InterRidge Program Plan Addendum 1996

(April, 1997)

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1.0 InterRidge Update Summary 1996

1.1 Membership

InterRidge Membership continues to expand. The InterRidge Chair and Steering Committee welcomed Germany and Norway as upgrading members. Germany upgraded to Principal Membership in 1996. Norway upgraded to Associate Membership and announced their anticipated participation through 1998. The number of Corresponding Members has also grown with the addition of Denmark. Australia announced that it hoped to become an Associate Member in 1997.

The tally of InterRidge Member Nations for 1996 stands at 6 Principal Members (France, Germany, Japan, Spain, UK, USA), 2 Associate Members (Norway, Portugal) and 11 Corresponding Members (Australia, Canada, Denmark, Iceland, India, Italy, Korea, Mexico, Russia, Sweden, Switzerland).

1.2 InterRidge Phase 2 Projects and Recent Progress

Global Studies:

- ***Global Digital Atlas:*** The establishment of a global multibeam bathymetric database by linking distributed databases via the World Wide Web. Chair: P. Blondel.
- ***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. Chair: C. Mével.
- ***Arctic Oceans:*** Co-ordination of planning efforts for mapping and sampling of the Arctic Ridges. Chair: R. Rihm.

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 scientific drilling. Chair: L.M. Parson.
- ***Quantitative Fluxes Experiment:*** Segment-scale experiment to measure integrated magmatic, thermal, chemical and biological fluxes at the Mid-Atlantic Ridge. Chair: TBA.
- ***Back-Arc Basin Database:*** Petrological database of Back-Arc Basins on the World Wide Web. Chair: K. Tamaki.

Active Processes:

- ***Event Detection and Response***: Detection of transient ridge-crest seismic, volcanic and hydrothermal events, and logistical responses to them through a strategy of international collaboration. Chair: K.L. Von Damm.
- ***Biological Studies at the Ridge Crest***: Promotion of integration of biological studies into ridge crest geosciences and advancement of this rapidly expanding field. Chairs: L.S. Mullineaux and D. Desbruyères.

4-D Architecture of the Oceanic Lithosphere

A meeting of the 4-D Architecture of the Oceanic Lithosphere Project working group was convened by L.M. Parson in parallel with the ODP-IR-IAVCEI Workshop in North Falmouth. Since ocean drilling will play an important role in the 4-D Architecture Project, it was deemed particularly relevant to schedule this working group meeting so that the results could be presented to the more general ODP-IR-IAVCEI community in attendance. During the meeting, the working group carried out an assessment of progress towards the goals identified at the Boston 1994 4-D Architecture Workshop.

Biological Studies at the Ridge Crest

Work on the Hydrothermal Vent Fauna Identification Manual, edited by D. Desbruyères and M. Segonzac of IFREMER, is reaching completion. A 1997 publication date is anticipated for the colour volume containing descriptions, line drawings and photographs of over 200 species.

1.3 WWW

Information continues to be added to the InterRidge World Wide Web pages. The InterRidge home page (currently still on a server at the University of Durham: **http://www.dur.ac.uk/~dgl0zz1/**, but soon to be moved to a server on the Jussieu campus in Paris) provides links to the InterRidge Researcher Electronic Directory, information concerning InterRidge program structure, an events calendar, workshop announcements, reports, proceedings and various national and international programme home pages.

1.4 Piggy-back Projects

Offers of ship time aboard the Russian vessels *RV Professor Logatchev* (three month cruise to the Mid-Atlantic Ridge in 1996) and *RV Academik Alexandr Karpinsky* (120 day cruise to the Southern Ocean in Spring 1997) were announced through the InterRidge Piggy-back Project service.

R.E. Thomson (Pacific Geoscience Centre, Institute of Ocean Sciences, Canada) asked for help with the deployment of satellite-tracked ALACE floats to study the deep flow structure downstream of a hydrothermal venting source. There were also other enquiries from investigators currently developing instrumentation. These proposals held promise for future piggy-back projects but were not yet at the implementation stage.

