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CESAR and Future Arctic Studies: A Workshop

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large mylonite belt, Simon introduced a new mylonite terminology based on grain size distribution within the porphyroclast population. The terms homoclastic and heteroclastic describe the dominance of one clast size over the others and the dominance of several clast sizes (or none), respectively.

A. Caron (grad. student, Memorial U.) reevaluated movement along the Dover Fault, Newfoundland, while C. Elliott (grad. student, UNB) described the confusing tectonic history of the many regional thrusts in central Newfoundland.

Other large-scale investigations included Phil Simony's (U. of Calgary) correlation of the field characteristics of allochthonous plutons in southeastern BC with thin-skinned tectonics of the Cordillera. Charlotte Hy (PDF, UNB) discussed changes in metamorphic grade related to two periods of schistosity development in the mica schists of the Monte Mucrone area, Sesia Lanzio Zone, western Italian Alps. Closer to home, Paul Clifford (McMaster U.) described the little deformed rocks of the Killarney Triangle Zone, Killarney, Ontario as possibly related to the anorogenic igneous terrane of the US. This zone is apparently unrelated to the Grenville Province (located to the southeast) or to the Southern Province (located to the north).

Don Rousell (Laurentian U.) and Paul Clifford have offered to host the next Canadian Tectonics Group Meeting at Sudbury, Ontario during the weekend of 18-19 October 1986 with a field trip across the Grenville Front. To be included in the first circular mailing list, contact: Dr. Paul Clifford, Dept. of Geology, McMaster University, Hamilton, Ontario, Canada L8S 4M1, or telephone (416) 525-9140.

References

Berthe, D., Choukroune, P. and Jegouzo, P., 1979, Orthogneiss, mylonite and non-coaxial deformation of granites: An example of the south Amorican Shear Zone: Journal of Structural Geology, v. 1, p. 31-42.

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CESAR and Future Arctic Studies: A Workshop

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The Alpha Ridge, the submarine ridge that stretches toward the North Pole from the continental shelf off Ellesmere Island, is tectonically enigmatic. It has in the past been thought to be either an extinct spreading ridge or a submerged strip of continent. In 1983, the Canadian Expedition to Study the Alpha Ridge (CESAR) occupied the Arctic ice 400 km from the North Pole and over a period of 8 weeks, conducted a series of geophysical, geological, oceanographic and other scientific investigations over the Alpha Ridge. The geophysical interpretation of these investigations is just now reaching synthesis. To act as a focus for this process and to take stock before planning new directions in the Arctic Basin, the Earth Physics Branch (EPB) of the Department of Energy, Mines and Resources invited 40-50 Canadian and US scientists to Ottawa, 12-13 November 1985.

In his introduction, EPB Director-General, Jim Tanner noted that co-operation was a key feature of Arctic studies, both co-operation between Canada and the US and between differing agencies and organizations. In particular, he praised the "workhorse" of Canadian Arctic science, the Polar Continental Shelf Project (PCSP) under George Hobson. Chairman Mike Dence (EPB) then briefly reviewed the main features of the Arctic Basin and the geophysical data in the region. In some ways, this is more notable for its gaps than its coverage. Serious gaps in bathymetry, gravity, and heat flow pose a number of problems. Aeromagnetic coverage, while better, still leaves the identification of ocean-floor lineations unresolved in some critical areas. The difficulties of access — physical, political and financial — mean that much of the Arctic Basin remains totally unexplored and unknown. Small patches, such as the CESAR area, are known in more detail but in comparison with the sea floor off western Canada, very poorly. As a consequence, views on the evolution of the Arctic Basin are very varied.

Hans Weber (EPB) then presented a review of the principal CESAR geophysical results and the compiled bathymetric and gravity maps of the area. The Alpha Ridge is rugged with long ridges and valleys parallel to the main axis. Thin sediments overlie a basement that is laterally uniform in both density and magnetization. There is no evidence for magnetic reversals. From gravity interpretations, the crest of the part of the Ridge observed has a crustal thickness of 36-40 km as compared with the Makarov Basin (15 km to Moho, probably oceanic) and the Lomonosov Ridge (27 km to Moho, continental) to the north-east.

Alan Green (EPB) showed the results of seismic refraction data from CESAR. Again a strong uniformity was observed in the upper (less than 14 km depth) crustal layers. Seismic velocities over 8 km s^{-1}, indicative of the base of the crust, were reached at depths of 25 km beneath the west flank of the Ridge, at around 40 km beneath its crest and then shallowed to 20-25 km beneath the flank adjoining the Makarov Basin. Comparing the Alpha Ridge with other oceanic structures he suggested that it was much simpler than Vancouver Island but had similarities with oceanic plateaus such as Ontong-Java. Seismic reflection data was described by Ruth Jackson (Atlantic Geoscience Centre (AGC)) as showing up to 500 m of sediment in grabens on the Ridge. Some faulting and possible extension is evident but the age of well-preserved foraminifera in the sediments suggests that there has been no major tectonism since the late Cretaceous.

