InterRidge Program Plan
Addendum 1994

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I InterRidge Update Summary 1994

In January of 1994, the InterRidge Office completed the first of its scheduled rotations moving from the University of Washington in Seattle, WA USA, to begin its new three year term of residence at the University of Durham in the United Kingdom. Since then efforts have been focused on publication of a series of workshop reports and the planning and organisation of a number of meetings and workshops scheduled for 1994 (see below). In addition, InterRidge has been working to strengthen formal links with such international ridge-crest research organisations as the Ocean Drilling Project (ODP), the Scientific Committee on Ocean Research (SCOR) and its parent body, the International Council of Scientific Unions (ICSU), as well as with a number of national ridge-crest research organisations.

As 1994 draws to a close, so does Phase I of the InterRidge Program Plan. This first phase in the decadal program was dedicated to improving co-ordination of on-going independent national and international co-operative projects. InterRidge set out to achieve this goal by enhancing, encouraging and actively facilitating exchange of ideas and information at a series of workshops attended by a broad spectrum of the international ridge-crest research community. These workshops fostered interdisciplinary, international approaches to problems in ridge-crest study. Their aim was to bring the best available expertise to bear on problems too large or logistically complex to be within the capabilities of any single national program. The success of this effort is partly reflected in the number of national ridge-crest study programs which have sprung into being over the last few years. These programs are now helping to co-ordinate research on both national and, in conjunction with InterRidge, international levels.

In 1994, InterRidge has become the community-supported international research initiative envisaged by scientists from 11 nations who attended the first formal InterRidge meeting held in France in 1989. InterRidge now counts 4 principal Member Nations: France, Japan, the United Kingdom and the United States; and 2 Associate Members: Germany and Portugal. Spain has also indicated its intention to join as a Principal Member in 1995. Canada and Iceland have expressed their intention to join as Associate Members. In addition, InterRidge maintains an active correspondence with ridge-crest researchers in Australia, Italy, Korea, Mexico, Norway, Russia and Sweden. It is hoped that India will soon enter into this correspondence and eventually become an InterRidge Member. InterRidge is also being brought to the attention of ridge workers in other countries as opportunities arise.

As InterRidge enters into the second phase of its program, which is designated to last from 1995 through 1997, the scope of its activities will broaden to include planning for international and interdisciplinary InterRidge Projects focusing on temporal variability and spatial characterisation of the ridge-crest. Phase 2 involves in-depth studies in the form of major interdisciplinary field efforts conceived and co-ordinated by InterRidge, and development of a database information catalogue accessible to the international ridge sciences community via the Internet.

Following on from the 1993 Meso-Scale and Global Workshops, three new InterRidge Workshops have been held or organised in 1994. Each is designed to pursue questions or themes identified at a previous workshop. Themes for two workshops came out of the Global Meeting held in Paris in 1993, "Indian Ocean Planning Meeting" and "Arctic Ridges: Results and Planning". The Meso-Scale Workshop held in Durham, UK, generated the subsequent "4-D Architecture of the Oceanic Lithosphere Workshop". Reports from the 1993 Meso-Scale and Global workshops have been published and are available in hard copy upon request from the InterRidge Office. Alternatively, they may be imported from the InterRidge Gopher (piglit.dur.ac.uk).

One of the main objectives of the "Indian Ocean Planning Meeting" held in Baltimore, USA on 22 May, was dissemination of information concerning scheduled field programs and further development of project co-ordination in the Indian Ocean. The other was to encourage interaction between geophysical/geochemical and biological/hydrothermal research communities. One of the outcomes of this meeting is the initiation of an "Indian Ocean Column" which will appear in InterRidge News starting with the Fall 1994 issue.

The second spin-off from the 1993 Paris Global Workshop was the "Arctic Ridges: Results and Planning Workshop" held in Kiel, Germany on the 15-17 November. The principal foci were to familiarise the community with existing Arctic data sets, identify data gaps and to define approaches and implementation plans to meet the scientific and logistical challenges presented by this region.

