Global Working Group Meeting Summary

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.

- Collation and synthesis of existing data on the Arctic ridges.
- Important scientific issues and opportunities.
- 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.