabric in the southern part of this area changes dramatically from NNW-SSE to almost N-S trend; that is interpreted as a result of the change in the spreading direction. Further analysis combined with crustal age and thickness estimations by vector geomagnetic anomaly and gravity data would lead whole tectonic evolution in this area. In addition, the morphologic feature in the forearc region indicates eight cones, and their magnetizations and densi-

ties will be estimated using gravity and geomagnetic anomalies. The results would lead to the sizes and the characters of the serpentine diapirs, which help us to understand the mechanism of their formation in the forearc region.

Ten LT-OBSs were deployed to investigate the image of deep structure beneath the Mariana trough, how the Pacific plate slab is subducting and stagnant. In addition, this seismic observation has a role of the feasibility study to know the deep seismic activity of this area, which has not been determined by on-land seismic observation networks. For this purpose, three of LT-OBSs (Fig. 1) are located off the main profile to surround the seismically active area where 600 km deep events are detected by a global seismic network. The LT-OBSs will be recovered in the winter of 2002 FY.

Electrical conductivity in the mantle depends on its temperature and/or existence of melts, so that the conductivity structure is useful to image a hot mantle material, upwelling regions, and a cold subducting plate. Therefore, ten ocean bottom electromagnetometers (OBEMs) were deployed in a line across the whole Mariana region through the Pacific plate, the trench, the arc and the backarc area (Fig. 1) to reveal regional and mantle conductivity structure. The deep conductivity structure beneath the slow spreading axis of the Mariana Trough is focused on intensively in this study, so that four of OBEMs are located within 15 km width from the spreading axis. These OBEMs will be recovered in the October of 2002.

Synthetic calculations of electromagnetic (EM) field on a priori models are carried out in order to know how the EM measurements by OBEMs are sensitive to a deep conductivity structure below the Mariana region. We calculated time variation of sea-floor electric and magnetic fields at arbitrary periods on several 2-dimensional conductivity models, and discussed a ratio and a phase difference between the elec-

International Research: Island arc/BAB: Goto *et al.*, cont...

tric and the magnetic fields. The calculation results indicate several important features:

- 1) A high conductive mantle wedge at the depth of 15 - 80 km will be well constrained by EM responses at the period of 100 - 5000 sec.
- 2) A high conductive zone below the Mariana Trough at the depth of 10 - 80 km will be also imaged by EM responses at the period of 100 - 1000 sec.
- 3) The effect of the subducting slab deeper than 100 km depth is not large, but it can be observed at the period greater than 5000 sec. The synthetic calculations encourage our OBEMs observation.

These geophysical surveys also have a role of pilot observation for later Japan-US international cooperative seismic and electromagnetic experiments planned in 2002-2005. Results of the surface geophysical mapping in the YK01-11 cruise will give us a model of an undergoing


tectonic process in the Mariana Trough. The deep seismic activity will help to design future seismic observation networks by dense broadband ocean bottom seismometers. Our seismic and electromagnetic experiments will give a coarse structural image of the upper mantle in the Mariana region, which is a first step to get further detailed images of the upper mantle, such as possible plumes beneath the trough, and the Pacific plate as subducting and stagnant slab.

#### Acknowledgement

We would like to thank Captain O. Yukawa, the officers and the crew of *R/V Yokosuka* for their careful consideration for the ship and on-board operation. We discussed scientific targets with S. Kodaira, JAMSTEC. T. Kodera, S. Hosoya and Y. Maezawa, Nippon Marine Enterprises Ltd., compiled the obtained bathymetric data on board. M. Shinohara,

T. Yamada, K. Nakahigashi of Earthquake Research Institute, Univ. Tokyo, helped us to prepare LT-OBSs. H. Shimizu, T. Koyama and S. Asari of Earthquake Research Institute, Univ. Tokyo, assisted with assembling of the OBEMs. R. Evans, J. Bailey, and A. D. Chave of WHOI helped us to make electrodes for all the OBEMs. N. Isezaki of Chiba University kindly allows us to use his STCM system. T. Yamazaki of AIST and Y. Kido of JAMSTEC provide information on previous surface geophysical data. Figures are made with GMT software developed by Wessel, P. and W. H. F. Smith.

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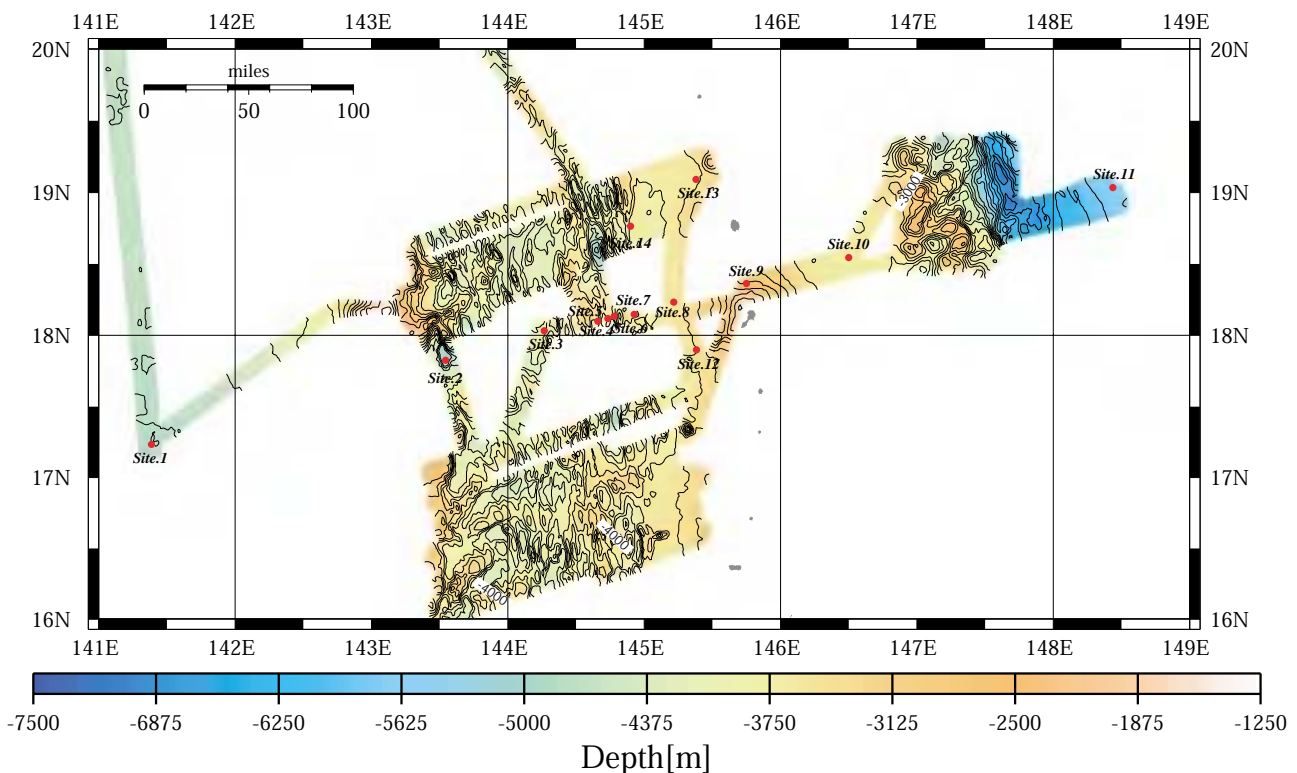


Figure 2. Bathymetric map obtained in the YK01-11 cruise.



## How back-arc basins evolved: tholeiite associations in the Kudi ophiolite of western Kunlun Mountains, northwestern China

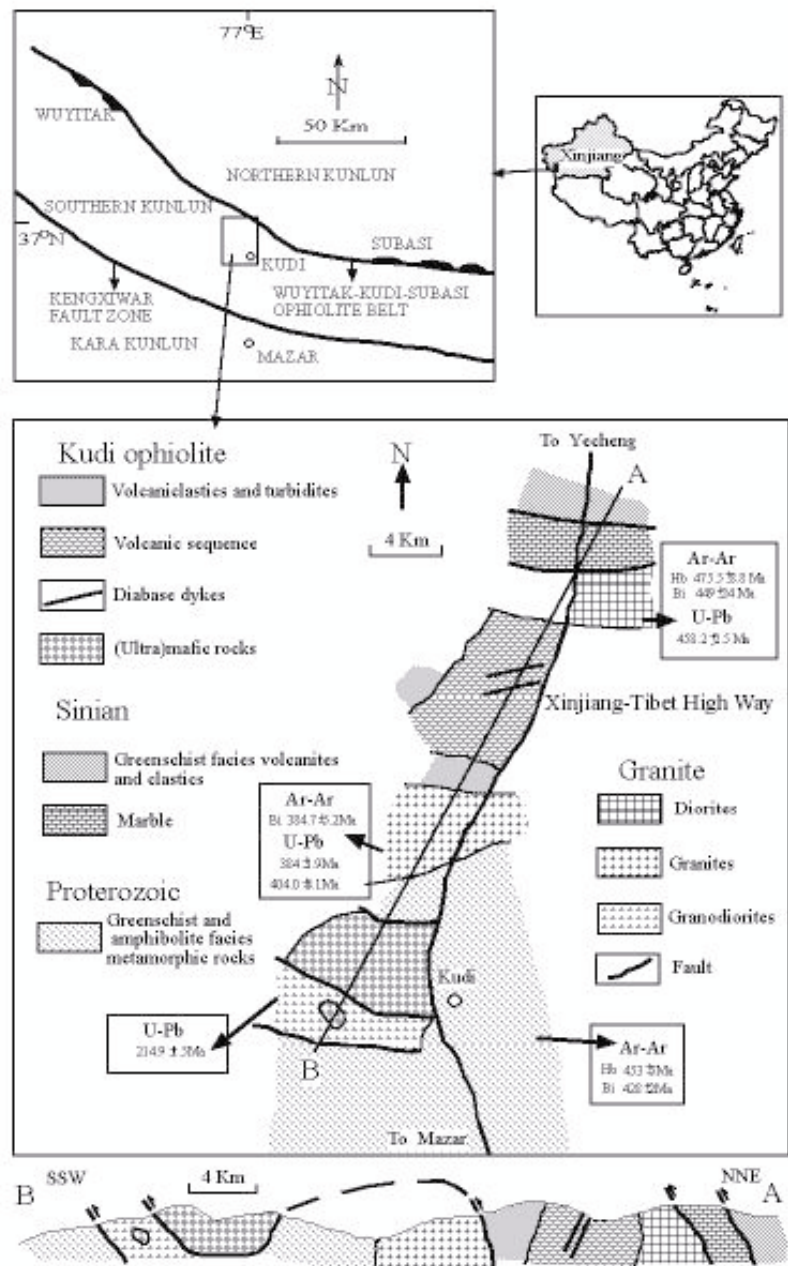
Wang Zhihong

Laboratory of Lithosphere Tectonic Evolution, Inst. of Geol. and Geoph., Chinese Acad. of Sci., Beijing, China

### Introduction and geological setting

The Kudi ophiolite, situated in the northwest segment of the western Kunlun orogenic belts, northwestern China (Fig. 1), is one of the well-preserved ophiolite sequences in the Kunlun Mountains. The origin and tectonic implications for the Kudi ophiolite have been previously discussed (Jiang *et al.*, 1992; Deng, 1995; Mattern *et al.*, 1996). Recent studies have reached a consensus view that the ophiolite was formed in a SSZ setting (Wang *et al.*, 2001). The aim of this paper is to constrain tectonic and magmatic events of this SSZ ophiolite by detailed geochemistry and by comparing them with volcanic suites from modern western Pacific arc-basin systems. And furthermore, we present a model of evolution of a back-arc basin to enhance the understanding of tectonic implications of the tholeiite associations.

The Kunlun Mountains are composed of orogenic belts, in which several ophiolite belts are exposed and regarded as suture zones between blocks (*e.g.*, Jiang *et al.*, 1992). Two major tectonic fault belts in the western Kunlun Mountains, the Wuyitak-Kudi-Subasi ophiolite belt and Kengxiwar fault zone, separate the northern Kunlun, southern Kunlun and Kara-Kunlun respectively (Fig. 1). Detailed description of these three blocks and the Kengxiwar fault zone can be found in related references (*e.g.*, Jiang *et al.*, 1992; Mattern *et al.*, 1996). There are four main lithological and tectonic units in the studied area: Proterozoic metamorphic rocks, Sinian metavolcanites and marbles, granitoids in different ages and the late Proterozoic-early Paleozoic Kudi ophiolite (Fig. 1).



**Figure 1.** Geological map and cross-section of the Kudi area along the Xinjiang-Tibet highway based on our field observations and mapping. The isotopic ages are discussed in the text.

## International Research: Ophiolites: Zhihong, cont...

### The Kudi ophiolite

The Kudi ophiolite is composed of a series of oceanic crustal and mantle fragments, including mafic and ultramafic rocks, volcanic rocks, the mafic dikes within the volcanic rocks and volcanoclastic flysch sediments and turbidites overlying on the volcanic sequence. The lithologic units of the mafic and ultramafic blocks are mainly harzburgites, dunites, cumulate dunites and pyroxenites, and cumulate and massive gabbros which overlain on the ultramafic rocks. Slightly serpentinized harzburgites and dunites were intruded by pegmatitic dikes of pyroxenite and gabbro. The volcanic and volcanoclastic rocks of the Kudi ophiolite are well-exposed in the north, and can be divided into three parts according to their lithological characteristics: (1) the first part is mainly composed of massive and pillow basalts intruded by diabase dikes; (2) the second part is characterized by amygdaloidal, massive basalts interlayered with andesitic basalts and tuffites; and (3) the third part is mainly composed of volcanoclastic flysch sediments, which contain basic volcanic lithic components with plagioclase phenocrysts (Mattern *et al.*, 1996), and turbidites with Bouma sequences. Most researchers favor formation of the ophiolite in the late Proterozoic-early Palaeozoic (*e.g.*, Deng, 1995; Mattern *et al.*, 1996).

### Petrology and mineralogy

The mantle peridotites from the Kudi ophiolite are mainly harzburgites with minor dunites. The harzburgites consists of olivine (Fo=90.9-91.7, 50-90 modal%), Cr-spinel (<5%) and orthopyroxene (En=90.3-91.9, 5-40%) with exsolution lamellae of diopside and augite (En=48.7-53.3). Serpentinization is weak (generally less than 10 modal %). The dunite consists of olivine (Fo=90.3-90.5, about 95%), orthopyroxene (En=91.5-92.2, <5%) and Cr-spinel. The Cr-spinels in the Kudi mantle peridotites have high Cr number (Cr#=100Cr/(Cr+Al)=60-67), and are

of the III-type peridotite proposed by Dick and Bullen, indicating that the highly depleted mantle peridotites are of arc-related petrogenesis and formed in an environment associated with a subduction zone. The pyroxenes in the harzburgites have low Al<sub>2</sub>O<sub>3</sub> contents (1.09-1.79wt%) and low TiO<sub>2</sub> contents (0.01-0.09wt%), suggesting that the harzburgites are residual mantle peridotites after high degrees of partial melting.

The Kudi cumulate complex is composed of pyroxenites and gabbros with minor dunites. The Cr# and Mg# of spinels in the cumulate dunites are in the range of 49.1-52.8 and 43.5-46.6 respectively. In the Cr#-Mg# diagram, the spinels in the dunites plot near the back-arc basin field. The pyroxenite is composed of mainly clinopyroxene (60-80%) and orthopyroxene (<30%), and most primary minerals have been partly to completely replaced by amphibole and chlorite. The gabbro mainly consists of plagioclase (40-60%) and pyroxene (20-40%) with minor magnetite, and most fresh pyroxene is clinopyroxene. Amphibolitization and chloritization also occur in the gabbros.

The Kudi diabases crop out as isolated dikes or as dike swarms. They are composed of plagioclase, pyroxene and minor olivine. Some primary pyroxenes have been replaced by amphibole and chlorite, while some plagioclases replaced by chlorite and epidote. Calcite veins occur locally. Massive basalts have diabasic textures and are mainly composed of pyroxene and plagioclase. Pillow basalts are fine-grained and also composed of pyroxene and plagioclase. Primary minerals in massive and pillow basalts are generally replaced by chlorite and epidote. Amygdaloids of amygdaloidal basalts are mainly filled with chlorite and fine-grained felsic minerals. Chloritization and epidotization are also common in these rocks.

### Geochemistry

The Kudi mantle peridotites have high Mg# (91.1-91.9) and are highly

depleted peridotites. The Al<sub>2</sub>O<sub>3</sub> and CaO contents in the rocks are low, 0.62-1.15 wt% and 0.3-0.95wt% respectively. The TiO<sub>2</sub> content of the mantle peridotites varies from 0.003 to 0.014 wt%, lower than those of mid-ocean-ridge mantle rocks (0.1-0.4 wt%) and similar to those of mantle rocks from ophiolites formed in supra-subduction zone environments (<0.1 wt%) (Pearce *et al.*, 1984).

Relative to primitive mantle values, the Kudi mantle peridotites are slightly richer in Th and U (1-10' primitive mantle) and poorer in Ti (0.1-1' primitive mantle). The Kudi mantle peridotites display LREE-enriched chondrite-normalized rare-earth-element patterns with LREE/HREE=3.2-5.6 and (La/Yb)<sub>n</sub>=2.1-3.4 (Wang *et al.*, 2001).

The contents of Al<sub>2</sub>O<sub>3</sub>, CaO, SiO<sub>2</sub> and TiO<sub>2</sub> increase from the mantle peridotites to pyroxenites and to gabbros. The Al<sub>2</sub>O<sub>3</sub>, CaO and FeO\* contents in the pyroxenites have wide ranges, reflecting the variability of pyroxene mode and compositions. The gabbros are high in Al<sub>2</sub>O<sub>3</sub> and low in FeO\*, though both have limited ranges.

Chondrite-normalized trace element patterns for the cumulate pyroxenites and gabbros exhibit marked negative Nb and Ti anomalies (Wang *et al.*, 2001). The pyroxenites have flat REE patterns and the REE concentrations are 1-10' chondrite (Wang *et al.*, 2001). The REE patterns for the gabbros are also flat (Wang *et al.*, 2001).

TiO<sub>2</sub> contents clearly separate the extrusive rocks into three different magmatic suites. Group 1 basalts are characterized by moderate TiO<sub>2</sub> contents (0.8-1 wt%), and group 2 basalts have higher TiO<sub>2</sub> contents (1-1.6 wt%, most of them are higher than 1.1 wt%), while group 3 basalts have lowest TiO<sub>2</sub> contents (0.16-0.38 wt%). The TiO<sub>2</sub> contents of the diabases are similar to that of group 2 basalts.

Group 1 basalts display similar N-MORB normalized trace element patterns with that of the Tofua arc, and more enriched in La and Ce also

International Research: **Ophiolites: Zhihong, cont...**

as shown by their LREE-enriched chondrite-normalized REE patterns (Fig. 2a). On N-MORB normalized trace element patterns, group 2 basalt display marked negative Nb anomalies. Furthermore, these basalts have slightly LREE-depleted or flat chondrite-normalized REE patterns (Fig. 2b). Diabase dikes are similar to group 2 basalts both in trace and rare-earth elements geo-

chemistry (Fig. 2b), as their major elements. Group 3 basalts have low  $\text{TiO}_2$  (0.16-0.38 wt%),  $\text{P}_2\text{O}_5$  (0.01-0.03 wt%), Zr (4-30 ppm) and Y (7-11 ppm); and high Mg (Mg#=62-72) and Cr (300-500 ppm). They display similar N-MORB normalized trace element patterns (low levels of HFSE) with that of the boninites from the Bonin Islands (even more enriched in LILE) and slightly U-shaped or

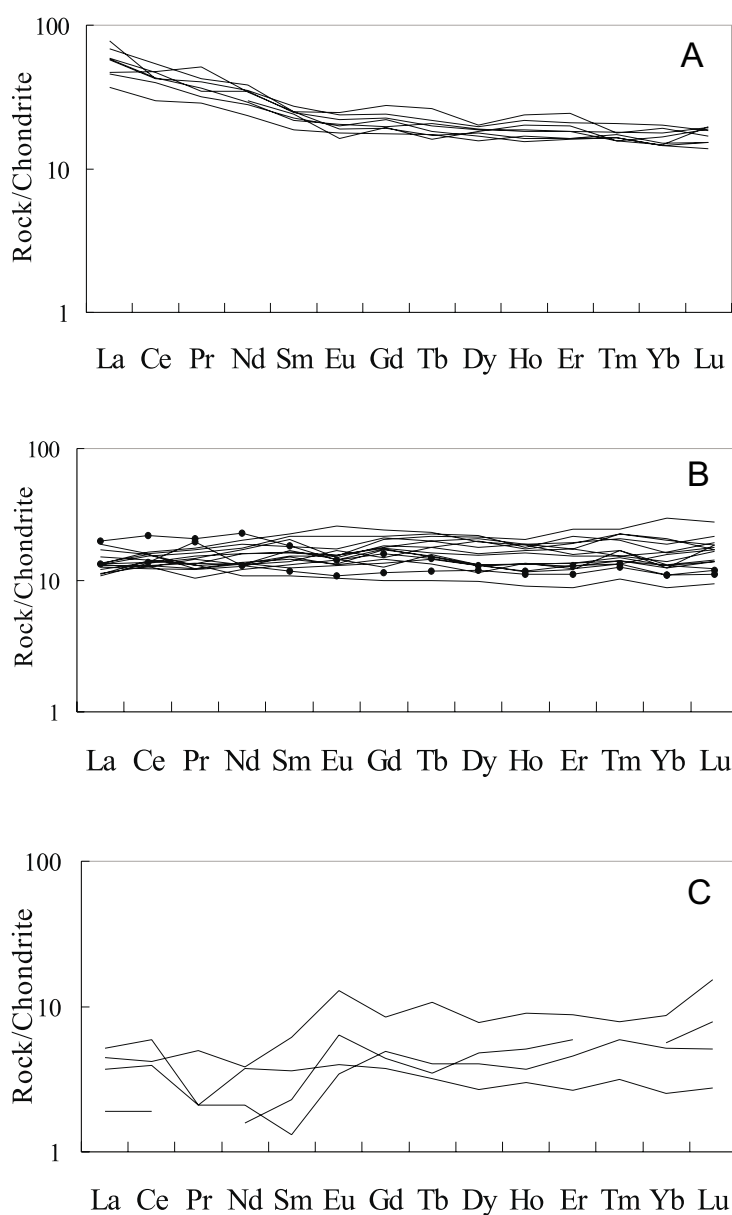
LREE-depleted chondrite-normalized REE patterns with low levels of HREE (Fig. 2c). In conclusion, the Kudi extrusive rocks are composed of three different tholeiite associations.