The "4-D Architecture of the Oceanic Lithosphere Workshop" held in Boston, USA on 23 & 24 September, was an expansion on the theme of spatial and temporal characterisation of second order ridge segmentation. The principal objective for this follow-up workshop was to draft a plan for co-ordinated segment-scale studies over the next five years. It is anticipated that work involving the resources of the Ocean Drilling Program will play an important role in the design of this project.

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

Global Studies:

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

Meso-Scale Studies:

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

Active Processes:

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

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

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

The InterRidge objective of promoting multi-national and interdisciplinary ridge-crest research also continues to develop via the activities of working groups centred around the themes of Global, Meso-Scale and Active Processes. Initiation of a new Ad Hoc Committee focusing on Biological Studies is being undertaken by D. Desbruyères.

Working Group Summaries

A General InterRidge Meeting will be hosted by DeRidge in Kiel, Germany in 1995. It will concern InterRidge policy for the most part, particularly Phase 2 of the science Program Plan; however, it will include 'state-of-InterRidge' science presentations as updates on the working groups' progress during the past 2 years.

In addition to the meetings listed above, an agreement on international data exchange formats is being sought.

Workshop reports and other pertinent InterRidge documentation, announcements and information will soon be available on an Internet-accessible "gofer". This service is a precursor to the eventual creation of a data index and information directory for the global mid-ocean ridge system.

Global

Charlie Langmuir, Chair

The Indian Ocean has been identified by the Global Studies Working Group as a current focus for global-scale investigation of the mid-ocean ridge. A one day InterRidge Global Workshop aimed at facilitating collaboration and co-ordination of various investigators involved in or planning to propose ridge-related studies in the Indian Ocean was convened in Baltimore by Jean-Christophe Sempéré on May 22, 1994, the day before the Spring Meeting of the AGU.

The report detailing the transactions and recommendations of the 1993 Global Workshop held in Paris was published in June, 1994. One of the recommendations of this report is the compilation of a global atlas of the mid-ocean ridge system. This atlas, to be made available both in hard copy and electronically via the Internet, is expected to be one of the Global Working Group's principal foci in upcoming years.

Meso-Scale

Martin Sinha, Chair

Recommendations issuing from the two Meso-Scale Working Group Meetings held in 1993 "Segmentation and Fluxes: A Symposium and Workshops" and "Back-Arc Basin Studies", have served as guidelines for the 1994 Working Group agenda. Significant interest demonstrated by Segmentation Workshop participants in the 4-D Architecture of the Oceanic Lithosphere has led to the development and planning of an InterRidge workshop centred around this theme held in Boston, 23 & 24 September 1994. Its objectives were to design experiments, establish implementation plans and designate experiment site(s) for investigation into the 4-D architecture of the Oceanic Lithosphere at the second-order spreading segment scale. This workshop will be followed by a US national workshop focused on more detailed discussion, planned and organised by RIDGE and it is hoped that other national programs may follow suit to plan their own contributions to the InterRidge program. Organisation of a "Fluxes at the Second-Order Spreading Segment Scale Workshop" is currently under discussion. A compilation and synthesis of petrological, geochemical and geophysical data collected in back-arc basins is being discussed and planned by participants in the Back-Arc Basins Studies Workshop.

Reports from the 1993 Meso-Scale Workshops were published in a single volume in June 1994.

Active Processes

Joe Cann, Chair

The first Active Processes Working Group Meeting is scheduled for 16-18 January, 1995, in Paris, France. This workshop will focus on the theoretical and technical development required to further our event detection and response capabilities and to establish a ridge-crest observatory.

Biological Studies Ad Hoc Committee

Daniel Desbruyères, Chair

This new committee is intended to meet the need expressed by biologists within the ridge-crest research community to focus on issues specific to the ecosystems found along the mid-ocean ridge, such that their investigation may be more effectively integrated into the interdisciplinary scheme of InterRidge. A provisional list of Ad Hoc Committee Members has been drawn up (see page 4). It is anticipated that a workshop will be convened by this committee in late 1994 or early 1995. The objectives of the Biological Studies Ad Hoc Committee are as follows:

- To understand and quantify the relevant biological production pathways and organic matter exportation to the deep-sea.
- To understand the evolutionary biology of vent organisms and their dispersal mechanisms at different time-space scales.
- To determine the relative influence of biological interactions and physical, chemical and geological processes on the distribution and abundance of organisms.