1.5 InterRidge Office Transfer

A bid to serve as InterRidge Chair and host the InterRidge Office for the 1997 - 1999 term was received from M. Cannat of the Laboratoire de Pétrologie, Université Pierre et Marie Curie, Paris, France. Following circulation and discussion of the bid amongst the Steering Committee Members, M. Cannat attended the 1996 InterRidge Steering Committee Meeting, where her bid was accepted.

1.6 Recent InterRidge Workshops

4-D Architecture of the Oceanic Lithosphere

A Meeting of the 4-D Architecture of the Oceanic Lithosphere Project Working Group was held in conjunction with, and results were presented in plenary session of, the ODP-InterRidge-IAVCEI Workshop "Oceanic Lithosphere & Scientific Drilling into the 21st Century".

ODP-InterRidge-IAVCEI Workshop

The Oceanic Lithosphere & Scientific Drilling into the 21st Century Workshop, convened by H.J.B. Dick and C. Mével, set out to define a unified drilling programme for mid-ocean ridges (MORs) and large igneous provinces (LIPs) in the next century. Five working groups drew up programmes for LIPs, Fast (hot) MORs, Slow (cold) MORs, Active Processes and Observatories, and Back-arc Spreading Centres. The Workshop is recommending a number of new ODP Working Groups to participate in ODP's proposal panel structure, and InterRidge was charged with nominating members for several of these (in some cases working with other interested programmes such as MARGINS).

FARA-InterRidge Mid-Atlantic Ridge Symposium

The results of the joint French-US FARA Program was summarised, and future research objectives formulated, at an international symposium held in Iceland from 17th - 21st June 1996. The meeting, sponsored by French and US science agencies to mark the end of the programme, was convened by C.H. Langmuir and H.D. Needham under the auspices of InterRidge.

1.7 Activity in the InterRidge Office

The major portion of the first half of 1996 was spent in preparation of the ODP-InterRidge-IAVCEI and FARA-InterRidge Symposiums and their associated abstract volumes. Both symposiums were well attended and on-site co-ordination was handled by the InterRidge Co-Ordinator. Publication of the Spring/Summer and Fall/Winter issues of InterRidge News went on as usual. The InterRidge Office also participated in editing the text of the InterRidge Hydrothermal Vent Fauna Identification Manual, compiled under the direction of the Biological Studies Project Working Group. The Office continues to reply to numerous e-mail inquiries from the international ridge crest research community on a daily basis. Information and documentation is also provided to various media projects and programmes not directly related to ridge crest research. The on-going effort to develop InterRidge membership continues to be a prime concern. In addition, a great deal of effort has gone into updating and maintaining the InterRidge World Wide Web pages, especially the Ridge-Crest

Researcher Directories and the Calendar of Meetings and Events, and the mailing list, which now contains nearly 2100 entries, and doubling the number of addresses on the e-mailing list. The Office has also taken steps to make the forthcoming transfer as smooth as possible.

2.0 InterRidge Structure December 1996

2.1 The Steering Committee:

R.C. Searle	(UK; Chair)	C. Mével	(France; *ad hoc*)
P. Blondel	(UK; *ad hoc*)	J.M.A. Miranda	(Portugal)
M. Canals	(Spain)	L.S. Mullineaux	(USA; *ad hoc*)
D.M. Christie	(USA)	L.M. Parson	(UK; *ad hoc*)
J.-J. Dañobeitia	(Spain)	R. Rihm	(Germany)
D. Desbruyères	(France; *ad hoc*)	E. Sundvor	(Norway)
J. Francheteau	(France)	K. Tamaki	(Japan)
C.R. German	(UK)	T. Urabe	(Japan)
P.M. Herzig	(Germany)	K.L. Von Damm	(USA)

2.2 InterRidge Member Nations:

At the end of 1996 InterRidge membership was as follows. Each member nation is listed with its National Correspondent(s) and national ridge research programme where they exist.