**Magma sources for the tholeiite associations**

On the  $\text{TiO}_2$ -Zr diagram, Group 3 basalts plot in and near the fields of Hunter Ridge and IBM forearc boninites, while group 2 basalts mimic the MORB trend ( $\text{Ti}/\text{Zr}=102$ ), and Ti/Zr values of group 1 basalts are mostly in the range of 75-100. These three groups of basalts are clearly separated on the diagram of La/Sm- $\text{TiO}_2$  (Fig. 3). Group 1 basalts plot in the field of Mariana arc and much LREE-enriched area, group 2 basalts in the field of Lau Basin, and group 3 basalts in and near the fields of Hunter Ridge and IBM forearc boninites. On the Hf/3-Th-Nb/16 diagram, group 1 and 2 basalts indicate a clear supra-subduction zone (SSZ) signature. Conclusively, we interpret group 1 basalts to be LREE-enriched island arc tholeiites (IAT), group 2 basalts to be back-arc basin (BAB) tholeiites, and group 3 basalts to be low-Ti island arc tholeiites (IAT).

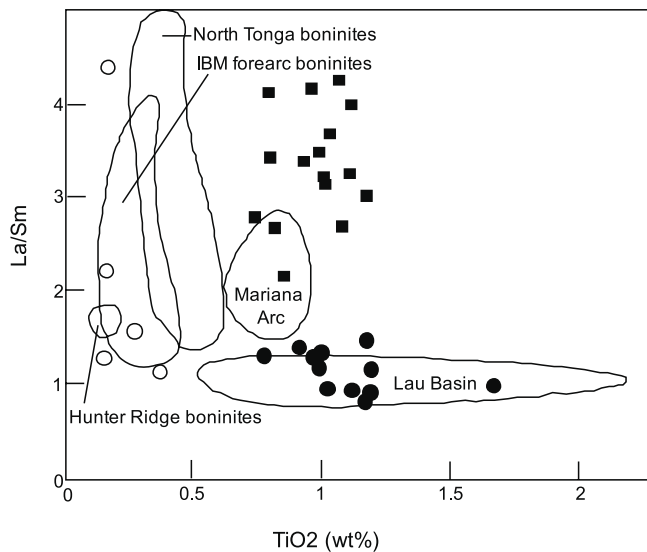
**Tectonic evolution of the Kudi ophiolite***An upper mantle and crustal section of a back-arc basin*

The mantle peridotites are rich in Mg and Ni and poor in Al and Ca; and the pyroxene is low in Al and Ti, and the spinel is high in Cr# ( $\text{Cr}\#>0.6$ ), indicating that they are highly depleted mantle residues and similar to those of mantle rocks from SSZ ophiolites. The cumulate pyroxenites and gabbros are Nb and Ti depleted and are of arc affinity. These cumulate rocks have flat REE patterns as that of group 2 basalts. The cumulate gabbros together with the diabase and group 2 basalts define a clear cogenetic trend in the Hf-Th-Nb diagram. As discussed earlier, the diabase dikes and group 2 basalts have indistinguishable geochemistry with that of tholeiites



**Figure 2.** Chondrite-normalized rare-earth-element patterns for the tholeiite associations from the Kudi ophiolite. (A)-LREE-enriched group 1 basalts; (B)-LREE-depleted and flat group 2 basalts (solid circles for the diabase dikes); (C)-U-shaped group 3 basalts. Normalizing values are from Sun and McDonough (1989).

## International Research: Ophiolites: Zhihong, cont...



**Figure 3.** Comparison of La/Sm and  $\text{TiO}_2$  for group 1 basalts (solid squares), group 2 basalts (solid circles) and group 3 basalts (open circles) from the Kudi ophiolite and modern arc systems.

from back-arc basins. In summary, the main parts of the Kudi ophiolite, namely the SSZ-type mantle peridotites, cumulate complex with arc tholeiite affinity, and BABB-type diabase dikes and group 2 basalts constitute an upper mantle and crustal section of a back-arc basin in a SSZ environment.

#### *Petrogenetic scenario for the low-Ti island arc tholeiites (IAT)*

Group 3 basalts share lots of common geochemical characteristics with the modern boninites, i.e., low Ti and HFSE, high Cr, and slightly U-shaped or LREE-depleted chondrite-normalized REE patterns with low levels of HREE, especially with the boninites from the Hunter Ridge and IBM forearc (Fig. 3). The geochemistry of the low-Ti IAT indicates that they represent melts derived from a depleted mantle source region modified compositionally by fluids and/or melts during subduction metasomatism. The occurrence of calc-alkaline volcanics and volcanoclastic sediments above the Kudi ophiolite, which is normally restricted to mature intraoceanic arcs, implies that these low-Ti IAT were not produced during the initiation of an island arc or not associated with the initiation of subduc-

tion. Field observations indicate that the low-Ti IAT generally overlay the BAB tholeiites and/or are interlayered with the BAB tholeiites locally, suggesting that they could have formed after the BAB tholeiites or approximately the same time. In other words, the low-Ti IAT produced during extension of the back-arc basin. We present here an interaction model between subduction and extension of a back-arc basin for interpreting tectonic and magmatic events responsible for the origin of the low-Ti IAT.

Intraoceanic subduction generally and firstly results in slab devolatilization, with focussed fluid efflux into the convecting mantle wedge triggering partial melting, and consequently arc volcanism is developed (Fig. 4a). Geophysical investigation of marginal basins in the western Pacific suggested that initiation of inter-arc basin extension is resulted from mantle diapir rather than a change of subduction zone configuration (e.g., trench rollback). The coupling of MORB-type mantle upwelling with fluid efflux from slab devolatilization would permit formation of BABB-type magmatism by which floored the extensional back-arc basin (Fig. 4b). Continued mantle upwelling and consequent extension

would possibly give birth to propagating of back-arc basin spreading ridge into a protoarc along the trend. Hydrous fluids enriched in LILE emanate from the subducting lithospheric slab into the formerly depleted (extraction of BABB magma) and hot refractory mantle (newly formed upper mantle in the back-arc basin), triggering partial re-melting, and consequently the low-Ti IAT magma formed. If the magma extrude right at the bottom of the back-arc basin, the low-Ti IAT will cover the former floored BAB tholeiites. If the magmas extrude into the propagating tip of the back-arc basin, the IAT will interlayer with the BAB tholeiites following continued basin extension (Fig. 4b).

#### *Tectonic implication of the LREE-enriched IAT*

It is different to distinguish the second-stage arc magma from the first-stage arc magma forming the protoarc (Fig. 4a). Group 1 basalts in the Kudi ophiolite are more enriched in LILE and LREE than the basalts from typical arcs (e.g., Fig. 3), suggesting that voluminous fluid efflux had entered into the mantle wedge possibly due to devolatilization of two subducting slabs (Fig. 4c) and/or much close to a subduction zone. The interaction occurred between the parental magma of group 1 basalts and the mantle peridotites from the mantle wedge and formerly the upper mantle of the back-arc basin (Wang *et al.*, 2001), spatially and temporally eliminating the possibilities of protoarc magmatism for group 1 basalts. This implies that a new subduction zone, indicative of closure of the back-arc basin, had emerged within the Kudi palaeo-back-arc basin, permitting hydrous fluids and/or melts from devolatilization of the back-arc basin lithosphere subducting slab to interact with the rocks in a newly formed mantle wedge (Fig. 4c).

#### **Conclusions**

We developed an evolution model of a back-arc basin to explain tec-



International Research: **Ophiolites: Zhihong, cont...**

tonic and magmatic events of the early Paleozoic Kudi SSZ ophiolite involving the production of three types of tholeiite associations.

The SSZ-type mantle peridotites, cumulate complex with arc tholeiite affinity, and BABB-type diabase dikes and basalts constitute an upper mantle and crustal section of a back-arc basin formed by coupling of MORB-type mantle upwelling with fluid efflux from slab devolatilization. The low-Ti IAT represent melts derived from a depleted mantle source region (extraction of BABB magma) modified compositionally by fluids and/or melts from the subducting lithospheric slab during propagation and extension of the back-arc basin. The emergence of the LREE-enriched IAT and the interaction between the parental magma of the IAT and the mantle wedge rocks indicate the closure of the back-arc basin.

**Acknowledgments**


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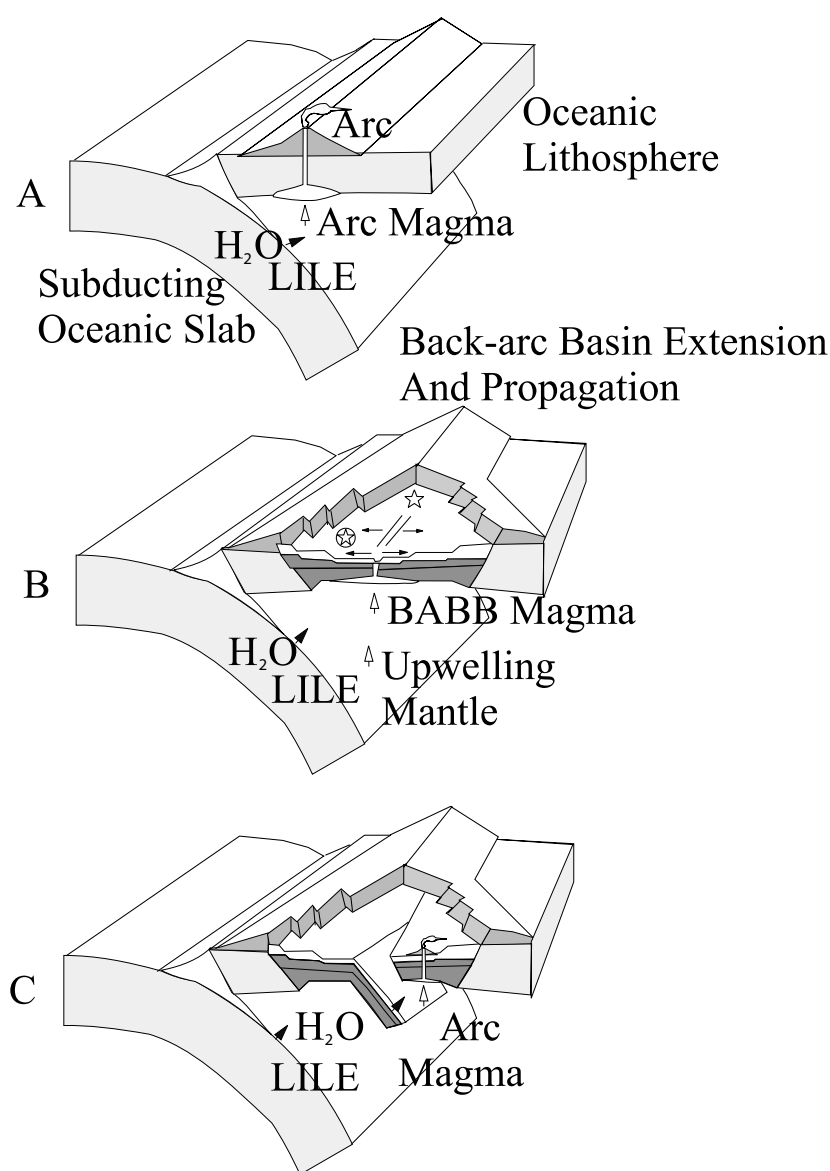
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**Figure 4.** Schematic diagram illustrating the evolution of a back-arc basin and production of three tholeiite associations. (A) A first-stage arc system (the protoarc). (B) Propagation and extension of a back-arc basin. The symbol of a star with in a round circle represents the low-Ti IAT generally overlaid the BAB tholeiites which floored the basin; and the star symbol represents the low-Ti IAT commonly interlayered with the BAB tholeiites at the propagating tip of the back-arc basin. (C) A second-stage arc magmatism related to formation of the LREE-enriched IAT during the closure of the back-arc basin, arousing the interaction between the arc magma and the mantle rocks. See text for detailed discussion.

## International Research: Pacific-Antarctic Ridge

## Widespread Silicic Volcanism and Hydrothermal Activity on the Northern Pacific – Antarctic Ridge

P. Stoffers<sup>1</sup>, T. Worthington<sup>1</sup>, R. Hekinian<sup>1</sup>, S. Petersen<sup>2</sup>, M. Hannington<sup>3</sup>, M. Türkay<sup>4</sup>, D. Ackermann<sup>1</sup>, C. Borowski<sup>5</sup>, S. Dankert<sup>2</sup>, S. Fretzdorff<sup>1</sup>, K. Haase<sup>1</sup>, A. Hoppe<sup>1</sup>, I. Jonasson<sup>3</sup>, T. Kuhn<sup>2</sup>, R. Lancaster<sup>3</sup>, T. Monecke<sup>2</sup>, A. Renno<sup>2</sup>, J. Stecher<sup>4</sup>, L. Weiershäuser<sup>6</sup>

<sup>1</sup>Institut für Geowissenschaften, Universität Kiel, Germany

<sup>2</sup>Institut für Mineralogie, Technische Universität Bergakademie Freiberg, Germany

<sup>3</sup>Natural Resources Canada, Ottawa, Canada

<sup>4</sup>Forschungsinstitut Senckenberg, Frankfurt, Germany

<sup>5</sup>Zoologisches Institut, Universität Hamburg, Germany

<sup>6</sup>Department of Geology, University of Toronto, Canada

The Foundation seamount chain was first visited during 1995 by the *R/V SONNE*, and subsequently in 1997 by the *R/VL'ATALANTE*. Geochemical and geophysical data from these cruises have shown that the Foundation seamounts formed during the passage of the Pacific Plate

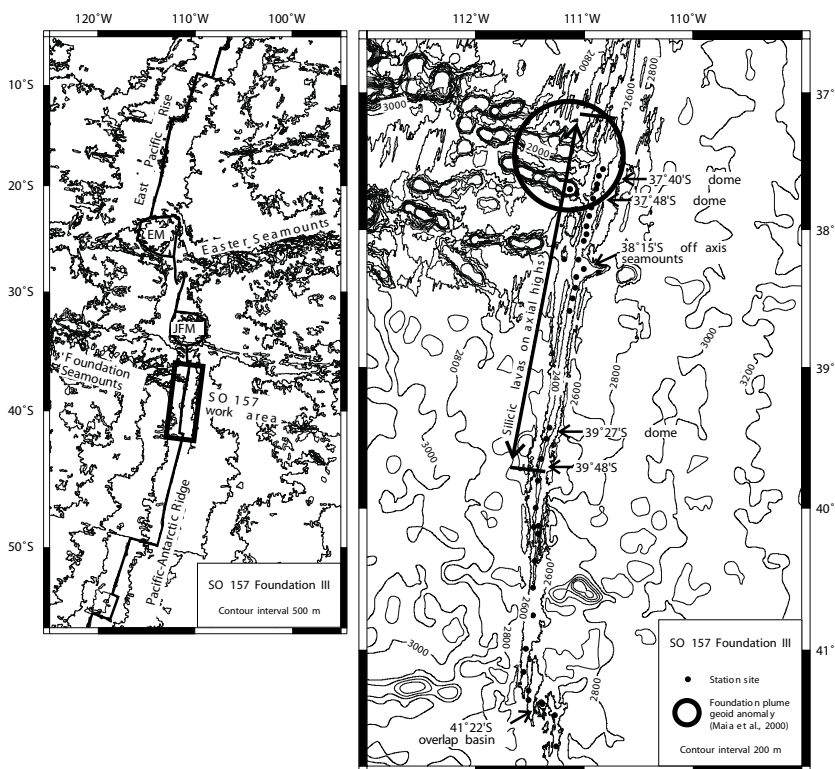
over a mantle plume, and that this plume is presently located 35 km west of the Pacific–Antarctic Ridge (PAR) near 37°25'S (Fig. 1; Maia *et al.*, 2000; 2001; O'Connor *et al.*, 2001). Surprisingly, silicic lavas (up to 64 wt.% SiO<sub>2</sub>) were recovered from the PAR crest adjacent to the young-

est Foundation seamounts (Hekinian *et al.*, 1997; 1999). Silicic volcanism (>55 wt.% SiO<sub>2</sub>) on mid-ocean ridges is rare, but does occur on the northern East Pacific Rise (10.5°N; Thompson *et al.*, 1989) and the 095° propagator of the Galapagos Spreading Centre (Clague *et al.*, 1981).

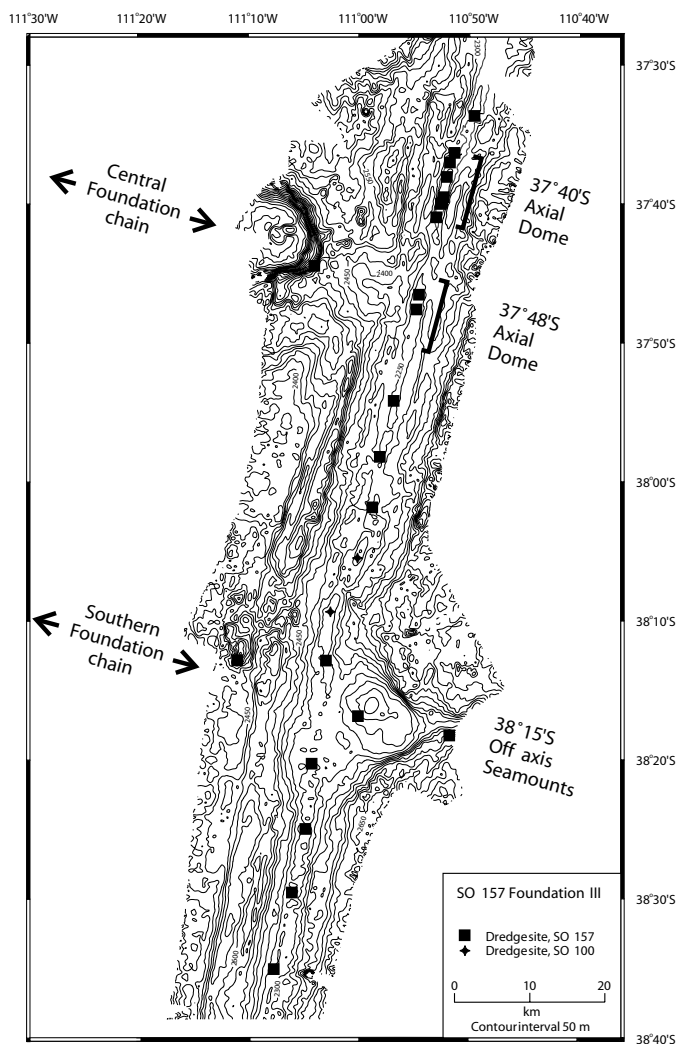
The prime objectives of the FOUNDATION III cruise (*R/V SONNE*-SO 157) in mid-2001 were to determine the extent of the silicic lavas along the PAR and to investigate associated hydrothermal activity. We examined a 630 km-long segment of the northern PAR bounded by large left-stepping overlapping spreading centres (OSCs) near 36.5°S and 41.5°S (Fig. 1). Detailed bathymetric data was collected using the newly installed SIMRAD EM120 onboard the *R/V SONNE*, and 65 stations were devoted to recovering seafloor samples in conjunction with video observations of hydrothermal activity and vent fauna.

### The PAR at 37.5 – 41.5°S

In the northern part of the surveyed area, the PAR axis forms a series of short (~15 km-long) non-overlapping segments (Fig. 2). Small right-stepping non-transform discontinuities offset each segment by ~1 km, although a more complex westward bending occurs around an off-axis seamount near 38°15'S. Each segment is dome-shaped, with the elevation decreasing gently



**Figure 1.** Tectonic setting and bathymetry of the northern PAR. Left- location of the SO 157 work area and major tectonic features (EM=Easter Microplate, JFM=Juan Fernandez Microplate). Right- SO 157 station sites along the PAR crest and features referred to in the text. Black bars indicate the extent of silicic lavas along the PAR crest.



**Figure 2.** Detailed bathymetry and dredge stations in the northern part of the work area.

along strike towards its ends. The domes are better developed north of the off-axis seamount, where they rise ~100 m above the segment ends. Graben-like clefts up to 200 m-wide and 50 m-deep cut through some of the domes.