II InterRidge Structure January 1994

1 The Steering Committee :

R.C. Searle	(UK; Chair)
D. Desbruyères	(France)
P.J. Fox	(USA)
J. Francheteau	(France)
C.H. Langmuir	(USA)
H.D. Needham	(France; ad hoc)
M.C. Sinha	(UK)
K. Tamaki	(Japan)
T. Urabe	(Japan)
A. Biologist	(ad hoc)

2 National Correspondents :

Australia :	T.J. Crawford
Canada :	S.K. Juniper, K.M. Gillis
* France :	J. Francheteau
+ Germany :	H.-U. Schmincke, R. Rihm
Iceland :	K. Gronvold
Italy :	E. Bonatti
* Japan :	H. Fujimoto
Korea :	Sang-Joon Han, Bong Choo Suk
Mexico :	J.E. Aguayo-Camargo
Norway :	E. Sundvor
+ Portugal :	J.M.A. Miranda
Russia :	L.V. Dmitriev
✣ Spain :	J. Acosta, M. Canals
Sweden :	N.G. Holm
* UK.:	J.R. Cann
* USA:	P.J. Fox

* Principal Members of InterRidge in 1994.
\+ Associate Members of InterRidge in 1994.
✣ Country which has indicated its intention to join as a Principal Member in 1995.

3 Working Groups :

3.1 Global Working Group

C.H. Langmuir	(USA; chair)
C.R. German	(UK)
J.E. Lupton	(USA)
T. Matsumoto	(Japan)
P. Patriat	(France)
K. Tamaki	(Japan)
V. Tunnicliffe	(Canada)

3.2 Meso-scale Working Group

R.S. Detrick	(USA; chair)
H. Elderfield	(UK)
H. Fujimoto	(Japan)
K. Fujioka	(Japan)
P. Gente	(France)
J. Hashimoto	(Japan)
C. Mével	(France)
R.C. Searle	(UK)
B. Taylor	(USA)

3.3 Active Processes Working Group

J.R. Cann	(UK; chair)
E.T. Baker	(USA; EDR*)
P.R. Dando	(UK; observatories)
J.R. Delaney	(USA; observatories)
D. Desbruyères	(France; observatories)
P. Einarsson	(Iceland; EDR)
D.J. Fornari	(USA; EDR)
J. Honnorez	(France; observatories)
J.M.A. Miranda	(Portugal; EDR)
T. Urabe	(Japan)
M. Yamano	(Japan)

* Event Detection & Response

4 Ad Hoc Committees :

4.1 Biological Studies

D. Desbruyères	(France; Chair)
P.R. Dando	(UK)
J.R. Delaney	(USA)
D.R. Dixon	(UK)
A. Fiala-Médioni	(France)
C.R. Fisher	(USA)
H. Fricke	(Germany)
F. Gaill	(France)
J. Hashimoto	(Japan)
S.K. Juniper	(Canada)
R.A. Lutz	(USA)
D.C. Nelson	(USA)
S. Ohta	(Japan)
A.-L. Reysenbach	(USA)
K.O. Stetter	(Germany)
V. Tunnicliffe	(Canada)

5 Liaisons with other projects and organizations :

Ocean Drilling Program (ODP): C. Mével
Int. Lithosphere Panel (ILP): J.C. Mutter
SCOR: M.C. Sinha

III InterRidge Publications 1994

InterRidge Meso-Scale Working Group Reports 1993:
Segmentation and Fluxes at Mid-Ocean Ridges: A Symposium and Workshops & Back-Arc Basin Studies: A Workshop, June 1994, pp. 67.
InterRidge Global Working Group Report 1993: Investigation of the Global System of Mid-Ocean Ridges, July 1994, pp. 40.
InterRidge News, 1994, 3, 1, pp. 28.
InterRidge News, 1994, 3, 2, pp. 44.

*InterRidge News presently has a circulation of 1,635.