Principal Members:
France - Dorsales - J. Francheteau
Germany - DeRidge - R. Rihm
Japan - InterRidge Japan - H. Fujimoto, T. Urabe
Spain - M. Canals, J.-J. Dañobeitia
UK - BRIDGE - R.C. Searle
USA - RIDGE - K.L. Von Damm

Associate Members:
Norway - E. Sundvor
Portugal - J.M.A. Miranda

Corresponding Members:
Australia - T.J. Falloon
Canada - CanRidge - S.K. Juniper, K.M. Gillis
Denmark - J.R. Hopper
Iceland - K. Grönvold
India - D. Gopala Rao
Italy - TBA
Korea - S.-M. Lee
Mexico - J.E. Aguayo-Camargo
Russia - A.V. Sobolev
Sweden - N.G. Holm
Switzerland - G. Früh-Green

2.3 Phase 2 Projects:

Theme/Working Group - Leader/Rapporteur

Global Studies
- SWIR Project - C. Mével
- Global Digital Atlas - P. Blondel
- Arctic Ridges - R. Rihm

Meso-Scale Studies
- 4-D Architecture of the Oceanic Lithosphere - L.M. Parson
- Quantification of Fluxes - TBA
- Back-Arc Basins - K. Tamaki

Active Processes
- Biological Studies - D. Desbruyères & L.S. Mullineaux
- Event Detection and Response - K.L. Von Damm

2.4 Liaison with other Projects and Organisations:

Ocean Drilling Program (ODP): C. Mével
- Lithosphere Panel: R. Rihm, P.R. Castillo
- Tectonics panel: J. Lin

SCOR: M.C. Sinha

3.0 InterRidge Mailing List at 3rd December 1996

Country	Mailing List		E-mail Addresses		Country's %age with E-mail Address
	Number	%age of Total	Number	%age of total	
1. Argentina	1	0.05			
2. Australia	22	1.06	21	1.30	95.45
3. Belgium	6	0.29	3	0.19	50.00
4. Brazil	2	0.10			
5. Canada	64	3.07	55	3.41	85.94
6. Chile	2	0.10	1	0.06	50.00
7. China	2	0.10	1	0.06	50.00
8. Czech Republic	1	0.05	1	0.06	100.00
9. Denmark	4	0.19	4	0.25	100.00
10. Ecuador	1	0.05			
11. Fiji	1	0.05			
12. France	214	10.27	174	10.79	80.93
13. French Polynesia	1	0.05			
14. Germany	130	6.24	82	5.08	63.08
15. Greece	2	0.10			
16. Iceland	14	0.67	10	0.62	71.43
17. India	11	0.53	8	0.50	72.73
18. Iran	1	0.05			
19. Ireland	8	0.38	8	0.50	100.00
20. Israel	2	0.10	1	0.06	50.00
21. Italy	7	0.34	5	0.31	71.43
22. Japan	152	7.30	93	5.77	61.18
23. Korea	8	0.38	5	0.31	62.50
24. Mexico	5	0.24	2	0.12	40.00
25. Netherlands	16	0.77	7	0.43	43.75
26. New Caledonia	1	0.05	1	0.06	100.00
27. New Zealand	5	0.24	5	0.31	100.00
28. Norway	11	0.53	8	0.50	72.73
29. Philippines	1	0.05			
30. Portugal	15	0.72	13	0.81	86.67
31. Puerto Rico	2	0.10	1	0.06	50.00
32. Russia	54	2.59	30	1.86	55.56
33. Slovenia	1	0.05	1	0.06	100.00
34. South Africa	4	0.19	4	0.25	100.00
35. Spain	23	1.10	11	0.68	47.83
36. Sweden	8	0.38	6	0.37	75.00
37. Switzerland	8	0.38	4	0.25	50.00
38. Taiwan	1	0.05	1	0.06	100.00
39. Turkey	1	0.05			
40. UK	202	9.70	179	11.10	88.61
41. USA	1067	51.22	868	53.81	81.35
42. Venezuela	2	0.10			
Total	**2083**		**1613**		**77.44**