The 37°40'S dome was selected for a detailed petrological and hydrothermal study. This dome rises to 2120 m-depth, and is cut by a cleft filled with fresh glassy lavas and talus from adjacent pillow mounds. Lavas from the summit and cleft include aphyric dacite and andesite, and have glass crusts >5 mm thick. Conchoidal fractures, together with numerous strongly elongate and flow-aligned vesicles, characterise these silicic lavas. At least one lava flow was emplaced since the area

was video surveyed by the *R/V L'ATALANTE* in early 1997. The new lava covers an area of 3.5 km x 200 m, and was erupted from a series of partly buried fissures whose location is marked by collapse pits. A more varied lava suite was recovered from the lower flanks of the dome, where the dominant lithologies were glass-encrusted sparsely phyric pillow andesite and basalt. Light dustings of MnOx suggest most of these lower lavas are older.

To the south of 38°15'S, the PAR axis continues at an almost constant depth of 2220–2250 m. Pillow and sheet flows of sparsely phyric andesite and basalt characterise this 120 km-long section. The section is terminated by two 120 m-high axial domes constructed near 39°20'S and

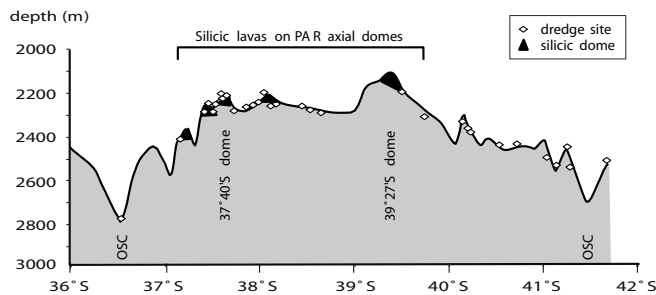
39°27'S (Fig. 1). The crest of the southern dome at 2090 m-depth is capped by a fresh 4 km-long tabular flow of glassy aphyric andesite with skeletal pyroxene and plagioclase crystals. Strongly elongated flow-aligned vesicles often contained pyrite-cubanite crystals, and released H<sub>2</sub>S when cut.

Further south, a series of 40–50 km-long ridge segments (each 40–50 km-long) are separated by left-stepping OSCs at 39°48', 40°09', 40°34', 40°55', and 41°19'S (Fig. 1). The ridge axis is offset by 4–5 km at each of these discontinuities, and the overlap distance varies from 5–22 km. MORB-like pillow lavas were recovered from these segments. Our survey terminated at the large left-stepping OSC near 41°22'S, where the ridge crest is offset by 18 km and the overlap extends for 10 km. An isolated 500 m-high seamount with a well-developed summit crater has been built in the overlap basin. Fresh aphyric basalt, older MnOx-stained sparsely phyric basalt and dolerite were recovered from the summit crater.

### Hydrothermal activity and vent fauna

Active hydrothermal vents, together with abundant vent fauna and fossil sulphide deposits, were located during video sled and TV-controlled grab surveys. These surveys provided comprehensive coverage of the 37°40'S and 37°48'S axial domes. The high-temperature sulphide deposits and vent fauna are the first reported occurrences from high latitudes on southern hemisphere spreading ridges.

Widespread diffuse venting (near-bottom water temperature anomalies up to 0.25°C) is associated with the young silicic flows in the cleft of the 37°40'S dome. Both the cleft walls and recovered rocks were commonly stained with Fe-hydroxides. Two partly talus-covered sulphide outcrops occur along the eastern cleft wall. Both are 30 m in diameter, and comprise sulphide rubble with halos of metalliferous sediment and Fe-hydroxide staining. Free-standing sulphide spires were seen

International Research: Pacific-Antarctic Ridge: Stoffers *et al.*, cont...

**Figure 3.** Bathymetric profile of the northern PAR. Silicic lavas predominate on the axial domes between 37°11'S and 39°48'S.

at the northernmost site. Three areas of dark, dusty hydrothermal sediment, interpreted as recent plume fallout, coincided with weak temperature anomalies. One was near a clam field seen during the 1995 *R/V SONNE* cruise, and another extended for 100 m over the post-1997 glassy silicic lava at the southern end of the cleft.

The 37°48'S axial dome consists of partly sediment-covered lavas buried by younger sediment-free flows, and lacks a central cleft. Nevertheless, near-bottom water temperature anomalies (up to 0.25°C) occur at deep fissures cutting the younger lavas on the southern dome flank. White hydrothermal fluid was observed near a sulphide outcrop 10 m across at one fissure, and the fissures are surrounded by a vesicomid clam bed 50 m in diameter and abundant vent fauna. A fossil sulphide outcrop 30 m across occurs 1.7 km north of the clam field, and includes two large sulphide spires up to 3 m high. There, an old sulphide mound has been partly buried and disrupted by young lavas. Abundant sulphide talus has been ramped onto the young lavas, and sulphide windows outcrop between pillows. The talus is strongly altered, and stained with bright red Fe-hydroxides, yellow jarosite, and bright green atacamite. Recovered sulphide blocks consisted of coalesced pyrite chimneys, massive recrystallised sphalerite and chalcopryrite, and included sulphide-pseudomorphed clams and large worm tubes up to 1.5 cm in diameter.

The faunal communities around the active hydrothermal vents are

dominated by *Bathymodiolus* and *Neolepas*, and mobile animals include bythograeid crabs, *Munidopsis*, and zoarcid fish. Unlike *B. thermophilus* found near sulphide-rich vent fluids elsewhere, the gills of our recovered *Bathymodiolus* specimens were only moderately hypertrophic and H<sub>2</sub>S was not released when the shells were opened. Polychaete worms and snails were collected from the vent sites, and dense beds of dead vesicomid clams were seen in the peripheral zone. Filter-feeders at the active vents and in the peripheral zone were hexactinellid sponges and sessile crinoids, whereas the more distal zones were dominated by large assemblages of serpulid tubes, actinians, coryphaenid fish and swimming crinoids. The abundance of swimming crinoids at the PAR is possibly unique, and they were a useful indicator of near-by hydrothermal venting.

### Summary


Silicic lavas have now been recovered from the upper flanks of PAR axial domes between 37°11'S and 39°48'S, a distance of 290 km. These lavas outcrop on the upper flanks and summits of the axial domes, whereas less silicic lavas are found on the lower dome flanks (Fig. 3). Widespread hydrothermal activity and sulphide deposits are associated with the silicic volcanism, and may reflect the high heat flow available from fractionating magma.

### Acknowledgements

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## Isotope provinces of mid-ocean ridges

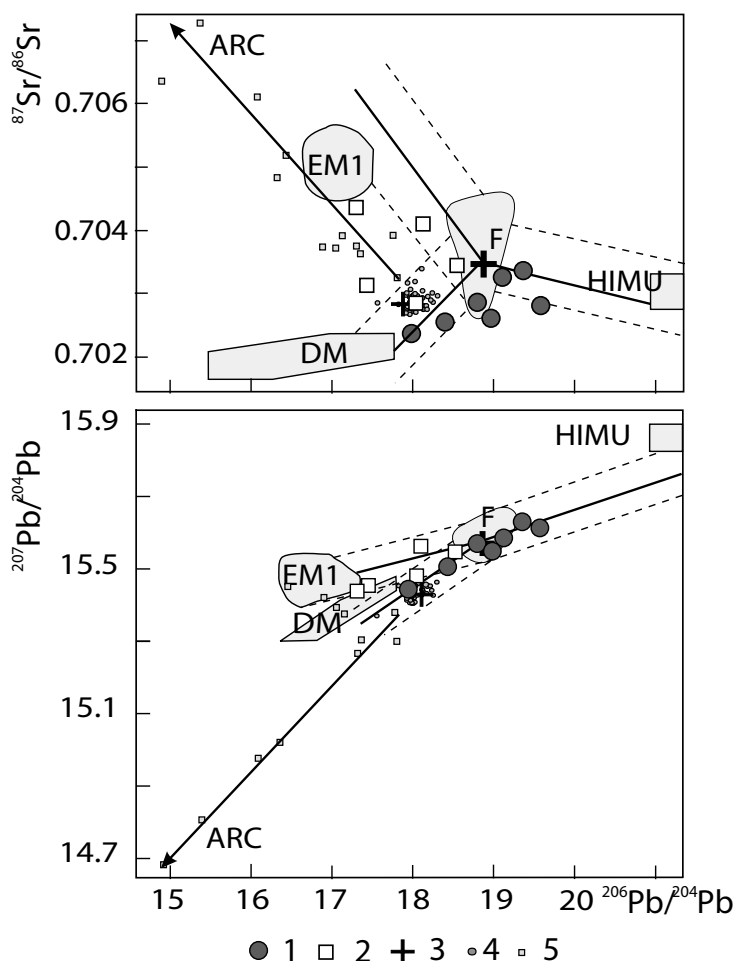
A.A. Pustovoy<sup>1</sup>, Yu.V. Mironov<sup>2</sup>, and V.M. Ryakhovsky<sup>2</sup><sup>1</sup> Shirshov Institute of Oceanology RAS, Atlantic Branch, Kaliningrad, Russia<sup>2</sup> Vernadsky State Geological Museum RAS, Moscow, Russia

## Introduction

Numerous previous studies have reliably established regional and local variations of isotope compositions for mid-ocean ridge basalts (MORBs). As early as in 1987, E. Ito and co-workers in their review emphasized the fact that Indian Ocean basalts are enriched in radiogenic Sr and Pb isotopes with respect to Pacific and Atlantic MORBs. At rough-

ly the same time, "enriched" MORBs were detected in the South Atlantic. This enabled S. Hart to establish the DUPAL anomaly of the Southern Hemisphere, so named after B. Dupre and C. Allegre, prominent researchers in the field of isotope geochemistry. The limited size of this paper compels us to refer hereinafter to the review (Hofmann, 1997). Besides, there exist a huge number

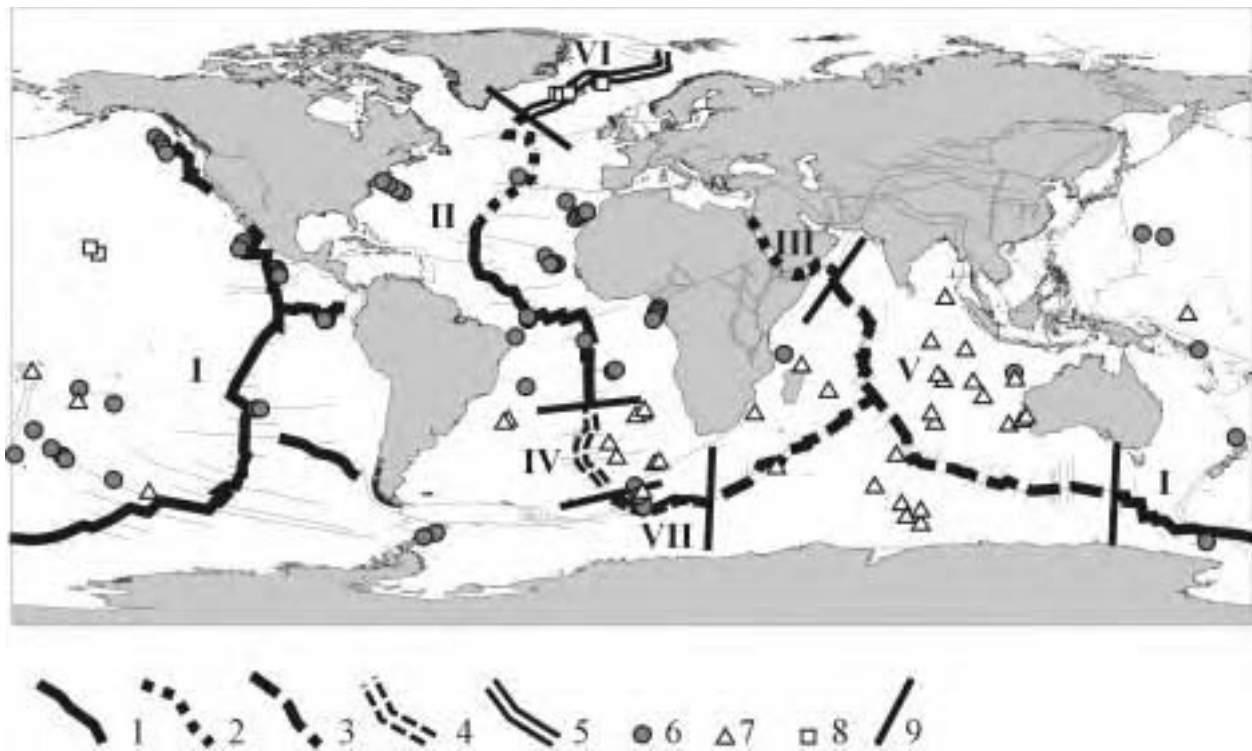
of published work that address finer variations in MORB composition within specific regions. In most cases, MORB isotope systematics draw in one way or another on the "mantle tetrahedron" of A. Zindler and S. Hart (1986). Its corners are made by the so-called end members which include DM (depleted mantle), HIMU (high  $\mu$  mantle, where  $\mu$  is  $^{238}\text{U}/^{204}\text{Pb}$ ), and two types of enriched mantle, EM1 and EM2. Some authors believe that the DUPAL anomaly is easiest to explain by introducing a certain "composite" end member, LOMU ("low  $\mu$  mantle"), which is a mixture of EM1 and EM2 (Douglass and Schilling, 1999). Besides, in use are a number of within-tetrahedron components (FOZO, PREMA, C, etc.) (Hofmann, 1997), one of which (C, or "common") is viewed as being common to MORBs from different oceans (Hanan and Graham, 1996). Many workers note the similarity of within-tetrahedron components and use them as indicators of lower-mantle plumes (Hofmann, 1997). However, distinctions between these components are great enough. This results in considerable uncertainty and, not infrequently, inconsistency in systematics and interpretations of one and the same feature. This makes direct compilation of conclusions obtained by different workers rather hard. Our study presents results from data generalization for MORB compositions using all-embracing Sr–Nd–Pb isotope systematics, modified by means of multidimensional statistics.



**Figure 1.** MORB isotope systematic. 1-3 - the average isotope compositions for clusters of: normal (1); DUPAL (2) and "singular" MORB (3); 4 - individual compositions of "singular" MORB from Arctic province; 5 - flood basalts from Eastern Greenland.

## Methods used

The entire data set (820 published analyses) was convoluted using a multidimensional data agglomeration technique of our own, which

International Research: Mid-Ocean Ridge: Pustovoy, *et al.*, cont...

**Figure 2.** Isotope heterogeneity of World Ocean. Mid-ocean ridge isotope provinces: Pacific (I), Central Atlantic (II), Red Sea–Aden (III), South Atlantic (IV), Indian Ocean (V), Arctic (VI), and Transitional Indian-Atlantic (VII). Normal MORB suites: DM+HIMU (1) and DM+F+(HIMU) (2); DUPAL MORB suites: DM+F+(EM1) (3) and DM+F+EM1 (4); “Singular” MORB suite DM+F+(ARC) (5); isotope rock types from intraplate structures: F+HIMU (6), F+EM1 (7) and F+DM+(ARC) (8) (after Mironov *et al.*, 2000). The boundaries of the isotope mid-ocean ridge provinces (9).

affords the identification of compositional clusters in multidimensional space. A reference frame for the space under study was provided by the customarily used radiogenic/non-radiogenic isotope ratios ( $^{87}\text{Sr}/^{86}\text{Sr}$ ,  $^{143}\text{Nd}/^{144}\text{Nd}$ ,  $^{206}\text{Pb}/^{204}\text{Pb}$ ,  $^{207}\text{Pb}/^{204}\text{Pb}$ ,  $^{208}\text{Pb}/^{204}\text{Pb}$ ). To systematize the MORB clusters identified, we used our own modification of the “mantle tetrahedron” (Fig. 1) (Rundqvist *et al.*, 2000). Its crucial

classification element, along with the end members, is the F (“focal”) within-tetrahedron component. It was derived as the mean composition of an independent cluster in the course of a similar analysis of data, dominantly from intraplate oceanic structures. The component F turned out to be close in composition to the mean for all the within-tetrahedron components known so far, including C. We regard the component F as

a general characteristic for within-tetrahedron components, constrained using multidimensional statistics techniques. Previously, variance of MORB isotope composition was shown to be due principally to mixing of the component F with DM (Rundqvist *et al.*, 2000). For this reason, for the purposes of MORB systematics, we used an additional classification element, the join F–DM (Mironov *et al.*, 2000).

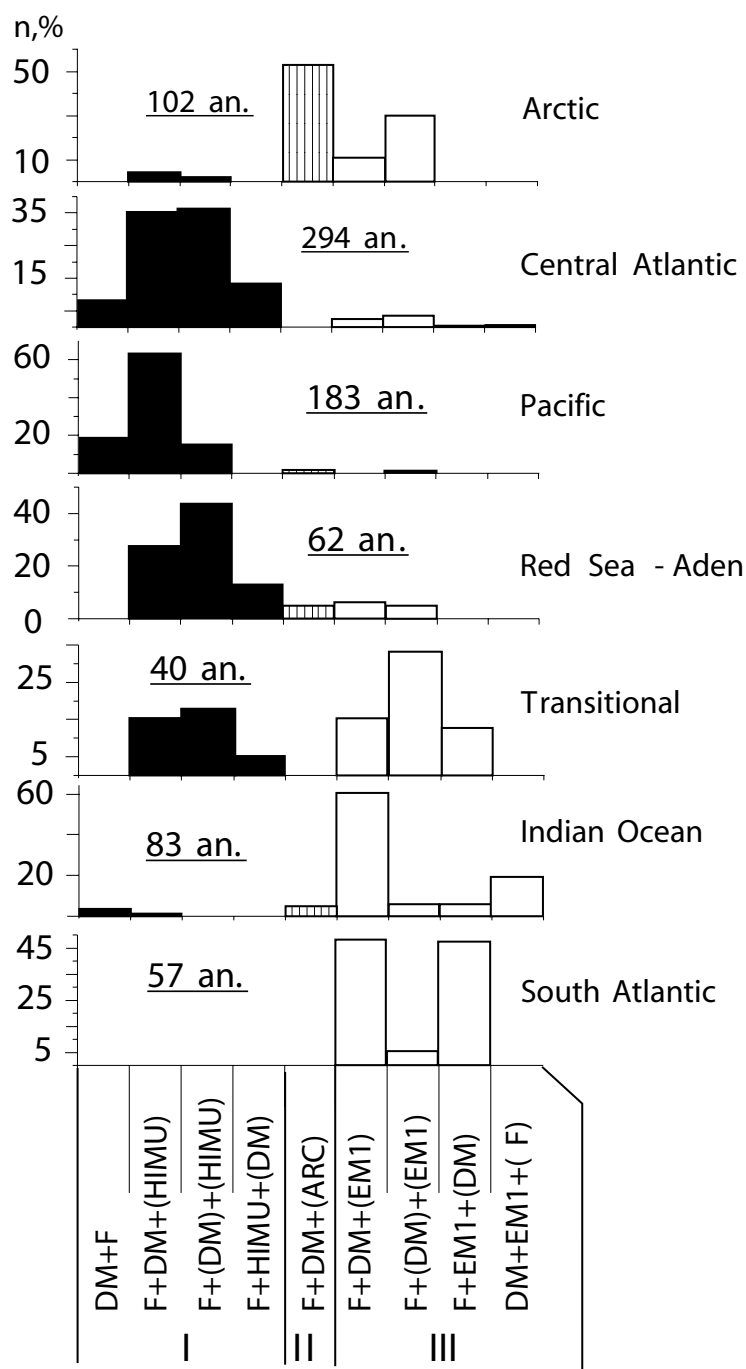
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### MORB types and isotope provinces of mid-ocean ridges

Based on how mean compositions of the clusters plot with respect to the mixing line F + DM, three principal types of MORB can be identified (Fig. 1). These types are spatially discrete and compose extensive provinces (Fig. 2). The first type, the counterpart to “normal” MORB, is featured by the presence of HIMU (F + DM + HIMU field). This type is

International Research: **Mid-Ocean Ridge: Pustovoy, *et al.*, cont...**

**Figure 3.** Frequency of occurrence of normal (I), "singular" (II), and DUPAL (III) MORB in mid-ocean ridge provinces.

widespread in the Central Atlantic, Pacific, and Red Sea–Aden provinces. The second type is developed within the DUPAL anomaly. Its hallmark is the presence of EM1 (F + DM + EM1 field). The South Atlantic and Indian Ocean provinces, which lie within the DUPAL anomaly, are separated by the Transitional (Indian–Atlantic) province, where both nor-