IV InterRidge Meetings and Workshops 1994

Global Working Group:
Indian Ocean Planning Meeting,
Baltimore, MD, USA; 22 May, 1994.
Arctic Ridges: Results and Planning
Kiel, Germany; 15-17 November, 1994.
Meso-Scale Working Group:
4-D Architecture of the Oceanic Lithosphere
Boston, MA, USA; 23 & 24 September, 1994.
Administrative Meetings:
Steering Committee Meeting
Tokyo, Japan; 5 & 6 September, 1994.
Steering Committee Meeting
San Francisco, CA, USA, 6 December, 1994.

1 Workshop Summaries

1.1 Global Working Group Report 1994

1.1.1 Indian Ocean Planning Meeting
Baltimore, MD, USA; 22 May, 1994.

Convenor: Jean-Christophe Sempéré

Introduction

The Global Structure and Fluxes program of InterRidge focuses on the large percentage of mid-ocean ridges which have remained poorly characterized. At least two types of scientific problems concerning mid-ocean ridges require a global approach. First, the accretion and evolution of oceanic crust are multi-dimensional processes which necessitate the investigation of distinct, representative survey areas to separate the influence of different parameters (e.g., spreading rate, mantle temperature, proximity to hotspots...). Second, some problems are global in scale and require survey areas which are very large compared to more conventional field programs (e.g., the characterization of global mantle reservoirs). These two factors explain why global scale studies of mid-ocean ridges are an important component of the InterRidge program.

The Indian Ocean includes three major mid-ocean ridges which are for the most part uncharted and unsampled. Thus, this region is of prime importance to the global component of InterRidge. The important scientific problems to be addressed in the Indian Ocean have been summarized in the report of the Global Working Group of InterRidge. This report can be obtained by request from the InterRidge Office. The availability of ships from several nations in the next 2-4 years in the Indian Ocean makes this region a natural focus of InterRidge. With this in mind, a meeting was held in Baltimore on May 22, 1994 to plan and co-ordinate international efforts in the Indian Ocean over the next few years.

Objectives of the meeting

The InterRidge Indian Ocean Planning had two main objectives. The first one was to disseminate information regarding scheduled field programs in the Indian Ocean, as well as to plan and coordinate the future efforts of investigators or groups of investigators in this region. The number of funded and proposed projects presented in Baltimore attests to the health of the global program of InterRidge and to the high interest level of many scientists in working in the Indian Ocean. The second objective of this meeting was to allow the geophysical and geochemical communities and the biological and hydrothermal communities to interact. The success of the global program rests not so much on mapping remote spreading centers, but on obtaining an interdisciplinary data set over one or several supersegments. Inclusion of the hydrothermal and biological communities is an important component of our program. A large part of the discussion at the meeting was devoted to devising realistic strategies to achieve this goal.

Planned and proposed field programs in the Indian Ocean

Approximately half of the meeting was spent discussing planned and proposed field programs in the Indian Ocean. Individual investigators already funded to work in the Indian Ocean outlined the scientific objectives of their field programs and discussed their survey strategy. Table 1 lists the programs which are currently funded for the 1994, 1995 and 1996 field seasons. It is expected that ship tracks and sampling sites will be made widely available within a few weeks after each cruise, and that interested parties will be able to obtain more detailed information necessary for proposal writing or cruise planning (i.e., bathymetric grids, sample composition) by contacting the principal investigators.

Table 1: Funded Programs

Dates	Objectives	Investigators
Dec 94 - Mar 95	Geophysical and geochemical study of the Southeast Indian Ridge between 90°E and 120°E	D.M. Christie (OSU) J.R. Cochran (LDEO) F.A. Frey (MIT) D.W. Graham (OSU) J. Mahoney (SOEST) J.-C. Sempéré (UW)
TBA	Geophysical study of the Southwest Indian Ridge between 15°E and 35°E	N.R. Grindlay (UPR) J. Madsen (UD) K.C. Macdonald (UCSB) J.G. Sclater (SIO)
TBA	Mantle composition and ridge dynamics of the Southeast Indian Ridge near the Amsterdam /St. Paul hotspot	K.T.M. Johnson (Bishop Mus.) D.W. Forsyth (Brown) D.S. Scheirer (UCSB) D.W. Graham (OSU)
Oct 95 - Nov 95	Geophysical study of the Southwest Indian Ridge near the Galliéni Fracture Zone	P. Patriat (IPG)

In addition to the funded studies, at least two programs have been proposed in 1994 to various funding agencies. Table 2 lists the programs that were discussed at the Baltimore meeting. Additional information regarding funded and proposed field programs in the Indian Ocean can be obtained directly from the principal investigators.