4.0 InterRidge Publications 1996

Meso-Scale Studies Workshop Report: Quantification of Fluxes at Mid-Ocean Ridges: Design/ Planning for the Segment Scale Box Experiment, pp. 20, March 1996.
Active Processes Workshop Report: Biological Studies at the Mid-Ocean Ridge Crest, pp. 25, August 1996.
Active Processes Workshop Report: Event Detection and Response & A Ridge Crest Observatory, pp. 61, December 1996.
Steering Committee Meeting 1995 Report, pp. 22, February 1996.
Steering Committee Meeting 1996 Report, pp. 17, December 1996.
InterRidge Program Plan Addendum 1995, pp. 14, September 1996.
InterRidge News, vol. 5, no. 1, pp. 52, 1996.
InterRidge News, vol. 5, no. 2, pp. 68, 1996.

5.0 InterRidge Meetings and Workshops 1996

Meso-Scale Studies:
4-D Architecture of the Oceanic Lithosphere Working Group Meeting
North Falmouth, MA, USA, 26th May 1996
Administrative Meetings:
Steering Committee Meeting
Estoril, Portugal, 25th & 26th September 1996
Symposia:
ODP-InterRidge-IAVCEI Scientific Drilling into the 21st Century
North Falmouth, MA, USA, 26th - 28th May 1996
FARA-InterRidge Mid-Atlantic Ridge Symposium
Reykjavík, Iceland, 19th - 22nd June 1996

Meeting and Workshop Summaries

5.1 Meso-Scale Studies:

5.1.1 4-D Architecture of the Oceanic Lithosphere: Working Group Meeting
North Falmouth, MA, USA, 26th May 1996
Convenor: L.M. Parson

In the course of the workshops held so far, it was recognised that this project would be made up of two types of experiments: Those that did not require international collaboration (Type 1) and those that did (Type 2). Only 2 components of the 4-D Architecture of the Oceanic Lithosphere project require international collaboration: Drilling and seismic experiments. The membership of the 4-D Architecture working group has been somewhat fluid resulting in a haphazard approach to this project.

The following fundamental questions arose from the workshops held in 1993 and 1994:

1. What is the 3-D magmatic plumbing system of a spreading segment?
2. What is the 3-D hydrothermal system of a spreading segment?
3. How is the extension accommodated in 3-D by brittle/ductile/magmatic/mechanic and what controls the geometry?
4. How is mantle upwelling coupled to lithospheric accretion and deformation?
5. What are the fundamental causes of segmentation? What controls temporal variability in spreading segments?

The experiments were also split into fast- and slow-spreading ridge experiments. It was decided that the fast-spreading experiments required sampling of the deeper levels of the oceanic crust so that a tectonic window into the crust would be necessary. For this reason Hess Deep was selected as the experiment site.

For slow-spreading ridge environments, a number of generic, non-site-specific experiments were described and a short list of 4 sites selected based on the history of work at these sites. These experiments include detailed characterisation of axial and off-axis geology, with use of a drill ship (type 2 experiment), geodetic strain measurements, and an integrated along axis and off axis seismic reflection and refraction survey and tomography experiment, with long-term monitoring of seismic activity (type 2). The point was made that these experiments should be carried out at a site where the general bathymetric, gravity, magnetic and geological framework is well characterised, over the length of 2 to 3 segments along axis, and up to at least 10 Ma-old lithosphere. The following list of data that are currently available for the 4 prospective sites was drawn up:

	MARK	TAG	29°N	35°N
Geophysical mapping > 10 Ma	x	x	x	
Deep-towed or Submersible Survey/Seafloor Experiment	x	x	x	x
3-D Seismics	x	x	x	x
Rock Sampling (by dredging, submersible or drilling)	x	x		x

The MARK area was recognised as being the site that had the best characterised axial and off-axis seafloor geology. The 35°N site is the only one with segment scale along-axis and off-axis seismic reflection and refraction data. It was considered counterproductive for InterRidge to go any further toward selecting a site at this point. As for the seismic part of the project, it was noted that even a 30% success of the MELT project would prompt funding for long term seismic monitoring.