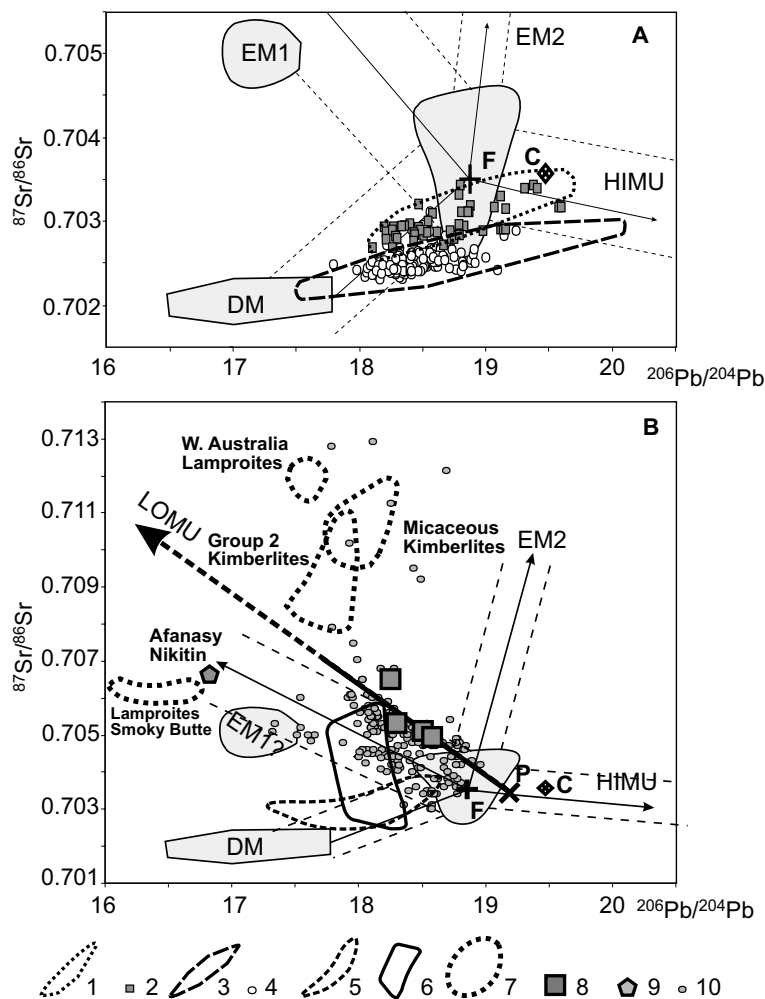
mal and DUPAL-MORB coexist. In addition to these rather well-known types, we established a third type of MORB, which defines the singularity of the Arctic province. The latter encompasses the ridges of the North Atlantic and the Norwegian–Greenland Basin, including the northern Reykjanes Ridge on the south and the Gakkal Ridge on the north. As

noted earlier, Gakkal Ridge basalts are isotopically similar to DUPAL-MORB (Muhe *et al.*, 1997). Indeed, in terms of most isotope characteristics, such as  $^{206}\text{Pb}/^{204}\text{Pb}$  vs.  $^{87}\text{Sr}/^{86}\text{Sr}$  (Fig. 1),  $^{206}\text{Pb}/^{204}\text{Pb}$  vs.  $^{143}\text{Nd}/^{144}\text{Nd}$ , and  $^{206}\text{Pb}/^{204}\text{Pb}$  vs.  $^{208}\text{Pb}/^{204}\text{Pb}$  variations, this type is analogous to DUPAL-MORB. However, in terms of  $^{206}\text{Pb}/^{204}\text{Pb}$  vs.  $^{207}\text{Pb}/^{204}\text{Pb}$  variations, it matches normal MORB (Fig. 1). This peculiarity cannot be due to EM1 admixture, as in the southern DUPAL anomaly. The most likely explanation is a certain degree of contamination of oceanic lithosphere in this region by another component, which, for the time being, we term tentatively ARC ("Arctic"). This component is located far beyond the "mantle tetrahedron," in the region of extremely low  $^{206}\text{Pb}/^{204}\text{Pb}$  and  $^{207}\text{Pb}/^{204}\text{Pb}$  values.

Boundaries of isotope provinces for mid-ocean ridges fit in with those of E–W transoceanic heterogeneities delineated earlier based on isotope compositions of volcanites on intraplate rises and islands (Fig. 2) (Rundqvist, 2000). Remarkably, the MORB signature of a given province is defined by the same admixture (EM1 or HIMU) that prevails in volcanic compositions on latitudinally close rises and islands, where it forms quasi-binary mixtures with the component F (Mironov *et al.*, 2000). In this respect, the Arctic province is somewhat different. Here, the component ARC, critical to the recognition of the province, makes only a minor admixture in mixing products of F and DM not solely in mid-ocean ridges, but on islands as well. At the same time, quasi-binary mixing of F and ARC is recorded only in the continental flood volcanites, which preceded the opening of the North Atlantic (Fig. 1).

#### Comparative characteristics of isotope provinces

Cluster frequency histograms show that provinces composed of the same MORB type still differ from each other to some extent (Fig. 3). Thus, the Central Atlantic province

International Research: Mid-Ocean Ridge: Pustovoy, *et al.*, cont...

**Figure 4.** Isotope suites of normal (A) and DUPAL (B) MORB. Isotope mid-ocean ridge provinces: Central Atlantic, northern segment (1), Red Sea - Aden (2), Central Atlantic, southern segment (3), Pacific (4), Indian Ocean (5), South Atlantic (6); intraplate structures, data from which were used for definition of component LOMU: Africa and Australia (7), Gough, Tristan da Cunha, Discovery (8), Afanasy Nikitin (9) (after Douglass, Schilling, 1999); other intraplate DUPAL structures (10).

(unlike the Pacific one) is characterized by the presence of “normal” MORB varieties with a high proportion of F and HIMU components. This and other distinctions are more readily evident in a section of the mantle tetrahedron (Fig. 4). In the Central Atlantic province, two MORB suites are distinguished clearly. One suite, widespread in the northern segment of the province (Fig. 2), originates from mixing of F and DM with a minor HIMU admixture. A similar suite is developed in the Red Sea-Aden province. The second suite, intrinsic to the southern segment of the Central Atlantic province (24°N–24°S), is more consistent with direct mixing of the two end members, DM and HIMU (with a minor F admixture). Compositional range of this MORB suite accommodates all MORB compositions from the Pacific province as well, with Pacific basalts having a much narrower range, tending towards DM.

No less clear distinctions exist between the Indian Ocean and South Atlantic provinces, composed of DUPAL-MORB (Fig. 4). Variance of Indian MORB is due mainly to mixing of DM and F (with EM1 admixture). Compositional variations of South Atlantic MORB can be explained by mixing of two “composite” components. One of these corresponds roughly to the mean composition of Indian MORB. The other component is closely similar to the

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Agnieszka Adamczewska  
*InterRidge News* Editor

volcanites of the neighboring hot spots (Gough, Tristan da Cunha, Discovery). Compositions of these and most other within-plate volcanites of the South Atlantic and Indian Ocean cluster along the mixing line of F and a component which is best approximated by EM1, of the known end members. In this context, it would stand to reason to modify EM1, which is used conventionally in isotope studies, toward somewhat greater  $^{87}\text{Sr}/^{86}\text{Sr}$  ratios (roughly, 0.7065–0.7075). An EM1 component so refined has the same meaning as LOMU (antithetical to HIMU), proposed recently in explanation of the singularity of the DUPAL anomaly (Douglass and Schilling, 1999). However, the trend that stretches from a plume component P, and on whose basis LOMU was recognized—and, accordingly, LOMU itself—are displaced perceptibly from the mixing line of F and the refined EM1 into a region with still greater  $^{87}\text{Sr}/^{86}\text{Sr}$  values (Fig. 4). This might be due to the fact that the slope of the trend was determined chiefly from data points for Gough, Tristan da Cunha, and Discovery rocks, which differ from the other within-plate DUPAL structures in having somewhat higher  $^{87}\text{Sr}/^{86}\text{Sr}$ . Precise characteristics of LOMU as the center of a rather vaguely delimited region of African and Australian kimberlitic and lamproitic compositions are quite hard to obtain. At the same time, the refined EM1 is consistent with real rocks dredged from the Afanasy Nikitin Rise, Indian Ocean.

### Summary

In the framework of our own modification of A.Zindler and S.Hart's Sr–Nd–Pb isotope systematics, mid-ocean ridge basalts are defined dominantly as products of mixing of depleted mantle with a mantle reservoir F, which is involved in both rift-related and intraplate oceanic magmageneses. This reservoir is close to the average composition of all the components earlier proposed (C, FOZO, PREMA, etc.) within the mantle tetrahedron. MORB



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types that have distinctive admixture components are spatially discrete and form extensive isotope provinces of mid-oceanic ridges. In addition to the known MORB types, normal (with HIMU admixture) and DUPAL-MORB (with EM1 admixture), a “singular” type is recognized. The latter, in terms of most parameters, is a counterpart of DUPAL-MORB, but it has  $^{206}\text{Pb}/^{204}\text{Pb}$  and  $^{207}\text{Pb}/^{204}\text{Pb}$  ratios similar to normal MORB. This type is characteristic of the ridges of the North Atlantic and Norwegian–Greenland Basin, which are recognized as constituting a separate Arctic province. Boundaries of isotope provinces for mid-ocean ridges fit in with those of E–W transoceanic heterogeneities identified earlier by our study on isotope compositions of rocks on intraplate rises and islands.

### Acknowledgments

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## International Research: Mid-Atlantic Ridge

## New data on hydrothermal activity in the area of 12°57'N, MAR: initial results of the *R/V Professor Logatchev* cruise 20.

V.Ye.Bel'tenev<sup>1</sup>, I.I.Rozhdestvenskaya<sup>1</sup>, A.V.Nescheretov<sup>1</sup>, G.A.Cherkashev<sup>2</sup>, S.M.Sudarikov<sup>2</sup>,  
A.B.Rumyantsev<sup>1</sup>, V.F.Markov<sup>1</sup>, A.G.Krotov<sup>1</sup>, E.A.Zhirnov<sup>2</sup>

<sup>1</sup>Polar Marine Geosurvey Expedition, 34 Pobedy Str., Lomonosov, Russia

<sup>2</sup>VNIOkeangeologia, 1 Angliysky Pr., St.Petersburg, 190121, Russia

### Introduction

In September-November 2001, during the cruise of *R/V Professor Logatchev*, the Polar Marine Geosurvey Expedition (PMGE) in association with VNIOkeangeologia conducted comprehensive investigations in the axial MAR segment between 13° and 18°N. The goal to be sought was to reveal evidence of recent and ancient hydrothermal activity and to discern areas perspec-

tive for massive sulphides. One of the sites is located 20 km north of the Marathon Fault which is situated at 12°48' -13°04'N and 44°44' -45°00'W.

The presence of stockwork sulphide mineralization on the corner rise located at the rift valley/ Marathon Fault junction at 12°48'N was mentioned by P.A.Rona (1986) and later confirmed during cruise 9 of the *R/V Akademik Nikolai Strakhov* (Raznitsyn *et al.*, 1991).

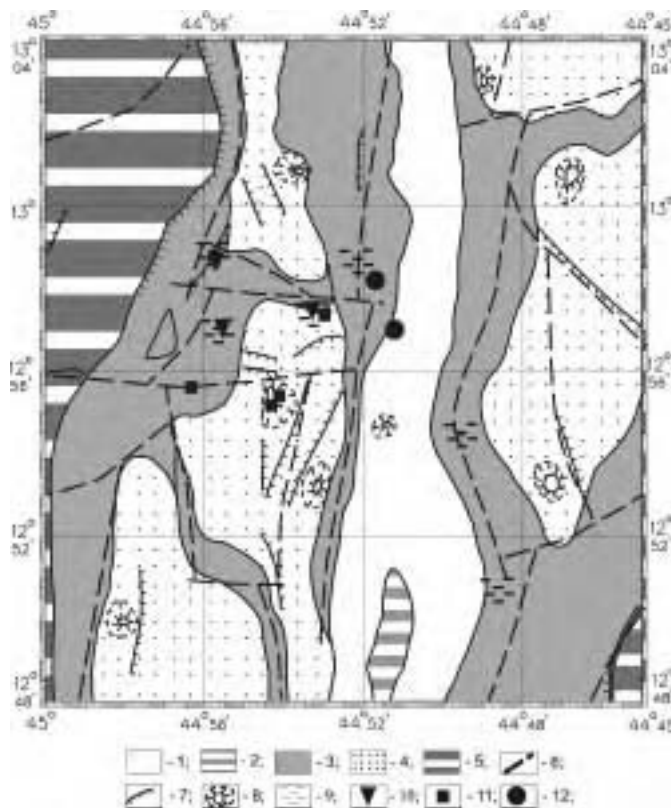
The basis for the investigations was provided by the results of *R/V Geolog Fersman* 10-th cruise (1991-1992) and by new data obtained in cruises of *R/V Yuzhmorgeologia* (Sudarikov *et al.*, 2001) and *R/V Atlantis* (Sudarikov and Zhirnov, 2001). During these expeditions, anomalies were recorded in bottom waters of western side of the rift valley between 12°54' -12°56'N and 44°52,5' -44°55,5'W (the Neptune's Beard area), rock samples with sulphide stringers and dissemination were recovered from dike rocks in the southeastern corner rise and high contents of iron hydroxides were recorded in the surface layer of bottom sediments. These data were the evidence for the presence of an active hydrothermal source in the study area.

### Results

The site is of complex structure comprising of intensively dislocated volcanic and plutonic rocks throughout the section of the oceanic crust from mantle restite peridotites up to basalts. The latter are common in the valley floor and in southern part of the site, plutonic rocks – in its northern part, though basalts, gabbroids and peridotites often meet in one dredge.

Bedrocks showing hydrothermal-metamorphic alteration within the site are confined to three structural elements (Fig. 1):

- 1) a steep slope in lower part of eastern side of the rift valley;
- 2) a gentle slope in western side of the valley, dividing the floor and tectonic step;



**Figure 1.** Structures and indications of hydrothermal activity. 1 - valley floor; 2 - axis neovolcanic rise; 3 - slopes of the rift valley; 4 - tectonic steps of rift valley slopes; 5 - rift mountains; 6 – tectonic faults; 7 - scarps; 8 – volcanic mounds; 9 - hydrothermal-altered rocks; 10 - sulphide dissemination; 11 - Fe-Mn crusts; 12 - anomalies in bottom water

International Research: **Mid-Atlantic Ridge: Bel'tenev, et al., cont...**

3) a steep bench in upper part of western side of the rift valley over the tectonic step.

Within these structures the evidence of hydrothermal-metamorphic rock recrystallization is associated with submeridional faults embracing the rift valley floor or dividing some tectonic steps on the valley sides.

The evidence of stockwork sulphide mineralization (pyrite and pyrrhotite) was recorded in one of the fragments of serpentinized peridotites. Silvery yellow-shaded sulphides are present in the rock as rounded prolate grains, up to 3 mm in size. In metabasalts from two stations, dispersed sulphide mineralization was recorded as rare quartz-sulphide veins or minor accumulations, 2-4 mm in size.

The easily observable sulphide mineralization may be considered in metabasalts and especially in peridotites as the direct evidence of hydrothermal activity within the site. It should be especially noted that all the rocks with sulphide mineralization were sampled from the western side of the rift valley from a small area (Fig. 1) located at 12°56'-12°59'N and 44°53'-44°56'W.

Based on evidence from CTD and hydrochemical investigations, the most promising location of hydrothermal activity is the northwestern area of the site, showing evidence of a hydrothermal plume (Fig. 1).

On one of the stations turbidity is 0.003-0.006 NTU and 0.012 NTU, more than background values in layers 3660-3880 m and 3740-3780 m,

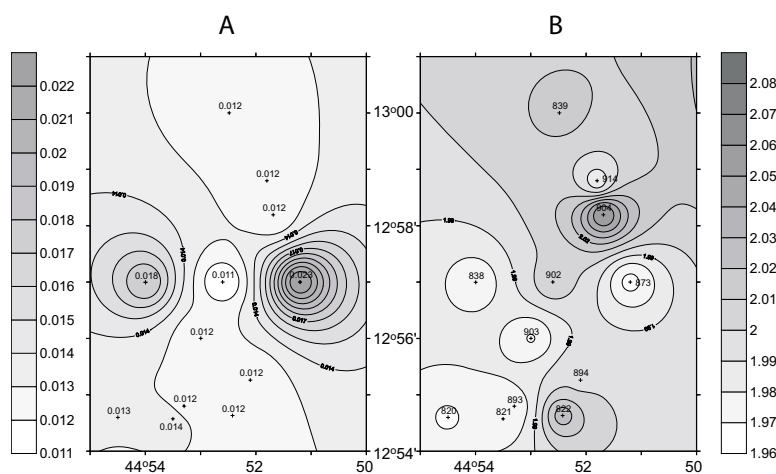
respectively (Fig. 2a). Local maximum of turbidity in layer 3757 m is 0.055 NTU, that is 6 times more than background values. The anomaly of turbidity was recorded both downward and upward CTD, the turbidity being slightly higher downward. It is of interest that temperature at the turbidity anomaly level is lower than that of surrounding water (Fig. 2b), and concentrations of dissolved manganese are anomalous (4 times higher than background values).

On the second station located 2 km north of previous, in layer 3900-3950 m, turbidity increases up to 0.032 NTU (Fig. 3a), this is more than 3 times higher than background values. A local maximum temperature is observed in layer 3760 m (Fig. 3b) and concentrations of dissolved manganese and methane are anomalous (7 and 5 times higher than background values, respectively).

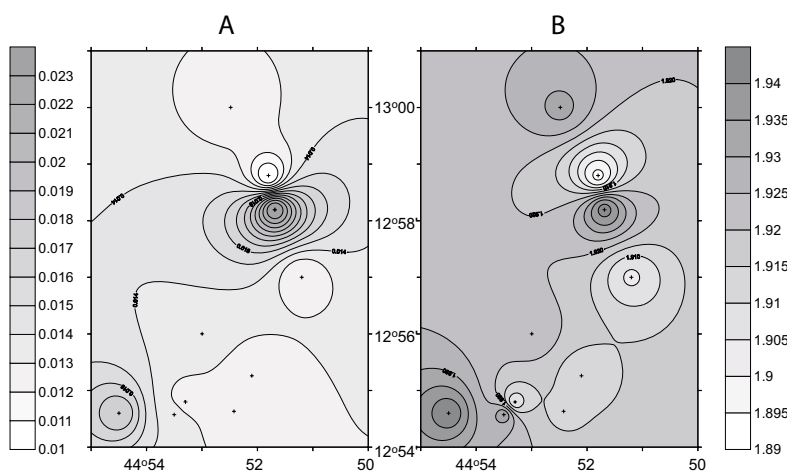
The preliminary data show the source of hydrothermal plume to be located northwest of these stations whereby hydrothermal products are transported southward by deep currents.

Bottom sediments are very common in the study area and assigned to carbonate coccolith-foraminiferal oozes. In order to reveal distribution haloes of minerals (indicators of hydrothermal supply), mineralogical analysis of surface layer (0-5 cm) of bottom sediment samples (0.5 l in volume) were performed onboard the ship. Immersion method was used for silty and sandy fractions. The sediments from central part of the site were studied thoroughly, where the anomaly centre had been recorded during the *R/V Yuzhmorgeologia* cruise at 13°54.9'N and 44°53'W (Sudarikov et al., 2001).

The surface layer of sediments contains minerals-indicators of hydrothermal activity: pyrite, chalcopyrite, pyrrhotite, native copper, atacamite, barite, intermetals and iron hydroxides. Pyrite, barite and iron hydroxides prevail. Single signs of these minerals are present in most of the sediment samples, but their highest concentrations in the surface



**Figure 2.** Water transmissivity (A) and temperature (B) at the depth 3750m



**Figure 3.** Water transmissivity (A) and temperature (B) at the depth 3910m



International Research: **Mid-Atlantic Ridge: Bel'tenev, et al., cont...**

layer are recorded in sediments from the terrace of western side of the valley in the site centre (12°56'-12°58'N and 44°54'-44°56'W). Figure 4 shows distribution of pyrite, barite and iron hydroxides in the surface sedimentary layer. Signs of these minerals regularly increase in amount westwards to the slope foot; direct correlation being observed between pyrite and iron hydroxides suggesting a common source they are supplied from. A source of these minerals is probably located in the foot or on the slope of upper western side of the rift valley. High concentrations of barite in the sediments probably suggest the presence of a low-temperature hydrothermal vent in the immediate vicinity.

On four stations in central part of the site low-temperature manganese crusts were sampled (Fig. 1); they represent unconsolidated sooty formations of ellipsoidal or flattened shapes, 1-2 cm up to 10-16 cm in sizes. In some instances they form on sediments, in others, on both sediments and basalt fragments.

### Conclusions

1) The vicinity of the transform fault determines the morphological and structural features of the study area; numerous tectonic dislocations of different strikes form a blocky structure and

suggest tectonic activity. In turn, conditions favorable for deep penetration of water forming hydrothermal fluid are created in tectonically active zones.

- 2) The source of hydrothermal plume in bottom waters is probably located on the rift valley side in northwestern part of the study area.
- 3) In the central part of the site (12°56'-12°58'N and 44°54'-44°56'W) in the surface sedimentary layer of the terrace of western valley side stable dispersion haloes of hydrothermal minerals are observed, indicators include: pyrite, barite and iron hydroxides. Low-temperature Fe-Mn formations were sampled here on four stations.
- 4) Rocks showing evidence of hydrothermal-metamorphic recrystallization associated with submeridional faults; sulphide mineralization in metabasalts and peridotites suggest hydrothermal activity.
- 5) The authors hereof consider most promising for massive sulphides the foot and the slope of the upper valley side above the terrace with coordinates 12°56.5'-13°00'N and 44°55.5'-44°57.5'W.