Table 2: Proposed Programs

The distribution and character of hydrothermal tracers along the Southeast Indian Ridge	G.P. Klinkhammer (OSU) R.W. Collier (OSU) J.-L. Charlou (IFREMER)
Geophysical study of the Central Indian Ridge between 14°S and 20°S	A. Briais (CNES) P. Patriat (IPG) L.M. Parson (IOSDL)

Biological studies in the Indian Ocean

Biogeographic patterns of vent faunas are a priority for understanding the origins of vent communities. The Indian Ocean represents one of several areas remote from known hydrothermal communities. Thus, ridge-crest biological communities in the Indian Ocean should provide an important datum in our studies of global vent biogeography. Unfortunately, virtually nothing is known about hydrothermal activity in the Indian Ocean. Two hydrothermally-active segments of the Central Indian Ridge have been identified. However the exact location of the sources of these plumes is not known. Characterization of the hydrothermal setting of these segments of the Central Indian Ridge is viewed as a priority for initial hydrothermal investigations in the Indian Ocean. C.L. Van Dover has agreed to take the lead in organizing an interdisciplinary/international group of investigators to study one of these hydrothermal areas. We expect this work to generate strong interest from hydrothermal groups in InterRidge countries.

During the meeting, A.-L. Reysenbach discussed the use of biological films mounted on deep-sea instruments to obtain microbiological samples. Investigators planning to deploy instruments near Indian Ocean spreading centers are encouraged to contact Dr. Reysenbach for further information. This technique will be used this Fall in conjunction with the deployment of ocean bottom seismometers along the Southeast Indian Ridge. The preservation of deep-sea animals fortuitously sampled during dredging operations was also discussed. The InterRidge office will ensure that global investigators have access to the necessary items to preserve biological samples. Investigators planning to carry out dredging operations in the Indian Ocean should contact the InterRidge office to obtain the items necessary to preserve biological samples.

Future activities

The role of InterRidge in the characterization of Indian Ocean spreading centers was discussed several times during the meeting. A few specific tasks for the InterRidge office were suggested.

Data archiving and dissemination are two important functions that are at present not overseen by any organization. The ready availability of basic information about Indian Ocean spreading centers was viewed by all participants as important. It was felt that InterRidge should take the leadership in creating a database accessible via Internet and, ultimately, publishing an atlas of the data to be collected in future field programs.

The Baltimore meeting was a good example of the important role that InterRidge can play. The information disseminated at the meeting appears to have been beneficial to all participants. An annual Indian Ocean meeting organized by InterRidge in the next few years would continue to ensure proper dissemination of information and data. The next meeting should probably be held in Europe to facilitate the participation of European scientists who were under-represented in Baltimore. In addition, an "Indian Ocean Column" in *InterRidge News* will be created to further facilitate the exchange of information regarding activities in the Indian Ocean.

1.1.2 Arctic Ridges: Results and Planning

Kiel, Germany; 15-17 November, 1994

Convenors: Roland Rihm and Mark Langseth

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

Three topics dominated the workshop sessions.

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

Synthesis of existing data:

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

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

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

Scientific issues:

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

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

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

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

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

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

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

Future exploration:

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

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

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

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

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

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

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

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

1.2 Meso-Scale Working Group Report 1994

1.2.1 4-D Architecture of the Oceanic Lithosphere

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

Convenors: Lindsay Parson, Jian Lin and Catherine Mével

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

Fast-spreading experiment: Hess Deep

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

Slow-spreading experiment: Mid-Atlantic Ridge

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

Ridge Drilling

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