The point was made that it would be very useful to have a geologic map of the segment at which the seismic experiments would be carried out. Knowledge, of the material through which the seismic waves travel, helps to prepare the ground for a seismic experiment. For the time being most is known about the MARK area. InterRidge could make a compilation of the most recent work by soliciting data from PIs carrying out work. From this a geologic map could be made.

5.2 Symposia:

5.2.1 ODP-InterRidge-IAVCEI Ocean Lithosphere & Scientific Drilling into the 21st Century
North Falmouth, MA, USA, 26th - 28th May 1996
Convenors: H.J.B. Dick and C. Mével

InterRidge has a long standing interest in collaborating with ODP as closely as possible. Drilling has always been seen as a vital tool for ridge research. This workshop grew out of some work done by H.J.B. Dick who originally set up a group called DOCUM which focused on ocean drilling in the USA. R.C. Searle addressed P-COM about a year ago during which the idea of ridge crest drilling was informally discussed. This idea was formalised in this workshop.

Five thematic working groups were set up at the meeting: Fast-spreading Ridges, Slow-spreading Ridges, Active Ridge Processes, Large Igneous Provinces and The Arc Environment. There weren't many people involved in arc environments present at the meeting and it was thought that a further workshop to target those people might be held.

The main conclusions came from the first 4 working groups. LIPs are not closely linked to ridge processes so InterRidge is principally concerned with the results of the first three groups. Each working group identified first-order scientific questions and the objectives needed to answer them.

- One of these was total penetration of the crust from the top of the extrusive basalt layer into the mantle for both fast- and slow-spreading ridges. A variety of reasons were presented for this: Limited resolution of geophysical methods, interest in the way the crust is built up, the way melt is delivered from the mantle into the crust, how well does the layered seismic/ophiolite model correspond with real oceanic crust generated at a mid-ocean ridge.
- The techniques of offset drilling and drilling tectonic windows at both fast- and slow-spreading ridges were emphasised in order to look at lateral variability and extend the knowledge gained from single deep holes.
- It was recognised that the deep holes would require new technology and consideration was given to planning into the next century. A planning programme was generated to the year 2003 and onwards.

The plans for drilling match very closely those which were generated at the InterRidge 4-D Architecture of the Oceanic Lithosphere Workshop held in Boston. It is probably through implementing this type of plan and by writing drilling proposals and getting them funded that we will implement much of the 4-D Architecture project plan.

The slow-spreading targets selected were the 15°N area where there are large outcrops of serpentinized peridotite, and the generic site for the InterRidge 4-D Architecture experiment (see Section 5.1.1). The 15°N target was identified because it is thought to provide the best opportunity to carry out the mantle study objectives of the 4-D experiment. While this is separated geographically from the main 4-D Architecture experiment it therefore remains thematically similar. It calls for an array of 5 - 6 relatively shallow holes to be drilled in order to investigate the upper mantle and lower crust. The drilling plan for the 4-D experiment generic site involves two transects of holes perpendicular to the ridge trend. About three holes would be drilled from very young crust to 10 Ma crust at a segment centre where there's a well developed mantle Bouguer anomaly low and presumably thick magmatic crust. Another three holes would be drilled at a segment end where there's a mantle Bouguer anomaly high and presumably thin magmatic crust. This drilling project would start with the existing capability of the *JOIDES Resolution* with shallow holes. As drilling technology advances, a pair of those holes would be chosen, one at the segment centre and the other at the segment end, to deepen for full crustal penetration. This would be coupled with arrays of offset drilling holes around the two deep holes.