### Acknowledgements

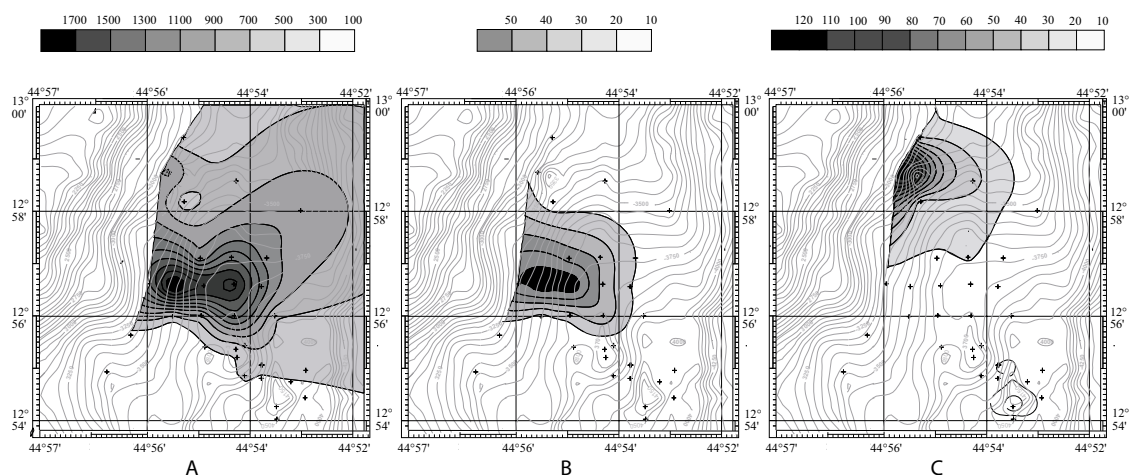
The authors are thankful to the crew of *R/V Professor Logatchev*, and to the research staff of the expe-

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**Figure 4.** Distribution of hydrothermal minerals in surface sediments: (A) Fe-hydroxides; (B) Pyrite; (C) Barite. Crosses - location of sampling stations. The grey scale corresponds to amount of mineral grains (per 1 liter of sediment).



## Sulphide mineralization, volcanic and tectonic activity of the MAR near Sierra Leone F.Z.: 10 cruise R/V “Akademik Ioffe” (preliminary results)

S.Skolotnev<sup>1</sup>, A.Peyve<sup>1</sup>, N.Bortnikov<sup>2</sup>, N.Tsukanov<sup>3</sup>, S.Lyapunov<sup>1</sup>, V.Kolobov<sup>4</sup>, A.Mochalov<sup>2</sup>, D.Krinov<sup>2</sup>, E.Sharkov<sup>2</sup>, N.Razdolina<sup>2</sup>, M.Stoliarov<sup>2</sup>, A.Cipriani<sup>5</sup>

<sup>1</sup>Geological Institute, Russian Academy of Sciences, Moscow, Russia

<sup>2</sup>Institute of Geol. of Ore Deposits, Petrography, Mineralogy and Geochem., Russian Acad. of Sci., Moscow, Russia

<sup>3</sup>Institute of Oceanology, Russian Academy of Sciences, Moscow, Russia

<sup>4</sup>United Institute of Geology, Geophysics and Mineralogy, Russian Academy of Sciences, Novosibirsk, Russia

<sup>5</sup>Instituto di Geologia Marina CNR, Bologna, Italy

The 10th cruise of R/V “Akademik Ioffe” took place in the Central Atlantic from 3 October to 2 November 2001. This was a continuation of the previous expedition of the 22nd cruise R/V “Akademik Nikolaj Strakhov” to 5° - 7° N MAR (Sierra Leone F.Z. area) (Peyve *et al.*, 2000), where mapping by a multi-

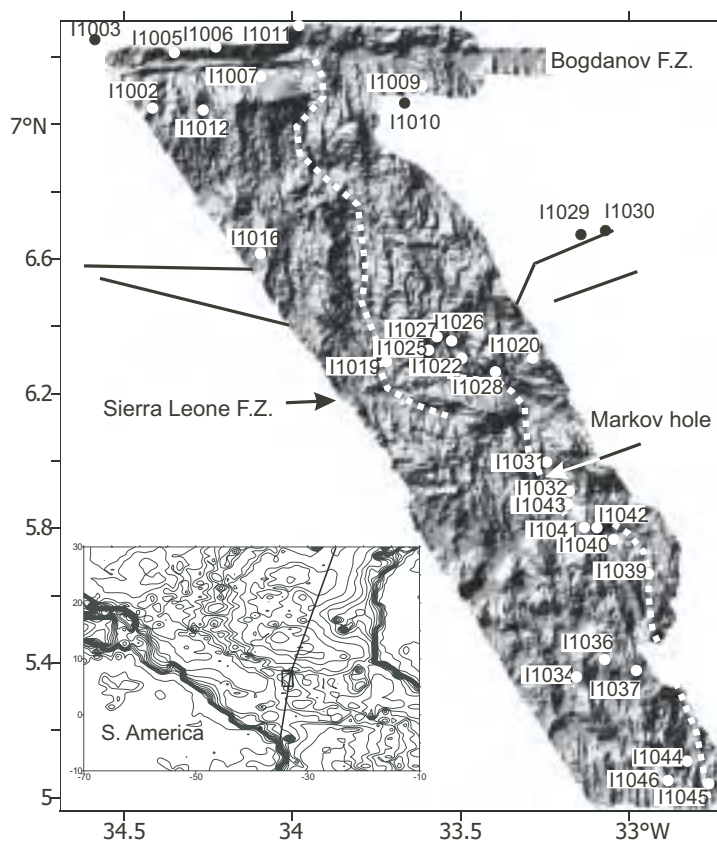
beam EM 12S echosounder and extensive dredging were carried out.

It was shown that this segment is cut by only one major transform fault - 7°10' (Bogdanov\*), which divides this area from the segment to the north which has different structure (Peyve *et al.*, 2001). In the 5° - 7° N area, the MAR rift valley is displaced

by dextral faults including the Sierra Leone F.Z. Rift segments with oblique spreading and overlapping rift valleys are typical to this part of the MAR. The axial part of the MAR is asymmetrical in this region. Elongated ridges predominate to the west from the rift valley, to the east the sea bottom has a chaotic morphology and consists of separate isometric highs and ridges. Several deep basins, including Markov\* hole (5°55' N, 33°11' W), about 5000 m deep, were found in the rift valley (Fig. 1). According to the dredging results the rift valley floor, its ramps and nearby ridge slopes are composed of serpentinous peridotites and gabbro. Basalts are locally distributed. All these peculiarities speak for the predominance of the tectonic processes upon magmatic in this MAR area. Dolerites with sulphide mineralogenesis (cubanite, chalcopyrite and pyrrhotite) were dredged in one of the overlapping segments just north from Sierra Leone F.Z. (Mazarovich *et al.*, 2001).

The current expedition set out with the following aims:

- to dredge different morphostructures of the Bogdanov F.Z.,
- to specify rock distribution in the MAR axial part, especially in the area with sulphide mineralogenesis and
- to study flanks of the MAR crest using multibeam ECHOS XD echosounder and high frequency profiler PARASOUND.



**Figure 1.** Bathymetric map of the study area. Circles - dredge stations; white dotted line - axis of the ridge; black line - PARASOUND tracks

International Research: **Mid-Atlantic Ridge: Skolotnev, et al., cont...**

We have found that basalts compose huge neovolcanic highs (dredgestations S2246, I1039, I1045) on the east rift flank (Fig. 1). These features indicate that powerful impulses of volcanic activity are taking place along with predominating tectonic processes. Only basalts were dredged from the flanks of the MAR crest (dredges I1009, I1010, I1012, I1016, I1029, I1030, I1034, I1036, I1037, I1046) (Fig. 1). Chaotic topography change to regular ridges on the east flank. These data let us think that geodynamic conditions of normal spreading with domination of magmatic processes, changed not far ago to geodynamic regime with the domination of tectonic processes. This happened approximately 2 ma ago, judging from the spreading rate and distance from the rift axis to the area with different morphology and composition.

Basalts with quartz veins (up to 5 mm) containing pyrite, chalcopyrite and atacamite (?), as well as amphibole – chlorite metasomatic rocks, containing pyrite (dredge I1025) were collected near the point where dolerites with sulphides were found in 22 expedition of “Akademik Nikolaj Strakhov” (Fig. 1). Gabbro and numerous metasomatic rocks with sulphide inclusions, quartz and barite veins with sulphide grains (sphalerite?) and non-oxidized massive sulphide ore fragments were collected from the east flank of the Markov hole (dredge I1032) (Fig. 1). Petrography studies have shown that metasomatic rocks were formed after cataclastic gabbros. According to X-ray diffraction studies metasomatic rocks are composed of prehnite, epidote, chlorite and amphibole and ore is composed of chal-

copyrite with some epidote and chlorite. New data (Bazilevskaya, Skolotnev, in press) has shown that thin Fe-Mn oxide films on basalt surfaces from Markov hole (dredge I1043), are fertilized in Cu, Zn, Fe & Mn<sup>2+</sup>, in comparison to Fe-Mn crusts from neighboring regions. These data make it possible to think that recently or maybe today “black smoker” type ore formation is taking place in the Markov hole. If this finding will be confirmed by more detailed studies this will prove the validity of observation made by (Mazarovich, Sokolov, 1998) that ore deposits like “black smoker” are situated in MAR areas with reduced seismicity. The MAR between 5° - 7°N is also characterized by low seismicity. Our observations let us think that combination of intensive tectonic processes and powerful impulsive magmatic activity is favourable for creation of sulphide deposits.

Dredging of the Bogdanov F.Z. has showed that serpentinous peridotites and gabbro predominate there, which is typical of the majority of transform faults.

Study of the sediments structure in depressions on the flanks of the MAR crest with profiler “PARASOUND” has shown that sediments are deformed there by numerous horst structures. This is evidence of widespread distribution of vertical intraplate deformations in this segment of the MAR.


#### Acknowledgements

We are grateful to technicians: V. Velinskiy, A. Nosov, V. Kuznetsov, S. Dremutchev, V. Rastorguev; captain V. Sazonov and crew of the vessel “Akademik Ioffe”.

\* Name approved by the Four-

teenth meeting of the GEBSCO, 17-20 April 2001.

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MOMAR II Workshop - 15-17 June 2002, Horta, Azores

<http://www.ipgp.jussieu.fr/~escartin/MOMAR.html>

**Preliminary results of a recent cruise to the Northern Central Indian Ridge**

Droliya R.K.<sup>1</sup>, Sridhar D.Iyer<sup>5</sup>, Chakraborty B.<sup>5</sup>, Kodagali V.N.<sup>5</sup>, Mukhopadhyay R.<sup>5</sup>, Nanyasi S.K.<sup>5</sup>,  
 Sarma K.V.L.N.S<sup>5</sup>, Rajasekhar R.P.<sup>5</sup>, Misra S.<sup>2</sup>, Ray D.<sup>3</sup>, Andrade R.<sup>4</sup>, Lasitha S.<sup>4</sup>, Varghese J.<sup>4</sup>,  
 Jacob J<sup>5</sup>, Sukumaran N. P<sup>1</sup>, Pednekar A<sup>5</sup>, Furtado R<sup>5</sup>, Nair A.<sup>5</sup>

<sup>1</sup> National Geophysical Research Institute, Uppal Road, Hyderabad-500007

<sup>2</sup> Department of Geology and Geophysics, IIT, Kharagpur, India

<sup>3</sup> Department of geology, Calcutta University, Kolkatta, India

<sup>4</sup> Department of Marine Geology and Geophysics, CUSAT, Cochin

<sup>5</sup> National Institute of Oceanography, Dona Paula, Goa-403004

**Introduction**

The Northern Central Indian Ridge (NCIR) spans from 12° to 2°S (Fig. 1) and constitutes an important regime of accreting plate boundaries of Australia-Africa in the south

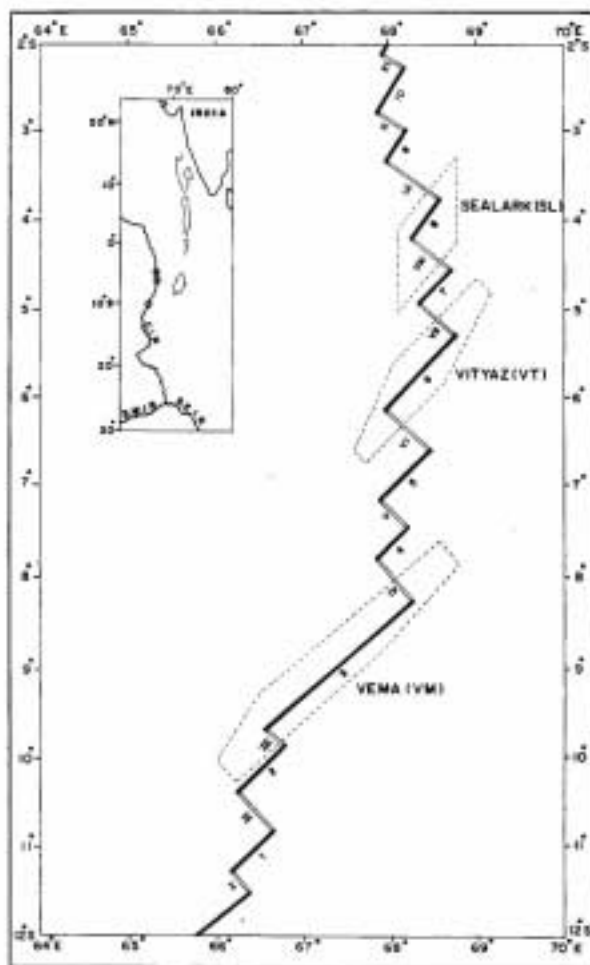
and India-Africa plate in the north separated by the intersection of CIR and WDZ (Wide Deformation Zone). Except the interpretation of few magnetic lines in the Vema Transform area (Kamesh Raju *et al.*, 1997) and

the discussion of tectonic implication of bathymetric and magnetic data of Vema region (Droliya *et al.*, 2000), results of reconnaissance survey during 28<sup>th</sup> cruise of *R/V Sonne* (1983), no data of significance is available from the study areas.

In the NCIR lacunae exist concerning plate kinematics, segmentation pattern, petrologic variations and the influence of Ridge – Transform Interactions (RTI) on plate geometry or on the formation of triple junction. The complex structural features and magmatic processes constrain the formation of the new crust along the CIR and probably play a major role in geochemical and thermal evolution of the study region. Further, probable hydrothermal fluid circulation along this ridge contributes in regulating ocean chemistry. This is probably one of the few areas in the world ocean where the kinematics of slow accreting plate boundaries and associated triple junction formation with low seismic activity remains poorly known.

A 35 days expedition, on board *R/V Sagar Kanya* (Cruise SK-165, 28<sup>th</sup> May to 2<sup>nd</sup> July, 2001) was undertaken under the InRidge programme. This was the 2<sup>nd</sup> cruise to visit NCIR after the one in July-Aug. 1997. The three fold objectives of the present cruise were

- 1) to establish the complexly faulted and segmented nature of the NCIR between the region 3.5°S-10.5°S, 66-66°E,
- 2) to obtain evidence for the nascent



**Figure 1.** Location map of the study areas : Sealark (SL), Vityaz (VT) and Vema (VM). NW-SE oriented double lines are ridge segments. NE-SW trending solid black lines are Transform faults.

## International Research: Indian Ridge: Drolia, *et al.*, cont...

triple junction in the region south of Vityaz and North of Vema Transforms and

- 3) to search for signatures of hydrothermal activity.

### Data Acquisition and processing

The coverage consists of forty five 110-160 km long profiles, oriented N50°E across seven ridge segments on either side of Sealark, Vityaz and Vema Transform faults between latitudes 3°S–10°S. We have collected high quality multi-beam swath bathymetric, gravity and magnetic data over three intersecting regions of Sealark Transform Fault (TF)-NCIR (SL area), Vityaz TF-NCIR (VT area) and Vema TF-NCIR (VM area). Integrated and Global Positioning system (GPS) was used for navigation. The digital magnetic data and analog bathymetric charts were acquired using Geometric Proton Magnetometer and a Honewell-Elac deep Sea Wide beam Echo Sounder. The estimated accuracy of the recorded average depth was 10 m. The multi-beam Hydrosweep system (STN Atlas Elektronik GmbH) was used to obtain swath bathymetric data in the survey area. The system was operated at 15.5 kHz and makes use of 59 Pre Formed Beams (PFBs) with an average beam width of 2.3°, providing swath coverage of twice the water depth. For 100% coverage (insonification), interline

spacing of two nautical miles was used during the survey.

Three major TFs, Sealark, Vityaz and Vema were mapped in detail for the first time. Additionally the Transform just north of Vema TF (christened as Ehrlich Transform) was mapped in detail. Rocks and water samples from axial valley, Ridge-Transform Interaction (RTI) and near-axis seamounts were recovered.

Post-cruise processing involved digitization of echograms and interpolation of magnetic data at 1-minute intervals, and merging of the magnetic field intensity data with bathymetric data. Mathew's correction was applied to the bathymetric data to get corrected depth. In case of any discrepancy we had retained Central beam depths provided by multi beam data. We interpolated the magnetic and bathymetric data at 1-km intervals. The magnetic anomaly was computed by subtracting IGRF 2000 from the observed interpolated total intensity data. We have used the revised ridge-transform geometry of northern CIR (Fig. 1) based on latest satellite – derived gravity map (Sandwell and Smith, 1997). To facilitate the discussion of the accretionary units the ridge segments have been numbered I to IX and the transform faults / Fracture zones as D1 to D9 from south to north.

Using the reversal time-scale of Cande and Kent (1995), we have modeled the observed magnetic profiles and identified the anomalies. We have taken an average spreading rate of 18mm /yr, magnetized layer thickness of 500m and susceptibility contrast of 0.01 c.g.s. units. We were able to identify magnetic anomalies 1 to 3.

Multibeam Swath Bathymetric data were processed to obtain Bathymetric maps of the three regions in the study area. The tectonic elements of the Transform Faults: *i.e.* Transform Tectonized Zone (TTZ), Transform Fault Zone (TFZ) and Principal Transform Displacement Zone (PTDZ); have been estimated by analyzing the multi-beam swath data. The Transform azimuth from trends of the Transform Valleys was measured.

### Results and Discussion

The study region is characterized by seven short ridge-segments and six offsets with the longest offset being the 255 km Vema Transform. The ridge segments are shorter than transform segments with the sense of ridge offsets along the fracture zones being uniformly right lateral.

Our results show that the sea floor depths vary from 1500 to 6200m but are generally in the order of 2500-4000m. The ridge segments are characterized by along-axis depth variations: deepening at segment ends and swallowing at the central portion. In Vema and Vityaz region the ridge segment deepens at centre and shallows towards RTI. The Vityaz TF shallow and narrows towards SW as its width varies from 11 km in NE to 7 km in SW. The maximum –recorded depth is 5400 m in NE part of the TF. The Vema TF is characterized by undulating valley floor having wavelength of 50 km and amplitude varying between 400 and 450 m. The width of the TF varies from 20 km in SW to 35 km in NE with 6-15 km wide floor humps of 200-300 m high in the central part. These humps may suggest that magma is upwelling through discreet feeder channels.



## SWIR Workshop

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Workshop targets:

- synthesise most recent results obtained on the SWIR
- develop plans for future study of the Indian ocean ridge system

Papers from this meeting will be incorporated into a **proceedings volume** in the **electronic journal, G-cube:**

(G3 <http://g-cubed.org/>).

International Research: **Indian Ridge: Drolia, et al., cont...**

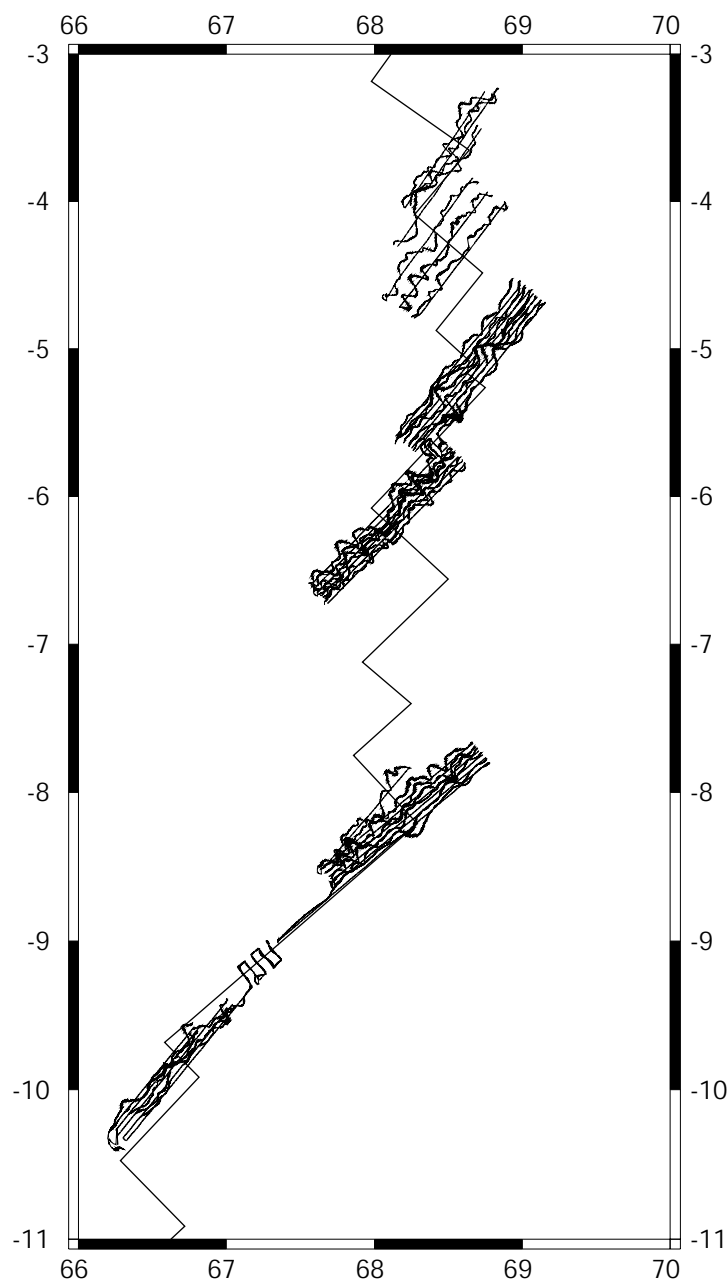
The average depth of the TF floor is 6000m, which shallows to 4615m towards NE with the maximum depth of 6500m recorded on the flanks in the central region.