The drilling targets for fast-spreading crust were initially off-axis in mid-plate at the H2O site half way between Hawaii and the western US coast. There is a submarine cable at this site. The precise location would be decided by the people who write the drilling proposal. If drilling is successful at this site, the hole would be maintained and a deep crustal section would be drilled during the next decade or so. If this site was not successful, the focus would move to medium-spread crust at the Costa Rica Ridge. A hole would be drilled very quickly, without sampling, down to the depth reached at hole 504B and then deepened down to the Moho. Alongside that, offset drilling would be carried out at Hess Deep as discussed in the 4-D Architecture project plan.

The Active Processes working group gave highest priority to drilling at the ridge axis. They propose drilling and instrumenting 5 holes in conjunction with a ridge axis observatory. The ideal configuration would be 4 holes to ~500 m depth and 1 hole to ~2 km depth. These holes would be logged and CORKed and instrumented in order to determine the physico-chemical state of the crust in the region of an active volcano-hydrothermal system and monitor the fluid and geochemical evolution of the system over decade timescales. Other critical environments for Phase 3 drilling include the flank of the Juan de Fuca Ridge, mid-plate volcanoes and convergent margin hydrothermal systems.

The main recommendation to ODP was that working groups should be set up to take the ideas issuing from this workshop forwards. ODP is in the process of structural reorganisation. What has been P-COM over the past few years will divide into an Operations Committee and a Science Committee (SCICOM). SCICOM will continue to send out proposals for peer review, but it will also set up working groups called Project Planning Groups which will report to it. They will be pro-active in developing drilling proposals. It will still be possible for individuals to develop proposals for submittal to SCICOM. However, ODP is encouraging proposals to be submitted via the Project Planning Groups which will be set up in conjunction with thematic programmes like InterRidge.

The workshop recommended that 4 Project Planning Groups be set up: Ridges (both fast- and slow-spreading), Large Igneous Provinces, Active Processes and Biology. The Biology Planning Group was inspired by the recent discovery of biological activity deep in the crust and the general thought was that this was an opportunity to be seized. One of the recommendations was, as a matter of urgency, to set up a proper microbiological laboratory on the *JOIDES Resolution*.

InterRidge was tasked with recommending membership of the Ridges (and with MARGINS, the LIPs) Project Planning Groups. InterRidge would not be the sole organisation having input, but a large part of the recommendations was expected to come from InterRidge. It was also recognised that, since a Biological Studies Working Group already exists within InterRidge, that group of people might assist ODP in composing a suitable ODP Biology Project Planning Group. SCICOM was due to meet in February 1997 when they would formally set up or invite nominations for these working groups.

5.2.2 FARA-InterRidge Mid-Atlantic Ridge Symposium
Reykjavík, Iceland, 19th - 22nd June 1996
Convenors: C.H. Langmuir and H.D. Needham

This symposium, focused on the Mid-Atlantic Ridge (MAR) between 15° - 40°N, marked the completion of the FARA (French American Ridge Atlantic) project. Results obtained by FARA and other national and international projects in this region were reviewed. Eighty scientists from eight nations presented their recent research. The symposium incorporated some forty oral presentations and thirty posters and was planned primarily around sessions covering different portions of the ridge rather than by theme, hence emphasising the interdisciplinary nature of the research that has taken place. Generous time was allowed for discussion. A concluding session, preceded by introductory talks, was devoted to a brief review of current knowledge and to new perspectives. Several field trips provided opportunities for ridge scientists to familiarise themselves with the sub-aerial expression of the MAR and for further interaction with the geologists of Iceland.

Background

The FARA project was conceived and carried out under the US-France Co-operative Program in Oceanography. Principal objectives, outlined in a project plan published in late 1989, concerned the along-strike variability of the properties of the ridge in the axial zone and the associated distribution and character of hydrothermal systems. The first field programmes took place in 1991 and the last of the sea-going operations were completed in 1996. During the same five-year period, the UK BRIDGE programme concentrated six expeditions on the region between 24°N and 30°N. Russia continued to focus on the 15°N area, the European Community co-ordinated a project near the Azores, the US Office of Naval Research (ONR) supported an off-axis study near 25°N, and the NSF funded a series of surface ship and submersible studies in the TAG area near 26°N, preceding and following a 2-month Ocean Drilling Program leg in 1995.

New Data

Results reported at the symposium complement those which have already been presented in scientific meetings or published, and offered an overview of observations made during the past 5 years. There is now virtually complete multibeam bathymetric coverage of 90% of the ridge axis in the 15°- 40°N region, with a few maps extending out to crustal ages of 10 Ma or more (30 Ma in the case of the ONR survey). Most of the recent surveys included underway geophysical, as well as bathymetric, data acquisition. Surface ship and deep-tow acoustic imaging has been achieved for significant portions of the ridge axis. *In situ* geophysical data were collected during micro-earthquake and seismic experiments near 29°N and 35°N. A submersible expedition was dedicated to seafloor gravity measurements in the 23°N area. There is new geochemical data from more than 250 surface ship sampling stations, particularly between 33°N and the Azores and in the 21°- 23°N area south of the Kane Fracture Zone. New fine scale volcanological and tectonic observations and precise sampling have been carried out by submersibles in several regions. Several surface ship cruises were designed for detecting hydrothermal signatures in the water column. The number of known hydrothermal sites (two at the outset of the recent work) has been quadrupled. The biology and geology of four of the new sites (at 14°45'N, 29°N, 37°20'N and 37°50'N) have now been studied from submersibles. The inactive site on the axial volcano at 20°30'N has been investigated. Hydrothermal plumes have been identified near 36°N and 36°40'N. In addition, past hydrothermal activity between 33°-40°N has been investigated through studies of sediments.

Some General Results

The new information has enabled a number of existing models of crustal accretion and associated hydrothermalism within the study area to be tested and modified, has led to the introduction of some new ideas to account for the data and has, in some cases, underlined the conflicting nature of different hypotheses.

The recently discovered hydrothermal sites which have been visited, and which include both black and white smokers, show variations in both the fluids and solid deposits as a function of water depth, volcanic and tectonic setting and source rocks. Properties of the two northern sites near the Azores (Menez Gwen at 37°50'N and Lucky Strike at 37°20'N) reflect their location on hot-spot crust enriched in incompatible elements, hence demonstrating direct links between mantle and hydrothermal signatures. The Logatchev site at 14°45'N is in an area of abundant peridotitic outcrops and is located at the faulted inner wall of the rift. The 36°N and 36°40'N plumes are at the ends of segments rather than near their centres, thus reinforcing the view that tectonics associated with rift-offset interaction can favour the location of hydrothermal activity, and that such activity is not always located near the mid-points of ridge segments. The methane anomalies which have been identified and mapped in the 15°N area are probably predominantly a product of serpentinisation. In the future, surveys will be needed to locate the sources of, and characterise, the hydrothermal signals which have, to various degrees, been detected along most of the ridge axis. Highly focused studies will be necessary to understand the properties of the hydrothermal sites, their geodynamic controls, and their variation through time.

The ecosystems at the new hydrothermal sites show limited species diversity of primary consumers. This low diversity, with either mussels or shrimps being the dominant organism, appears to be a characteristic of all Atlantic sites that have been investigated so far. The reason for this is not yet understood and is among the questions posed for future research concerning MAR biological populations. Is this low diversity a general Atlantic characteristic, and if so, why? How stable are the populations through time, and what are the environmental controls on the contrasting shrimp and mussel-dominated communities? Other important questions for the future are: How do organisms colonise and survive in the different sites? How do they adapt to toxic conditions? How much methane is necessary to meet the energy requirements? Do thermophilic CH_4-oxidizers exist? The question also still remains concerning the existence of a deep crustal biosphere in the Atlantic.