The characteristics of the RTI, axial valley and TFs including the occurrence of neo-volcanic zones along 29 ridge-normal profiles suggest predominance of tectono-magmatic activities in VT and VM areas and dominance of tectonic activities in SL area.

The Ehrlich Transform (TF just north of Vema TF) reveals a complex morphotectonic characters comprising of alternating trough (4800m) and crests (2300m) suggestive of intense deformation. Detailed analysis of the forces responsible for this deformation may provide some clue about the dynamics of triple junction evolution.

#### Magnetics

Magnetic anomalies up to chron 3



**Figure 2.** Plot of magnetic anomalies perpendicular to cruise track lines in the study area.

have been identified across the ridge segments III to IX on various profiles (Fig. 2) in the three regions. The median valley is characterized by broad amplitude anomaly of 200-400nT in the three regions. Magnetic anomalies associated with fracture zones are relatively subdued. The anomaly amplitude is less than 200nT across the deepest part of the Vema Fracture zone. We have estimated spreading rates along the Africa / India and Africa / Australia plate margins since the time of anomaly 3. The ridge-axis and anomaly 3 have been used for computing the flank spreading rates after matching the observed anomaly shape with the synthetic one. The mean half-spreading rate of 1.8cm/yr in the Sealark and Vityaz regions increases to 2.1 cm/yr to south of the Vema Transform. The nature of intra- and inter-segmental variations in magnetic anomalies suggest that the region between south of Vityaz TF and north of Vema Transform seem to have distinct signatures of Africa-India / Africa-Australia plate motion which could be possibly due to evolving triple junction in the region.

#### Petrology

Basalts from the axial valley are fresh, with a coating of glass (0.5 to 50mm) and contain abundant phenocrysts of plagioclase but rarely of olivine. Dredging the RTI yielded variably altered basalt and ferromanganese crusts and nodules and intensely bioturbated calcareous material with thick coating of Fe-Mn oxide (Mukhopadhyay *et al.*, 1998). During the SK 165, rocks from near-axis seamounts (Station 9DG on western side of segment III) were recovered. These are dominantly columnar while few are pillow basalts, suggesting the probability of eruption of two types of lava flow in the past. The first flow probably formed pillow basalts while the later eruption with columnar structure was emplaced as dyke. The presence of two types of basalts may help explain the rise and fall of tem-

## International Research: **Indian Ridge: Drolia, et al., cont...**

perature across the Curie point and consequently the observed overprint magnetization of the oceanic crust (Drolia *et al.*, 2000). The samples mainly have plagioclase that occurs as phenocrysts but mostly as laths and tabular forms. Olivine is less abundant and in some cases empty vesicles are very common. The occurrence of amphiboles in one sample is intriguing. The basaltic fragments of another near-axis seamount (24DG) are aphyric to sparsely phyrlic and altered.

The manganese nodules with low Mn/Fe ratio (<1) and low values of Cu and Ni than those from basinal regions indicate their possible hydrothermal-hydrogenous origin.

### Summary

The high quality multi-beam swath bathymetric, gravity, magnetic and bathymetric data were collected over three intersecting regions of Northern Central Indian Ridge (NCIR) during a recent cruise on board ORV SagarKanya. Preliminary results suggest along-axis depth variations: deepening at segment ends and shallowing at the segment


centre in Vema and Vityaz region whereas Sealark region depicts deepening at the segment end and shallowing at the segment centre. The Ehrlich Transform (TF just north of Vema TF) reveals a complex morphotectonic character suggestive of intense deformation. The nature of intra- and inter-segmental variations in magnetic anomalies suggest that the region between south of Vityaz TF and north of Vema Transform seem to have distinct signatures of Africa-India / Africa-Australia plate motion which could be possibly due to an evolving triple junction in the region.

### Acknowledgements

We acknowledge the Department of Ocean Development, New Delhi for kindly making *R/V SagarKanya* available for the cruise and the Department of Science and Technology for partial funding (grant # ESS/23/VES/060/99). We thank Dr. M. Sudhakar of National Centre of Antarctic and Ocean Research, for scheduling the cruise and logistic support and the Captain and crew of SK165 cruise for rendering all help.

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

A special double issue of the journal, *Exploration and Mining Geology*, was published on March 21, 2001 (Vol. 8, Nr 3 and 4, Jul. and Oct. 1999), dedicated to the memory of the eminent Russian ocean ridge geologist Sergey Krasnov (1952-1996). The special issue accesses for the first time new Chinese work on volcanogenic massive sulfide (VMS) deposits, as well as related seafloor hydrothermal research by the international community. The Chinese papers report a surge in exploration for and discovery of ancient VMS deposits in P.R. China stimulated by discoveries of active systems at ocean ridges and volcanic island arcs.

### **Peter A. Rona and Zengqian Hou, Guest Editors Preface**

The issue include: Ancient Volcanogenic Massive Sulfide Deposits In China and Modern Seafloor Hydrothermal Deposits (Volcanic Island Arcs and Ocean Ridges)

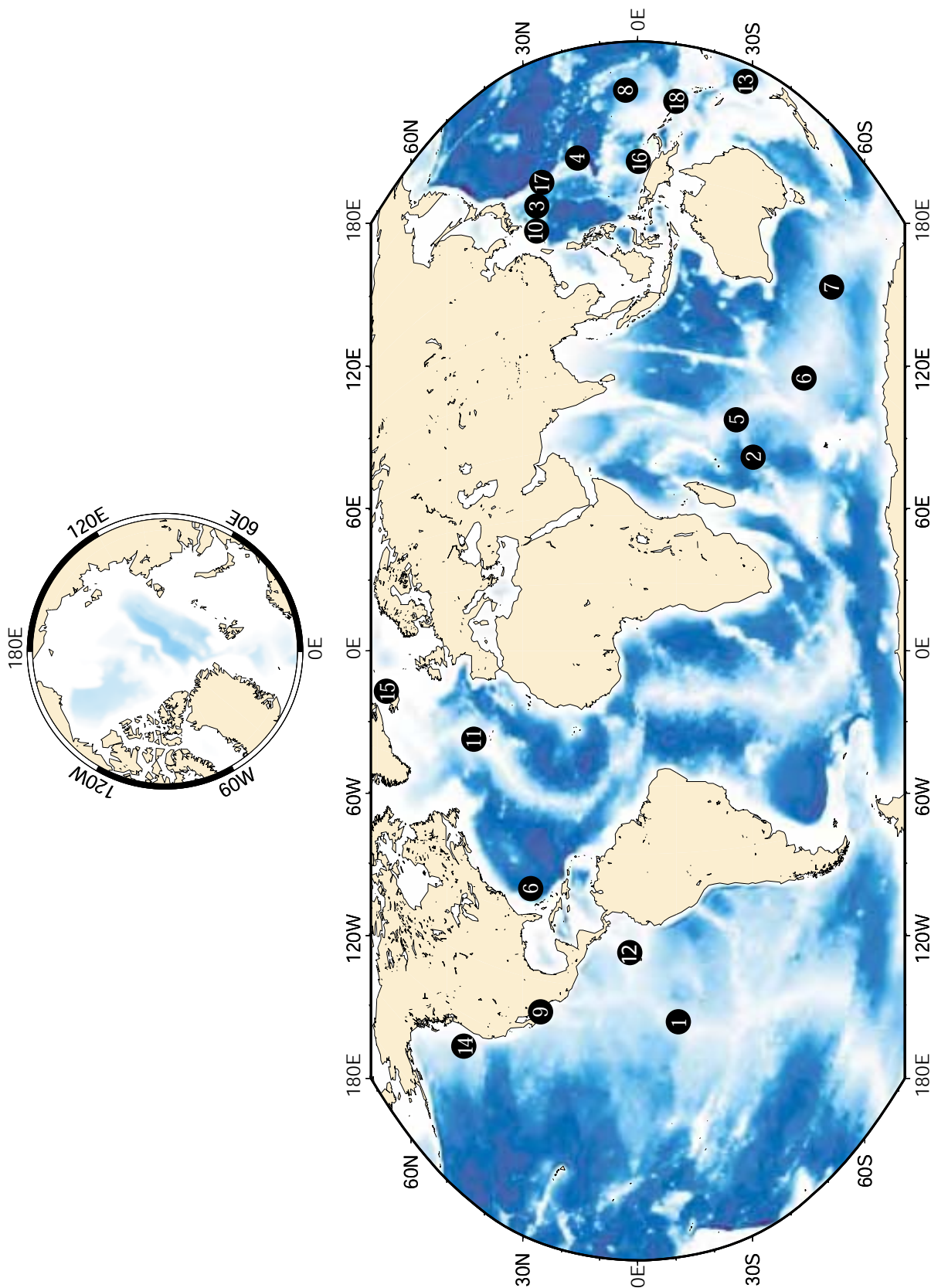
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World Ridge Cruise Map, 2002

A listing of international ridge cruises can be found on the following pages. Each cruise is coded with a number, which represents its location on the map below. The list of world cruises is organized by date. Please submit scheduled and upcoming cruises by filling in the online form at: <http://www.intridge.org/cruiseform.htm>



**Ridge Cruises 2002**

Map No.	Country	PI	Institution	Cruise ID/Location	Research Objectives	Ship	Dates
1	USA	Childress Fisher Van Dover	UCSB Penn State Wm&Mary	East Pacific Rise	Physiological Ecology of Hydrothermal Vent Chemoautotrophic Symbioses. Species Composition and Biodiversity in Mussel Bed Communities of Hydrothermal Vents	Atlantis	Dec 9, '01 - Jan 1, '02
2	Japan	Matsumoto	JAMSTEC	Southwest Indian Ridge Atlantis II FZ	Shinkai 6500 submersible dives at lower crust and mantle outcrop	Yokosuka	Dec 21, '01 - Jan 15, '02
3	Japan USA	Ohara	Hydrogr. Dept. Japan	Parece Vela Basin Philippine Sea	Petrological investigation of the Parece Vela backarc basin spreading center.	Kairei	Jan 6 - Jan 25, '02
1	USA	Von Damm	UNH	East Pacific Rise	East Pacific Rise Hydrothermal Systems: Continued Chemical Instability at 9-10 degrees N vs. Stability at 21 degrees N	Atlantis Alvin	Jan 6 - Feb 10, '02
4	Japan	Arima	Yokohama Ntnl. Univ.	Mariana Trough and Mariana Arc	Sediments and microbio sampling at a hydrothermal area	Kairei	Jan 8 - Feb 24, '02
5	Japan	Takai	JAMSTEC	Rodriguez triple junction	Shinkai 6500 submersible dives at hydrothermal sites	Yokosuka	Jan 21 - Feb, '02
6	USA	Cochran	LDEO	Southeast Indian Ridge	Effects of Changes in Mantle Temperature on Melt Supply and Crustal Accretion: An MCS Reflection and OBH Refraction Study of the Southeast Indian Ridge	Maurice Ewing	Jan 26, '02
7	Japan	Shinohara	ERI	Australia-Antarctica Discordance	Crustal study by OBMs and high resolution deep-tow magnetometer	Hakuho Maru	Jan 27 - Feb 12, '02
8	USA	Larson	URI	Southwest Pacific Basin	Mid-Cretaceous Tectonic Evolution of the Tongareva Triple Junction in the Southwest Pacific Basin	Melville	Mar 24 - Apr 13, '02
9	USA	Cowen	U of HI	Guaymas Basin	The Fate and Implications of Removal of Hydrothermally-Injected NH <sub>4</sub> <sup>+</sup> from Plume Waters	Atlantis Alvin	Apr 26 - May 11, '02

World Ridge Cruise Schedule, 2002, continued...

1	France	Gaill Bris	U. Pierre	East Pacific Rise - PHARE	In-situ experiments and biogeochemical interactions	L'Atalante ROV Victor	May '02
10	Japan	Tamaki	ORI	Southern Okinawa Trough	Deep tow sidescan sonar survey of the rift zone	Hakuho Maru	May 7 - Jun 24, '02
10	Japan	Fujikura	JAMSTEC	Southern Okinawa Trough	Vent biology by Submersible Shinkai 2000	Natsushima	May 13 Ð Jul 5, '02
1	USA	Schouten Tivey Fornari Madonald	WHOI UCSB	East Pacific Rise	Central Anomaly Magnetization High: Constraints on the Volcanic Construction and Architecture of Young Upper Oceanic Crust	Atlantis Alvin/ABE	May 14 - May 23, '02
11	France US Portugal	J. Goslin	U. Brest	Azores-Gibraltar (SIRENA - North Atlantic)	Deployment of six moored autonomous hydrophones 1) to monitor the seismicity of the MAR between the Azores and Gibbs FZ; 2) to produce a high-resolution tomographic model of the upper mantle below a ridge in a ridge/hotspot context	Le Suroit	May 23 - Jun 10, '02
12	USA	Hammond Embley Fornari Shank	NOAA WHOI	Galapagos Rift	Galapagos 25th Anniversary	Atlantis Alvin	May 24 - Jun 4, '02
13	New Zealand	Wright	NIWA U. Kiel VUW	Southern Kermadec Arc, 35-30 S	Multibeam mapping, rock dredging, seafloor photography, and epibenthic fauna sample along volcanoes of the arc front	Tangaroa	May 24 - Jun 14, '02
14	USA	Spieß	SIO	Juan de Fuca Ridge	Juan de Fuca Plate Geodesy: Juan de Fuca Ridge and Cascadia Subduction Zone	Roger Revelle	Jun 8 - Jun 22, '02
10	Japan	Tokuyama Okino Tamaki	ORI	Southern Okinawa Trough	High resolution deep-tow sonar mapping with geochemical sensors	Hakuho-maru	Jun 10 Ð Jun, 24, '02
13	New Zealand	Ronde Massoth	GNS NOAA U. Kiel Kyushu Univ.	Southern Kermadec Arc, 35-30 S	CTD and in situ chemical mapping and fluid sampling if hydrothermal plumes associated with active volcanoes	Tangaroa	Jun 16 - Jun 29, '02
15	Germany Iceland	Devey Scholten	U. Bremen	Tjoernes Fracture Zone	Volcanology of spreading north of Iceland Hydrothermalism of the Grimsey field Geochemistry of the plume-ridge transition	Poseidon	Jun 26 - Jul 14, '02

Map No.	Country	PI	Institution	Cruise ID/Location	Research Objectives	Ship	Dates
14	USA	Carbotte	LDEO	Juan de Fuca Ridge	New Content and Functionality for the RIDGE Multibeam Synthesis	Maurice Ewing	Jul 8 - Aug 7, '02
18	Korea	K-Y Lee	KORDI	North Fiji Basin	KODOS 2002 - Reconnaissance survey of hydrothermal vents.	Onnuri	Jul 14 - Aug 15, '02
17	Japan	Urabe	GSJ	Izu-Bonin Arc Suiyo Seamount	Shallow drilling at hydrothermal site of Suiyo Seamount, Izu-Bonin Arc for sub-vent biosphere	Hakurei-Maru	Jul 17 - Jul 27, '02
17	Japan	Ishibashi	Kyushu Univ.	Izu-Bonin Arc Western Pacific	Sampling of fluid, microbes and sediments from Suiyo Seamount, Archaean Park	Shinsei-Maru	Aug 3 - Aug 15, '02
14	USA	Cowen	U of HI	Juan de Fuca Ridge Endeavour	The Fate and Implications of Removal of Hydrothermally-Injected NH <sub>4</sub> <sup>+</sup> from Plume Waters	Atlantis Alvin	Aug 4 - Aug 25, '02
12	USA	Klein	Duke Univ.	Hess deep	Collaborative Research: Geochemical and Geological Investigation of the Incipient Rift at 2040°N, east of the East Pacific Rise	Melville	Aug 5 - Sep 2, '02
17	Japan	Kinoshita	JAMSTEC	Ogasawara (Bonin) Arc	Longterm observatory at vent sites by Submersible Shinkai 2000 and ROV	Natsushima	Aug 22 - Sep 18, '02
16	Korea	S-M Lee	KORDI	Daeyang Program 2002 Leg 1 Western Bismark Sea volcanoes, PACMANUS	Geophysical, multichannel seismic, near bottom observation, and geochemical and biological investigations of New Ireland Forearc Basin,	Onnuri	Aug 24 - Sep 9, '02
14	USA	Johnson Sharma Voight	UW Dartmouth Field Museum	Juan de Fuca Ridge	Collaborative Research: Direct Sampling of the Oceanic Sub-Surface Biosphere at Old and Young Seamounts.	Atlantis Jason II	Aug 29 - Sep 23, '02
16	Korea	S-M Lee	KORDI	Daeyang Program 2002 Leg 2 Sorol Trough and Caroline Plate	Seafloor mapping and geophysical investigation of the eastern boundary of the Caroline Plate and Sorol Trough, equatorial western Pacific.	Onnuri	Sep 10 - Sep 27, '02

World Ridge Cruise Schedule, 2002, continued...

16	Germany Canada UK	Herzig Hannington Skinner	Freiberg	New Ireland Basin SO-166, CONDRILL	Shallow drilling (5m) of an epithermal (gold) mineralization on top of Conical Seamount	Sonne	Sep 13 - Oct 11, '02
9	USA	Lizarralde	Georgia Tech	Gulf of California	Margins: Collaborative Research: Seismic and Geologic Study of Gulf of California Rifting and Magmatism	Maurice Ewing	Sep 17 - Nov 4, '02
14	USA	Cary Taylor Cavanaugh	U Delaware WHOI NOAA	Juan de Fuca Ridge	Collaborative Research: Eurythermal Adaptations to an Extreme Environment by the Symbionts of the Hydrothermal Vent Polychaete, Alvinella Pompejana. Microbiology and Ecology of Filamentous Sulfur Formation.	Atlantis Lexen, Alvin	Oct 20 - Nov 16, '02
4	Japan	Seama	Kobe Univ.	Mariana Trough	Upper mantle structure by electromagnetic study	Kairei	Oct 28 - Nov 12, '02
1	USA	Forsyth	Brown Univ.	East Pacific Rise	Collaborative Research: Investigation of the Origin of Non-hotspot, Intraplate, Volcanic Ridges and Cross-Grain Gravity Lineations	Melville	Nov 2 - Dec 5, '02
1	USA	Childress	UCSB	East Pacific Rise	Collaborative Research: Studies on the Physiological Ecology of Hydrothermal Vent Chemoautotrophic Symbioses	New Horizon (w/Atlantis)	Nov 9, '01 - Jan 3, '02
12	USA	Becker	U Miami	Costa Rica Rift	Long-Term Monitoring of Off-Axis Hydrogeology on the Costa Rica Rift Using an Instrumented Wireline Multi-Packer System	Atlantis Alvin	Nov 20 - Nov 26, '02
1	USA	Childress Fisher	UCSB Penn State	East Pacific Rise	Collaborative Research: Studies on the Physiological Ecology of Hydrothermal Vent Chemoautotrophic Symbioses	Atlantis Alvin	Nov 30 - Dec 22, '02
14	USA	Voight	Field Museum	Gorda Ridge Monterey Fan Valley seeps	Biological collections at vents and seeps, chemical and geological studies, mapping	Atlantis Alvin	2003

World Ridge Cruise Schedule, 2002, continued...

## National News....

## United Kingdom

An important first piece of news from the UK is that we have recently secured a transition for funding of UK membership of InterRidge from the now disbanded BRIDGE programme to its host funding agency, the Natural Environment Research Council.

With the current subscriptions finally in place, Chris German will now stand down as one of the UK's two national representatives. Paul Dando will continue in that role and a new second representative will be announced shortly (watch this space!)