Striking aspects of the basement morphology include the segment provinces a few hundreds of kilometres in length combined with a great diversity in the various characteristics of individual segments. The exceptionally shallow segments at 37°50'N and 38°20'N in the Azores area, identified from magnetics data and acoustic imagery, are - together with the 21°30'N segment - extreme examples of barely rifted segments that are not normally associated with the slow-spreading MAR. Elsewhere the now virtually complete bathymetric coverage of the axis displays the full range of segment and offset styles, including some segments dominated by tectonic extension and others by a high magmatic budget, and highlights common features such as the asymmetry of the rift valley walls. The contrast of thicker crust at segment centres than at segment ends, typically variable according to segment and offset lengths, appears to be confirmed as common and may be general. The model of active upwelling for the origin of these thickness variations has been tested both by geophysical (primarily gravity) and petrological modelling. Both approaches suggest that this model on the segment scale is not an adequate explanation for much of the data and that melt focusing towards segment centres may be substantial. High density rock sampling has also allowed a far better description of the effects of mantle heterogeneity in giving rise to the diversity of crustal compositions and has opened up new perspectives for deciphering relationships between the composition and temperature of mantle sources.

The surface ship and deep-towed side-scan sonar (and magnetics) results, coupled with the multibeam bathymetric data, have enabled fine-scale investigation of tectonic and volcanic features at the segment scale with implications for the distribution of magma within the crust. The deep-tow studies were conducted particularly in the area near the Azores and between 24°N and 30°N and include in some cases (the Broken Spur segment at 29°N) complete coverage of the greater part of the segment out to a crustal age of more than 2 Ma. These data allow basement sampling and composition to be related to specific volcanological and tectonic features on the seafloor with unprecedented precision for the Atlantic without the intervention of a submersible.

The combination of diverse geophysical datasets with rock sample analyses and seafloor observations has allowed unprecedented investigation of the geology of some portions of the MAR, particularly the region south of the Kane Fracture Zone. These studies are providing knowledge concerning faults and the surface distribution of rock types along and across segments that has to be incorporated into tectonic and magmatic models of spreading.

Future Directions

The results summarised above make it possible to formulate much more precise questions now than was possible five years ago, and provide an improved basis for deciding on future approaches to some of the unresolved problems.

There is a clear need for a better geological understanding of the MAR: Iceland is a reminder of the dearth of geological information. For example, how does the geology of the MAR change from the Kane transform to the Azores hot spot? How does it vary with magmatic budget? Are segments a single species which changes through time, or are there distinct sets of segments each of which has its own restricted range of evolution? Research into these issues can draw on larger scale observations, such as those coming from detailed bathymetry and from whole mantle tomography and satellite altimetry, but concentrated studies on selected areas are also now essential and timely. Understanding how magmatic and amagmatic extension are distributed, how basaltic dykes, gabbros and serpentinite bodies are emplaced, appear now as urgent issues. Another is the testing of the low angle (detachment) fault model, still neither well confirmed or refuted, which was developed for the inside corner area of the segment immediately south of the Kane Fracture Zone. Does this model apply elsewhere as well? And how does such a model evolve temporally?

While regional work at different wavelengths needs to continue, particularly off-axis, many of the most pressing questions now require more focused studies. The results of the last five years provide an adequate framework for the present plate boundary in the central north Atlantic within which multi-disciplinary efforts on a small number of selected segments and some offset zones can take place. This new work will need to be coupled closely with a drilling programme and possibly in due course with long-term monitoring of active processes.

Symposium Abstracts

Extended abstracts of the meeting were published in the Journal of Conference Abstracts: J. Conf. Abstr. 1(2), (1996), 749-888. The abstracts can also be accessed at the following World Wide Web address: http://www.campublic.co.uk/science/J.Conf.Abs./

AGU Volume

Following the Iceland Symposium, a volume of results from the 15°-40°N area of the Mid-Atlantic Ridge was planned for publication in the Maurice Ewing series through AGU. Submission of papers was to take place in late 1996 and early 1997, with publication in late 1997.