From a research perspective, we have four items of news worthy of particular mention:-

### 1) 6500m ROV.

The contract for a deep-diving 6500m ROV was placed by SOC, on behalf of the UK research community, with the Woods Hole Oceanographic Institution in late 2001. A team of UK engineers have now begun work with the Woods Hole team in the USA and completion of the build is scheduled for January 2003. Shiptime for delivery and training cruises is currently being negotiated for Spring/Summer 2003 with first research expeditions anticipated in 2004. For further details, contact Prof. Paul Tyler at SOC: [pat8@soc.soton.ac.uk](mailto:pat8@soc.soton.ac.uk) or check the website at: <http://www.soc.soton.ac.uk/OED/ROV/index.php#>

### 2) Seafloor Observatories.

A submission was presented to the NERC in late 2001 to support a UK observatories initiative (B-DEOS) with various mid-ocean ridge interests. Although this proposal, coordinated by Prof. Adam Schultz at the University of Cardiff, was not funded in the first instance, NERC have accepted the scientific merits of the case proposed and have adopted the B-DEOS initiative as an important future programme deserving of support. An important part of current UK thinking is that this may be an initiative best served through collaborative funding e.g. through a wider EC initiative linked to the MOMAR concept (note the InterRidge MOMAR II workshop in Horta, 15-17 June). Further details: [SchultzA@cardiff.ac.uk](mailto:SchultzA@cardiff.ac.uk).

### 3) Census of Marine Life/Chemosynthetic Ecosystems - ChEss.

On March 26<sup>th</sup> 2002, the Sloan Foundation Board met to review the Census of Marine Life (CoML) programme in its entirety, and among its deliberations approved funding of a pilot study "ChEss" to design and

initiate surveys of life in vent and seep communities on the ocean floor. The initial stages of this international project – which, clearly, will have significant interest to many members of InterRidge – will be co-hosted by Profs. Paul Tyler and Chris German at SOC, UK. Funding is for three years, in the first instance, commencing summer 2002. For further details, please contact Prof. Paul Tyler: [pat8@soc.soton.ac.uk](mailto:pat8@soc.soton.ac.uk).

### 4) Vent Aquaria.

An aquarium system for hydrothermal vent animals from the Mid-Atlantic Ridge has been developed, with funding from the EU VENTOX project, at the School of Ocean Sciences, University of Wales-Bangor. Cooled seawater tanks, in a quarantine facility, are supplied with both sulphide and methane. Vent mussels have maintained their symbionts for over 8 months in the system which, it is hoped, will provide a long-term source of living animals for biological studies. For further details, please contact Prof. Paul Dando: [oss109@bangor.ac.uk](mailto:oss109@bangor.ac.uk).

#### Dr. Chris German, National Correspondent

Challenger Div. for Seafloor Processes  
Southampton Oceanography Centre  
European Way, Empress Dock  
Southampton, SO14 3ZH,  
United Kingdom

Tel: +44 1703 596 542  
Fax: +44 1703 596 554  
E-mail: [cge@soc.soton.ac.uk](mailto:cge@soc.soton.ac.uk)

## InterRidge - Japan

Archaeon Park (AP) project (PI: T. Urabe) has been successfully pursued since its start in 2000. For the purpose of interdisciplinary characterization of subseafloor biosphere, the project plan, in 2001, involved drilling by BMS (Boring Machine System) and taking of

many samples from the caldera of Suiyo Seamount, a hydrothermally active volcano of the Izu-Bonin Arc in the Philippine Sea. Some of the preliminary results on geological, geophysical, geochemical, and microbiological studies were presented as six lectures and

five posters at the Ocean Science Meeting (AGU and ASLO) held at Honolulu on 11-15 February 2002 (<http://www.agu.org/meetings/os02top.html>). There were two sessions OS320 and OS31F (Physical, chemical, and biological processes



## National News....

associated with active submarine volcanism in the Pacific I (co-chaired by T. Urabe) and II (co-chaired by M. Kinoshita) for their presentations.

Targets of the Japan InterRidge-related projects of this year (2002) are chiefly in the northwestern Pacific Ocean close to Japan as described below.

The AP project will continue the investigations at Suiyo Seamount between July and September this year. Plans are to drill deeper holes and to deploy many more instruments for long term monitoring than last year. There are three cruises planned; by *R/V #2 Hakurei Maru* for BMS drilling (PI: T. Urabe), *R/V Shinsei Maru* (with ROV Hakuyo 2000; PI: J. Ishibashi), and *R/V Natsushima* (with 15 dives by DSRV Shinkai 2000; PI: M. Kinoshita) of JAMSTEC.

Investigations of ridge processes will also be carried out in the Okinawa Trough backarc basin, southwest of

Japan. Two cruises (with five legs) of *R/V Natsushima* (with DSRV Shinkai 2000; PIs: F. Inagaki, M. Tokeshi, and K. Fujikura) and a cruise by *R/V Hakuho Maru* of ORI, Univ. of Tokyo, are planned in April to July 2002. Shinkai 2000 will dive both in the mid-Okinawa Trough and in the southwestern most Okinawa Trough where many high temperature fluid venting sites have been located. The *Hakuho Maru* cruise (PI: H. Tokuyama) will utilize high resolution deep-tow side-scan sonar system WADATSUMI (ORI, Univ. Tokyo) together with a high quality SeaBeam 2120 system for

bathymetric surveys. For a detailed hydrothermal plume mapping, several MAPRs (Miniature Autonomous Plume Recorder) of NOAA/PMEL (PI: E. Baker) will be attached to WADATSUMI as a collaborative study between Japan and US RIDGE. After the WADATSUMI surveys, CTD hydrocasts (PI: T. Gamo), heat flow measurements (PI: M. Yamano), and rock dredges (PI: R. Shinjo) will be performed to get geophysical and geochemical data of the ridge activity.

Toshitaka Gamo  
Hokkaido University

## For more information on InterRidge-Japan contact:

**Kensaku Tamaki**

Ocean Research Institute,  
University of Tokyo  
1-15-1 Minamidai, Nakano,  
Tokyo 164-8639, Japan

Tel: +81 3 5351 6443  
Fax: +81 3 5351 6445  
E-mail: tamaki@ori.u-tokyo.ac.jp

## Korea

Two research cruises in backarc basin will be conducted by KORDI this year. The first is a short reconnaissance survey of the North Fiji Basin, which will be led by Dr. Kyoung-Yong Lee. During this cruise, scientists will collect rock samples in order to understand the hydrothermal mineralisation process in the backarc environment. This survey will be conducted from August 8 to 15 and upon completion of the surveys *R/V Onnuri* will make port call at Suva, Fiji on August 16-17. The second will consist of survey at three different sites in Papua New Guinea as part of Daeyang Program 2002. The three sites are New Ireland forearc basin south of Lihir Island, PACMANUS hydrothermal vent fields, and seamounts in the western Bismark Sea. The chief scientist of this cruise is Dr. Sang-Mook Lee. This cruise will take place from

August 24 to September 9 with port calls at Rabaul and Madang, Papua New Guinea. The objectives of this cruise are as follows. First, in the New Ireland forearc basin multichannel seismic profiling will be conducted over the Conical, TUBAF and Edison seamounts and the Horst Structure, which are the sites for an IODP proposal. Second, a deep-tow magnetic survey is planned over the sites drilling during ODP Leg 193 in order to resolve the detailed magnetic structure of felsic hydrothermal mound.

Third, a multibeam bathymetric survey will be performed over several seamounts, which form the western Bismark arc. From September 10 to 25, *R/V Onnuri* will also make a number of observations in the Philippine Sea and Caroline Sea on the way back to Korea. These include reconnaissance survey of the eastern boundary of the Caroline Plate and geophysical investigation of the Sorol Trough. Scientists from Australia, Germany, USA, and Papua New Guinea are expected to be involved in the second cruise.

**Sang-Mook Lee, National Corespondent**

Deep-Sea Resources Research Center

Korea Ocean Research and Development Institute

Ansan, P.O. Box 29  
Seoul 425-600, KOREA

Tel: +82 345 400 6363

Fax: +82 345 418 8772

Email: smlee@kordi.re.kr

## National News....

## USA: RIDGE

The Ridge 2000 programme (R2K) is a new, US National Science Foundation (NSF) sponsored research initiative to understand the Earth's spreading ridge system as an integrated whole, from its inception in the mantle to its manifestations in the biosphere and the water column. The R2K Programme was conceived to promote an integrated approach towards the study of mid-ocean ridges. Emerging from community workshops over the past two years, R2K builds directly on the scientific and technological successes of the RIDGE Programme. The scientific motivation for the R2K Programme is encapsulated in the phrase "from mantle to microbes" that expresses the inextricable linkages between processes of planetary renewal in the deep ocean and the origin, evolution and sustenance of life in the absence of sunlight. R2K is at the beginning of an anticipated 12-year programme.

The R2K Science Plan aims for a comprehensive understanding of the relationships among the geological processes of plate spreading at mid-ocean ridges and the seafloor and sub-surface ecosystems that they support. Research carried out under this new programme will be structured within an integrated, whole-system approach that will encompass a wide range of disciplines. Specific geographic areas will be the focus of detailed studies to yield new insights into the linkages among the biological, chemical and geological processes that are involved in crustal accretion and subsequent ridge crest processes. The R2K Programme will support two main research themes: Time-Critical Studies and Integrated Studies.

### Time-Critical Studies

The goal of the Time-Critical Studies element is to understand the nature, frequency, distribution and geobiological impacts of magmatic and

tectonic events along the global mid-ocean ridge system. To this end, the theme focuses on the immediate biological, chemical and geological consequences of active processes on the seafloor. Such processes generally occur as transient events and include volcanic eruptions and intrusions of magma at the ridge axis and faulting related to seafloor spreading.

Since 1993, event detection and response efforts have focused on two short ridge systems (the Juan de Fuca and Gorda Ridges, northeastern Pacific Ocean) and have revolutionized our understanding of these active processes. The field response to events detected using the SOSUS array (the Navy's cabled hydrophone system in the northeastern Pacific Ocean) has provided fundamental new information about the linkages between volcanic events at the seafloor, the development of hydrothermal plumes in the ocean above the ridge crest, hydrothermal circulation and vent biota.

Under the R2K Programme, Time-Critical Studies are dedicated to facilitating rapid-response missions that can observe, record and sample these critical transient phenomena in the ocean above the mid-ocean ridge as well as on the seafloor itself. In the initial phases of this element, the programme will be restricted to the northeast Pacific where real time detection is possible through the SOSUS array and where the facilities are available for a rapid response.

### Integrated Studies

The Integrated Studies theme of R2K is intended as a programme of focused, whole system research of global mid-ocean ridge processes. This component addresses the complex, interlinked array of processes that support life at and beneath the seafloor as a consequence of the flow

of energy and material from Earth's deep mantle, through the volcanic and hydrothermal systems of the oceanic crust, to the overlying ocean. Moreover, this part of the programme recognizes that the complex linkages between life and planetary processes at mid-ocean ridges can only be understood through coordinated studies that span a broad range of disciplines. Thus, Integrated Studies will consist of multidisciplinary research that is focused on a small number of pre-selected "type" areas that are designed to characterize segments of the mid-ocean ridge system. The objective of Integrated Studies is to develop quantitative, whole-system models through coordinated and interdisciplinary experiments. It will be necessary for scientists to understand the interactions and linkages between the volcanic, tectonic, geochemical and biological systems to achieve this goal.

The Integrated Studies theme will initially focus on three sites that were chosen on the basis of a community vote and a review by a special R2K Integrated Site Selection Panel (<http://R2K.bio.psu.edu/ISPANELRPT.htm>). These sites will be centered on a portion of:

- 9-10°N segment of the East Pacific Rise;
- The Endeavour Segment of the Juan de Fuca Ridge;
- Either the East or Central Lau Basin Spreading Center.

### Programme Status

The R2K Programme officially began October 15, 2001, when the office opened at Penn State University. Charles Fisher, a professor of biology at Penn State University is chairing the Steering Committee for the programme with guidance from an Executive Committee consisting of Deborah Smith from WHOI, James Cowen from

## National News....

the University of Hawaii, and David Christie from Oregon State University. In addition to Fisher, the R2K programme office has three full time staff members. Deborah Hassler is the Ridge 2000 programme coordinator. She is a graduate of the MIT/WHOI Joint Programme in Oceanography, and joined the programme following her NSF sponsored Postdoctoral Fellowship at Harvard University with Roberta Rudnick. Patty Nordstrom is the new programme assistant. Patty has a MS degree in extension education and brings a wealth of organizational, web, and practical experience to the office. Liz Goehring is the education and outreach coordinator for the programme. Liz had 10 years of experience as a systems engineer with IBM, before she obtained a MS degree in ecology, became involved in secondary education outreach activities and then taught for several years in the public school system.

Two workshops were conducted in early 2002, one for scientific background and one for planning. These workshops were designed to provide opportunities for a broad cross-section of scientists and engineers to share information about the Integrated Study sites and to participate in planning the implementation of the research programme.

The Community Education Workshop was held in Long Beach, CA Feb. 25-27, 2002. Approximately 110 people attended. The primary purpose of this workshop was to provide a forum for community education and the sharing of data among all investigators wishing to write proposals for work at one of the Integrated Study sites. Each day was devoted to one Integrated Study site and featured several in-

vised speakers, a discussion led by an interdisciplinary panel after each talk, and general poster sessions. Speaker notes and figures, white papers, available data sets, maps, publications, and bibliographies from the workshop can be found at the R2K website.

Implementation plans for each of the initial Integrated Study sites were developed at an open Implementation Plan Workshop on April 7-8, 2002 in Albuquerque, NM. These plans identified the geographic focus about which the nested components of each Integrated Study will be centered and provided the guidelines for the components that will constitute the set of Integrated Studies necessary at each site.

The NSF Programme Announcement for R2K is available on the NSF and R2K websites and proposals for funding work at the three Integrated Study sites will be considered beginning with the August 15, 2002 Ocean Sciences (OCE) target date. The results of the Community Education and Implementation Plan Workshops are also available on the web site. R2K proposals are subject to the normal peer-review process and will be reviewed by the regular NSF Ocean Science Division Panels. Additionally, the R2K Steering Committee will perform a relevancy review of all R2K proposals.

An important component of the R2K programme is a strong commit-

ment to data management and the rapid dissemination of metadata and data. Sharing data will maximize technology transfer across the programme, encourage integration of science, coordination of research, and the construction and testing of hypotheses. R2K is a time limited programme, thus all data collected will be rapidly released for maximum benefit to all. A draft statement regarding this policy is available on the R2K web site for comment.

Along with the programme elements discussed above, R2K is sponsoring a postdoctoral fellowship programme. The fellowship is intended to foster cross-disciplinary fertilization by providing opportunities for individuals to broaden their research expertise as well as to expand the breadth of ridge science.

#### Contact Us



To join the mailing list, for timetables, data, upcoming meetings and workshops, contacts and other information about the programme, email us at [ridge2000@psu.edu](mailto:ridge2000@psu.edu), see the website at <http://R2K.bio.psu.edu> or call 814-865-RIDG.

#### For more information contact:

##### RIDGE Office

208 Mueller Laboratory  
The Pennsylvania State University  
University Park, PA 16802,  
USA

Tel: +1 814 865 3365  
Fax: +1 814 865 9131  
E-mail: [ridge2000@psu.edu](mailto:ridge2000@psu.edu)  
URL: <http://R2K.bio.psu.edu>

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>**

## National News....

## MauRidge

By creating the Mauritius Oceanographic Institute (MOI) in January 2000, Mauritius has expressed its deepest interest towards ocean exploration and research. The idea of setting up such an institute was triggered by the fact that the Republic of Mauritius has an EEZ which is 1.9 million km<sup>2</sup> and, by the time of its creation, there was an urgent need to submit a claim to the United Nation Commission on the Limits of the Continental Shelf (UNCLCS).

The interest of the MOI to undertake ridge research was born from the fact that part of the Central Indian Ridge (CIR) falls within the EEZ of the Republic of Mauritius. Furthermore, ridge research is in its burgeoning stage and joining with the rest of the international community could only

be beneficial to the Mauritian scientists in terms of training and experience in that new area of research.

The academic and economic benefit that could be extracted from undertaking ridge research are significant to motivate and arouse the enthusiasm of Mauritian scientists to be among those in the front row of such scientific activities.

The increasing interest of the government of the Republic of Mauritius towards marine research, particularly ridge research, is visible in its action:

three foreign scientific cruises obtained the approval of the Government of Mauritius to run scientific expedition on the part of the CIR falling in our EEZ. We are presently working on bathymetric and magnetic data collected from the area limited by 18° S and 20.6° S along the CIR.

With the above-mentioned interest towards ridge research and particularly on the CIR, Mauritius is in the process of forming a national ridge research initiative: the Mauritius Ridge Research Group.

### Daniel MARIE

Mauritius Oceanography Institute  
4th Floor France Centre  
Victoria Avenue  
Quatre Bornes  
MAURITIUS

Tel: +230 427 4434  
Fax: +230 427 4433  
Email: moi@intnet.mu

## France

As planned, the Dorsales programme has ended last December, after 8 years of existence. The funding agencies (CNRS and IFREMER) are not suggesting that the French community should stop working on mid-ocean ridges. But they encourage the community to spend some time thinking about what should be our new orientations, and to propose a new plan for 2003 with focused objectives. In that sense, 2002 is a year of transition, during which France remains a principal member of InterRidge.

Several workshops have been organized during the passed six months to discuss these future issues.

At the first workshop held in Roscoff, in October 2001, the French community has agreed to concentrate efforts on long term observation and monitoring of active processes at mid-ocean ridges. This new orientation is

in agreement with the international context. Canada, Japan and the US have initiated long term observation programmes and are ready to install seafloor observatories.

Two further workshops (in March and April respectively) discussed possible targets. The first target will be the Mid-Atlantic Ridge south of Azores (MOMAR area). This area has the advantage of including three major hydrothermal fields (Menez Gwen, Lucky Strike and Rainbow) which cover various depths and lithologies.

French scientists have been very active in this area during the last decade, in the context of European programmes. Moreover, this site has been selected by InterRidge. The second target will be the East Pacific Rise at 13°N. This area will be more intensively targeted by biological studies, since the French biologists want to benefit from their record of 20 years of observation. In parallel, some activity will be maintained in the southern EPR, which corresponds to the fastest portion of the global ridge system.

For more information on the French programme contact:

### Catherine Mével,

Laboratoire de Géosciences Marines  
Université Pierre et Marie Curie  
4 Place Jussieu, Tour 26, 3ème étage  
75252 Paris Cedex 05, FRANCE

Tel: 33-1-44-27-51-93  
Fax: 33-1-44-27-39-11  
E-mail: mevel@ccr.jussieu.fr

## National News....

## Canada: CanRidge

Canadian ridge scientists and students will be participating in two field programs in the Northeast Pacific in Summer 2002, both using the ROPOS remotely-operated submersible. The first (July 12 to August 5, 2002) will be a collaborative cruise with the NOAA VENTS program in which ROPOS will be mobilised on the University of Washington research vessel *Thomas G. Thompson*. Along with NOAA and University of Washington colleagues, a Canadian team led by Prof. Steve Scott of the University of Toronto will first complete work at Axial Volcano on the Juan de Fuca Ridge, as part of the NeMO (New Millennium Observatory) program, which began in the summer of 1998. The focus of the NeMO program has been the documentation of the geological and biological events that followed a January 1998 seafloor eruption in the eastern portion of the Axial caldera. Following the work at Axial Volcano the cruise will move north to Explorer Ridge, a spreading ridge located to the north of the Juan de Fuca Ridge. Hydrothermal activity was first discovered on two Canadian cruises to Explorer Ridge in 1984, and portions of the ridge were revisited with ROPOS in the mid-

1990's. Several very large, hydrothermally active, polymetallic sulphide mounds have been found along a portion of the ridge that shoals to <2000m. While the area's notoriously bad weather has hampered extensive exploration, it is hoped that the larger, more stable platform offered by the Thompson will permit more extensive mapping and sampling of the Explorer Ridge fauna and sulphide deposits during the 12 days that the vessel will be on site.

Upon its return to port in Victoria, British Columbia on August 5, ROPOS and its deep-sea winch will be transferred from the deck of the *Thomas G. Thompson* directly to the deck of the Canadian vessel *John P. Tully*. The Tully will then set sail for a week of diving and exploration on a gas hydrate site on the Vancouver Island margin with a group headed by Prof.

Ross Chapman of the University of Victoria. On August 12, Prof. Chapman's group will be replaced by a new scientific party, led by Prof. Kim Juniper of the Université du Québec à Montréal. The Tully will then sail for the Endeavour Segment of the Juan de Fuca Ridge for sample collections, and the deployment and recovery of long-term faunal colonisation and mineral weathering experiments. Operations at Endeavour Segment will be mixed with dives at several nearby ODP drill sites, where ROPOS will be used for *in situ* downloading of data from instruments in sealed drill holes. One area of particular interest is Middle Valley where it is hoped that instruments in CORKed holes recorded last winter's major seismic event at Middle Valley. The Tully cruise will end in Victoria, British Columbia on August 22.

For more information on CanRidge contact:

**S. Kim Juniper, Canadian InterRidge Correspondent**

GEOTOP

Université du Québec à Montréal

P.O. Box 8888, Station A

Montréal, Québec, H3C 3P8

Canada

Tel: +1 514 987-3000 ext. 6603

Fax: +1 514 987 4647

E-mail: juniper.kim@uqam.ca

## Marine Protected Areas in Canada

University of Quebec, Endeavour hot vents area:

<http://www.er.uqam.ca/nobel/oasis/index2.html>

One of ten areas of interest set up as part of the  
Marine Protected Areas programme:

<http://www.dfo-mpo.gc.ca/oceanscanada/newenglish/htmdocs/mpas/endeavour.htm>

<http://www.pac.dfo-mpo.gc.ca/oceans/mpa/pilots.htm>

The Remotely Operated Platform for Ocean Science: <http://ropos.com/>

## Upcoming Meetings and Workshops

### Calendar of MOR Research related events (2002)

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>

- 
- |  |   |
|--|---|
| 11-15 February 2002  | <b>Ocean Sciences Meeting.</b> Honolulu, Hawaii   |
| 5-8 March, 2002  | <b>Oceanology International 2002.</b> London, UK  |
| 16-19 April, 2002  | <b>Underwater Technology 2002 International Symposium.</b> Tokyo, Japan   |
|  17-19 April, 2002        | <b>SWIR Workshop.</b> SOC, UK   |
| 20-25 April, 2002  | <b>"Minerals Of The Ocean" - International Conference.</b> St. Petersburg, Russia   |
| 21-26 April, 2002  | <b>European Geophysical Society.</b> Nice, France   |
| 28 May - 1 June, 2002  | <b>AGU Spring Meeting.</b> Washington, DC USA   |
|  10-12 June 2002        | <b>IR Next Decade Workshop.</b> Bremen, Germany   |
|  15-17 June 2002        | <b>MOMAR Workshop,</b> Horta (Azores, Portugal)   |
| 9-12 July, 2002  | <b>Western Pacific Geophysics Meeting.</b> Wellington, New Zealand  |
| 4 - 7 September, 2002  | <b>Plume Magmatism.</b> Petrozavodsk, Russia  |
|  13-14 September 2002   | <b>Steering Committee Meeting.</b> Italy  |
|  9 - 13 September, 2002 | <b>InterRidge Theoretical Institute (IRTI) Thermal Regime of Ocean Ridges and Dynamics of Hydrothermal Circulation.</b> University of Pavia, Italy. |
| 25-26 September, 2002  | <b>Unmanned Underwater Vehicle Showcase.</b> SOC, UK  |
| 6-10 December, 2002  | <b>AGU 2002 Fall Meeting.</b> San Francisco, USA  |
| 7-11 April, 2003   | <b>EGS-AGU-EUG Joint Assembly.</b> Nice, France   |

Email the InterRidge Office ([intridge@ori.u-tokyo.ac.jp](mailto:intridge@ori.u-tokyo.ac.jp)) with information on upcoming international ridge related meetings. We will publish them in IR news and add also post the latest information on the IR website.



## Upcoming Meetings and Workshops



## InterRidge Next Decade Workshop Call for white papers!

*10-12 June 2002, Bremen, Germany*

<http://www.intridge.org/ndir.htm>

**Organiser:** Colin Devey (Germany)

InterRidge Initiative will reach the end of its first 10 year period in 2003, providing an opportunity to assess what has been achieved and to plan for the next decade of ridge research.

This assessment and planning will take various formats, but a very important part of the process is this workshop. The aim of this workshop is to establish the goals for InterRidge for the next decade and to determine the organisational structure necessary to reach them.

For the workshop to be successful it is imperative that the views of the whole InterRidge community are incorporated into its planning and execution. Please take the time now to access the Workshop Web page and register yourself for participation at the workshop. If you cannot make room in your schedule to attend, please submit a summary of what you think InterRidge should try and achieve in the next decade in the form of a white paper (all information about what you might want to include are on the website).

### Provisional Agenda

#### *June 10th*

Vision statements from leaders in the fields of spreading axis biology, geology, geophysics and technology. The aim of this session is to set the framework for the workshop and to provide a common basis for the working group discussions

Discussions in discipline-orientated working groups (Biology, Geology, Geophysics, Technology...). The aim of these discussions is for each discipline to formulate and rank in terms of importance and feasibility their visions and aims for the next decade.

#### *June 11th*

Report session of disciplinary working groups. Discussion on the present InterRidge Working Group structure: are all working groups necessary, how long should they exist, do we need new one?

Interdisciplinary discussion in ad hoc working groups (if necessary) to define structure/organisation of InterRidge for the next decade and the finances necessary

#### *June 12th*

Plenary wrap-up, presentation of the draft plan for InterRidge Next Decade, division of responsibility and time plan for finishing official Next Decade plan

Working group leaders (both from the discipline-defined groups and the structure and finance groups if created) to write up texts for the Project Plan

Your participation in the future of InterRidge is important. Please make an input however you can. We look forward to seeing you in June!

## Upcoming Meetings and Workshops



## South West Indian Ridge Workshop (SWIR)

17-19 April 2002

Southampton Oceanography Centre, UK

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

### Organising Committee:

C. Mével, Co-chair ([mevel@ccr.jussieu.fr](mailto:mevel@ccr.jussieu.fr)),  
 L. Parson, Co-chair ([Imp@soc.soton.ac.uk](mailto:Imp@soc.soton.ac.uk)),  
 A. M. Adamczewska ([intridge@ori.u-tokyo.ac.jp](mailto:intridge@ori.u-tokyo.ac.jp))  
 H.J.B. Dick ([hdick@whoi.edu](mailto:hdick@whoi.edu)),  
 D. Sauter ([Daniel.Sauter@east.u-strasbg.fr](mailto:Daniel.Sauter@east.u-strasbg.fr)),  
 K. Tamaki ([tamaki@ori.u-tokyo.ac.jp](mailto:tamaki@ori.u-tokyo.ac.jp)),

Papers from this meeting will be incorporated into a **proceedings volume** in the **electronic journal, G-cube**: (G3 <http://g-cubed.org/>).

## Mantle Plumes and Metallogeny

International Symposium

September 4–7, 2002, Petrozavodsk, Russia

<http://www.intridge.org/plume02.pdf>

### Proposed Symposium topics:

General issues of mantle plume evolution  
 Mantle plumes and chemical geodynamics  
 Plumes and rifting, including pre-rift regime  
 Recent and Cenozoic mantle plumes in continental and oceanic lithospheres  
 Mantle plumes in the Phanerozoic and Precambrian  
 Mantle plumes as manifest in geophysical fields and deep structure  
 Numerical modeling of inception and development of mantle plumes  
 Mantle plumes and metallogeny  
 Plumes and biological catastrophes in the Earth's history

Pre- and post-Symposium field trips will introduce you to unique manifestations of plume magmatism in the Early Proterozoic of Karelia and Devonian magmatism of the Kola Peninsula and to the geological setup of Archean greenstone belts.

## Upcoming Meetings and Workshops

**The Fourth Unmanned Underwater Vehicle Showcase**

*25-26 September 2002,  
Southampton Oceanography Centre, UK*

**<http://www.uuvs.net/>**

**The Exhibition:** the showcase for leading manufacturers of vehicles and subsystems from around the world.

**The Conference:** a leading edge technical programme put together by a committee of industry experts featuring presentations from global leaders in the industry

**The Demonstrations:** see the vehicles and systems in operation in the dockside waters adjacent to SOC.

**MOMAR II Workshop**

*15-17 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/>

**Organisers:** Javier Escartin, France, ([escartin@ccr.jussieu.fr](mailto:escartin@ccr.jussieu.fr))  
Ricardo Serrão Santos, Azores ([ricardo@horta.uac.pt](mailto: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 constraints
- 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

**1<sup>st</sup> 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 will be held in the historic lecture theatre of the University of Pavia, situated approximately 30 miles/50 km south of Milano. The field course will be to the northern Apennine ophiolites, where exceptional hydrothermal alteration exposures can be observed. The workshop will be held at Sestri Levante.

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](mailto:intridge@ori.u-tokyo.ac.jp)).

We look forward to seeing you in Italy!

Chris German ([cge@soc.soton.ac.uk](mailto:cge@soc.soton.ac.uk)) & Jian Lin ([jlin@whoi.edu](mailto:jlin@whoi.edu))



## InterRidge National Correspondents

### Australia

Dr. Trevor Falloon  
Geology Department  
University of Tasmania  
GPO Box 252C, Hobart  
Tasmania 7001, Australia  
E-mail: Trevor.Falloon@utas.edu.au

### Austria

Dr. Monika Bright  
Marine Biol., Institute for Ecology  
and Conservation Biology  
University of Vienna, Althanstr. 14,  
A-1090 Vienna, Austria  
E-mail: monika.bright@univie.ac.at

### Brazil

Dr. Suzanna Sichel  
Dept. de Geologia - Lagamar UFF  
Av. Litorânea s/n° 4° andar  
CEP: 24210-340  
Gragoatá Niterói RJ Brazil  
E-mail: Susanna@igeo.uff.br

### Canada

Dr. Kim Juniper  
GEOTOP  
Universite du Québec à Montréal  
P.O. Box 8888, succursale Centre Ville,  
Montréal, Québec, H3C 3P8, Canada  
E-mail: juniper.kim@uqam.ca  
and

Dr. Kathryn M. Gillis  
School of Earth and Ocean Sciences  
University of Victoria, MS 4015  
Victoria, BC V8W 2Y2, Canada  
E-mail: kgillis@uvic.ca

### China

Dr. Wang Zhihong  
Laboratory of Lithosphere Tectonic  
Evolution  
Institute of Geology and Geophysics  
Chinese Academy of Sciences  
Beijing 100029, P.R. China  
E-mail: z-hwang@263.net

### Denmark

Dr. John Hopper  
Danish Lithosphere Centre  
Oester Voldgade 10, Kobenhavn  
DK-1350, Denmark  
E-mail: jrh@dlc.ku.dk

### France

Dr. Catherine Mével  
Laboratoire de Geosciences Marines  
IPGP - Université Pierre et Marie Curie  
Case 110, 4 place Jussieu,  
75252 Paris cedex 05, France  
E-mail: mevel@ccr.jussieu.fr

### Germany

Dr. Colin Devey  
Fachbereich 5 Geowissenschaften  
Universität Bremen  
Postfach 330440  
D-28334 Bremen, Germany  
E-mail: cwdevey@uni-bremen.de

### Iceland

Dr. Karl Gronvold  
Nordic Volcanological Institute  
University of Iceland  
Grensasvegur 50  
IS 108 Reykjavik, Iceland  
E-mail: karl@norvol.hi.is

### India

Dr. Sridhar D. Iyer  
E-mail: iyer@csnio.ren.nic.in  
and

Dr. K.A. Kamesh Raju  
E-mail: kamesh@csnio.ren.nic.in  
National Institute of Oceanography  
H.O. Dona Paula  
Goa 403 004, India

### Italy

Prof. Enrico Bonatti  
Istituto di Geologia Marina C.N.R.,  
Universita di Bologna,  
Via P. Gobetti 101,  
I-40129 Bologna, Italy  
E-mail: bonatti@ldeo.columbia.edu  
and

Dr. Paola Tartarotti  
Dipartimento di Geologia, Paleontologia  
e Geofisica, Universita di Padova,  
Via Giotto 1, I-35137 Padova, Italy  
E-mail: tar@dmp.unipd.it

### Japan

Prof. Nobuhiro Isezaki  
Department of Earth Sciences,  
Faculty of Science, Chiba University,  
Yayoi-cho 1-33, Inage-ku, Chiba-shi,  
Chiba 260, Japan  
E-mail: ishi@eqchem.s.u-tokyo.ac.jp

### Korea

Dr. Sang-Mook Lee  
Marine Geology and Geophysics Division  
KORDI, Ansan, P.O. Box 29  
Seoul 425-600, Korea  
E-mail: smlee@kordi.re.kr

### Mauritius

Dr. Daniel P. E. Marie  
Mauritius Oceanography Institute  
4th Floor, France Centre  
Victoria Avenue, Quatre Bornes, Mauritius  
E-mail: moi@intnet.mu

### Mexico

Dr. J. Eduardo Aguayo-Camargo  
Inst. de Ciencias del Mar y Limnología  
U. Nacional Autónoma de México  
Apartado Postal 70-305  
Mexico City, 04510, Mexico  
E-mail: jaquayo@mar.icmyl.unam.mx

### Morocco

Prof. Jamal Auajjar  
Université Mohammed V  
Agdal Ecole Mohammadia des Ingenieurs  
Départ. de Genie Minéral, Avenue Ibn Sina,  
BP 765, Agdal, Rabat 10 000, Morocco  
E-mail: auajjar@emi.ac.ma

### New Zealand

Dr. Ian Wright  
Nat. Inst. of Water and Atmospheric  
Research, P.O. Box 14-901  
Wellington 3, New Zealand  
E-mail: i.wright@niwa.cri.nz

### Norway

Prof. Rolf Pedersen  
Institute of Solid Earth Physics  
University of Bergen  
Allegt. 41, 5007 Bergen, Norway  
E-mail: rolf.pedersen@geol.uib.no

### Philippines

Dr. Graciano P. Yumul, Jr.  
National Institute of Geological Sciences  
University of the Philippines  
Diliman, Quezon City, 1101, Philippines  
E-mail: rwg@i-next.net

### Portugal

Prof. Fernando Barriga  
Departamento de Geologia  
Facul. de Ciências  
Universidade de Lisboa  
Edifício C2, Piso 5, Campo Grande  
PT 1700 Lisboa, Portugal  
E-mail: fernando.barriga@cc.fc.ul.pt

### Russia

Dr. Sergei A. Silantyev  
Vernadsky Inst. of Geochemistry  
Russian Academy of Sciences  
19, Kosygina Street  
Moscow 117975, Russia  
E-mail: silant@chat.ru

### SOPAC

Dr. Russell Howorth  
SOPAC,  
Private Mail Bag,  
Suva, Fiji  
E-mail: russell@sopac.org.fj

### South Africa

Dr. Anton P. le Roex  
Department of Geological Sciences  
University of Cape Town  
Rondebosch 7700, South Africa  
E-mail: alr@geology.uct.ac.za

### Spain

Dr. Juan José Dañobeitia  
Inst. Jaime Almera de Ciencias de la  
Tierra, CSIC  
C/Lluís Sole i Sabaris s/n  
08028 Barcelona, Spain  
E-mail: jjdanobeitia@ija.csic.es

### Sweden

Dr. Nils Holm  
Dept. of Geology and Geochemistry  
University of Stockholm  
S-106 91 Stockholm, Sweden  
E-mail: nils.holm@geo.su.se

### Switzerland

Dr. Gretchen Früh-Green  
Department of Earth Sciences  
ETH-Z, Sonneggstr. 5  
CH-8092 Zurich, Switzerland  
E-mail: gretli@erdw.ethz.ch

### United Kingdom

Dr. Chris German  
Challenger Division for Seafloor Processes  
Southampton Oceanography Centre  
European Way, Empress Dock  
Southampton, SO14 3ZH, UK  
E-mail: cge@soc.soton.ac.uk

### USA

Dr. Charles Fisher, RIDGE Chair  
RIDGE Office  
Department of Biology,  
Pennsylvania State University,  
208 Mueller Laboratory,  
University Park PA 16802, USA  
E-mail: cfisher@psu.edu



## InterRidge Steering Committee

### **Dr. Kensaku Tamaki**

InterRidge Chair  
Ocean Research Institute,  
University of Tokyo  
1-15-1 Minamidai, Nakano,  
Tokyo 164-8639, Japan  
Tel: + 81 3 5351 6443  
Fax: + 81 3 5351 6445  
E-mail: tamaki@ori.u-tokyo.ac.jp

### **Prof. Fernando Barriga**

Departamento de Geologia  
Facul. de Ciencias  
Universidade de Lisboa  
Edifício C2, Piso 5, Campo Grande  
PT 1700 Lisboa, Portugal  
Tel: +351 1 750 0066  
Fax: +351 1 759 9380  
E-mail: fernando.barriga@cc.fc.ul.pt

### **Dr. Phillippe Blondel, ad hoc**

Department of Physics  
University of Bath  
Bath BA2 7AY, UK  
Tel: + 44 1225 826 826  
Fax: + 44 1225 826 110  
E-mail: pypsb@bath.ac.uk

### **Prof. Enrico Bonatti**

Instituto di Geologia Marina C.N.R.  
Universita di Bologna  
Via P. Gobetti 101  
I-40129 Bologna, Italy  
Tel: + 39 51 639 8935  
Fax: + 39 51 639 8939  
E-mail: bonatti@ldeo.columbia.edu

### **Dr. Dave M. Christie**

COAS, Oregon State University  
104 Oceanography Adm. Building  
Corvallis, OR 97331-5503, USA  
Tel: + 1 541 737 5205  
Fax: + 1 541 737 2064  
E-mail: dchristie@oce.orst.edu

### **Prof. Paul R. Dando**

School of Ocean Sciences  
University of Wales-Bangor,  
Menai Bridge  
Anglesey, LL59 5EY, UK  
Tel: + 44 1248 382 904  
Fax: + 44 1248 382 620  
E-mail: oss109@sos.bangor.ac.uk

### **Dr. Colin W. Devey**

Fachbereich 5 Geowissenschaften  
Universität Bremen  
Postfach 330440  
D-28334 Bremen, Germany  
Tel: + 49 421 218 9205  
Fax: + 49 421 218 9460  
E-mail: cwdevey@uni-bremen.de

### **Dr. Jérôme Dymont**

CNRS UMR 6538  
Institut Univ. Europeen de la Mer  
Universite de Bretagne Occidentale  
1 Place Nicolas Copernic  
29280 Plouzane, France  
Tel: + 33 2 9849 8720  
Fax: + 33 2 9849 8760  
E-mail: jerome@univ-brest.fr

### **Dr. Javier Escartín, ad hoc**

Laboratoire de Geosciences Marines  
IPGP - Université Pierre et Marie Curie  
Case 89, 4 place Jussieu,  
75252 Paris cedex 05, France  
Tel: + 33 1 4427 4601  
Fax: + 33 1 4427 3911  
E-mail: escartin@ipgp.jussieu.fr

### **Dr. Charles Fisher**

Department of Biology,  
Pennsylvania State University,  
208 Mueller Laboratory,  
University Park PA 16802, USA  
Tel: +1 814 865 3365  
Fax: +1 814 865 9131  
E-mail: cfisher@psu.edu

### **Dr. Françoise Gaill, ad hoc**

Laboratoire de Biologie Marine  
CNRS UPR 7622  
Université Pierre et Marie Curie  
(Paris 6), 7 Quai Saint-Bernard  
F-75252 Paris Cédex 05, France  
Tel: + 33 1 44 27 30 63  
Fax: + 33 1 44 27 52 50  
E-mail: francoise.gaill@snv.jussieu.fr

### **Prof. Toshitaka Gamo**

Division of Earth and Planetary  
Sciences Graduate School of Science  
Hokkaido University  
N10 W8  
Sapporo, 060-0810, Japan  
Tel: +81 11 706 2725  
Fax: +81 11 746 0394  
E-mail: gamo@ep.sci.hokudai.ac.jp

### **Dr. Christopher R. German, ad hoc**

Challenger Div. for Seafloor Processes  
Southampton Oceanography Centre  
Southampton, SO14 3ZH, UK  
Tel: + 44 1703 596 542  
Fax: + 44 1703 596 554  
E-mail: cge@soc.soton.ac.uk

### **Dr. Kim Juniper**

GEOTOP  
Université du Québec à Montréal  
P.O. Box 8888, Station A  
Montréal, Québec, H3C 3P8, Canada  
Tel: + 1 514 987 3000 ext. 6603  
Fax: + 1 514 987 4647  
E-mail: juniper.kim@uqam.ca

### **Dr. Masataka Kinoshita**

Deep Sea Research Department  
JAMSTEC, 2-15 Natsushima  
Yokosuka, 237-0061, Japan  
Tel: +81 468 67 9323  
Fax: +81 468 67-9315  
E-mail: masa@jamstec.go.jp

### **Dr. Jian Lin, ad hoc**

Department of Geology & Geophysics  
Woods Hole Oceanographic Institution  
Woods Hole, MA 02543-1541, USA  
Tel: + 1 508 289 2576  
Fax: + 1 508 457 2187  
E-mail: jlin@whoi.edu

### **Dr. Sang-Mook Lee**

Deep-Sea Resources Research Center  
KORDI, Ansan, P.O. Box 29  
Seoul 425-600, Republic of Korea  
Tel: +82 31 400 6363  
Fax: +82 31 418 8772  
Email: smlee@kordi.re.kr

### **Dr. Catherine Mével**

IPGP - Université Pierre et Marie Curie  
Case 110, 4 place Jussieu,  
75252 Paris cedex 05, France  
Tel: + 33 1 4427 5193  
Fax: + 33 1 4427 3911  
E-mail: mevel@ccr.jussieu.fr

### **Dr. Abhay Mudholkar**

National Institute of Oceanography  
Dona Paula, GOA 403 004, India  
Tel: + 91-832 221-322 ex 4322  
Fax: + 91-832-223-340  
E-mail: abhay@csnio.ren.nic.in

### **Prof. Rolf Pedersen**

Institute of Solid Earth Physics  
University of Bergen, Allegaten 41,  
N-5007 Bergen, Norway  
Tel: + 47 5558 3517  
Fax: + 47 5558 9416  
E-mail: rolf.pedersen@geol.uib.no

### **Dr. Ricardo Santos, ad hoc**

University of the Azores  
Dept. of Oceanography and Fisheries  
PT- 9901-862 Horta (Azores), Portugal  
tel: +351 292 292 944  
fax: +351 292 292 659  
e-mail: ricardo@dop.uac.pt

### **Dr. Spahr C. Webb, ad hoc**

Lamont Doherty Earth Observatory,  
Columbia University  
New York 10964, USA  
Tel: + 1 845-365-8439  
Fax: + 1 845-365-8150  
E-mail: scw@ldeo.columbia.edu