Alan Judge (EPB) reviewed the heat flow and thermal conductivity measurements made during CESAR, noting that the conductivities are not similar to normal ocean sediments. Calculated heat-flow values vary from 39-67 mW m^{-2}, averaging about 50. This is similar to other values in the Arctic Ocean basin and if used to determine age, could indicate an age of 50-120 Ma. Satellite magnetic anomalies (nominal altitude 370 km) presented by Richard Coles (EPB) reveal a dramatic 30nT high over the Alpha Ridge. Similar highs occur over northern Greenland and Iceland. Modelling confirms that the rocks of the Mendeleyev Ridge (a possible continuation of the Alpha Ridge towards the USSR margin) are not as magnetic as those of the Alpha Ridge. Calculations of the magnetizations necessary to model the anomaly suggest that comparisons with Iceland may be valid.

Magnetotelluric investigations were reported by Ron Niblett (EPB) who outlined how high frequency data essentially followed the bathymetry. However, "low-pass" (low frequency) data sampled much greater depths within the earth and indicated a major drop in resistivity near 85 km depth. Interpreted as the base of the lithosphere, this compares with results from the same technique of 120-150 km under Lomonosov Ridge,

70-80 km under the Fram Basin (the ocean floor between the Lomonosov Ridge and the presently spreading Nansen-Gakkel Ridge) and 40 km beneath the active Juan de Fuca Ridge off western Canada.

Jo Popelar (EPB) summarized the navigation operations of CESAR which involved a number of systems for locating both the CESAR camp and the operations which moved out from the base. The primary Transit satellite system gave positions of ±50 m, improving to ±15 m after post-processing. Omega and Decca systems were much less accurate, in the case of Decca because of transmission problems and poor lane intersection geometry. Peta Mudie (AGC) summarized the results of sediment coring as published in the Initial Geological Report on CESAR (published by the Geological Survey of Canada as Paper 84-22). She noted that sedimentation rates of the upper sediments were very low but that there was a traceable magnetostratigraphy from core to core. The oldest sediment recovered in Core 6 was a rythmically laminated biosiliceous ooze of probable Maastrichtian age (~70-75 Ma). This was overlain by mudstone and some volcanic ash units which could be mid-Eocene (~45-50 Ma).

The session then continued with four reviews of the scientific accomplishments of the present Ice Island project. The Island was first occupied in September 1984 and is now situated south-west of Nansen Sound off Axel Heiberg Island. It is hoped that in future years it will follow the polar margin to Alaska, move out into the Arctic Ocean and follow a clockwise path around the Basin.

Using the Ice Island as a base, a joint Geological Survey of Canada (GSC) and EPB team has conducted seismic refraction experiments. Isa Asudeh (EPB) presented results from observations out to distances of 250 km that indicate a major difference in crustal structure across the shelf with Moho at 25 km near the shelf edge and a shallow sedimentary basement along the inner shelf. Larry Sobczak (EPB) reporting on preliminary gravity observations confirmed the existence of a gravity "high" along the inner shelf which he termed the Sverdrup "rim" anomaly and which supported the seismic refraction interpretation. Peta Mudie (AGC) noted that preliminary analysis of sediment samples showed siliceous reef-building sponges which had only been previously observed in Antarctica and off Japan. Mike Schmidt (EPB) in presenting the navigation results and proposals for the Ice Island, felt that there was as yet too much post-processing involved in obtaining positions. With the use of improved computing facilities and GPS navigation, future results could probably be produced in real time.

The first day's session ended with the viewing of news and TV magazine clips of CESAR that were broadcast during 1983. The emphasis on the political justification of "sovereignty" and the possibility of the Alpha Ridge being a "natural" prolongation of Canada's continental shelf that could lead to a major claim in the Arctic Ocean, raised a few chuckles from the participants. Nevertheless, the clips served to underline that considerable public interest can be aroused by Arctic operations and that considerable public funds are needed to mount them.

The first session of the second day was entitled "The Alpha Ridge and the Evolution of the Arctic Basin" and consisted of seven presentations on the origin and nature of the Alpha Ridge. Hans Weber (EPB) began by enumerating what he thought were the main features of the Ridge that have to be explained in any tectonic synthesis. Amongst the more important features are its uniform magnetization and upper crustal structure, its gradual structural transition into the adjoining ocean basins, its thin sediment cover and its deep "V-shaped" root. There is no apparent continuity with the Ellesmere Island continental shelf (a key element of the "political" motivation of CESAR) and the crust is, on average, denser than the probably continental Lomonosov Ridge. Dave Forsyth (EPB) concentrated on the seismic refraction data and its strong similarities to a refraction section in Iceland that traversed from the ocean floor near the mid-Atlantic spreading axis onto Iceland itself. The shallow 8 km s^{-1} velocities of the west flank of the Alpha Ridge, deepening to 40 km near the crest, are remarkably similar to the lateral changes from oceanic to "hot-spot/continental" structure seen on the Icelandic section. The absolute motions of plates also suggest that the Icelandic "hot-spot", traced backward in time, runs northward through Greenland (creating the Thule volcanic province) to be off the tip of Ellesmere Island at around 80 Ma. Although there are major uncertainties, it seems possible therefore that the Alpha Ridge could be the product of the Icelandic "hot-spot" as it passed beneath the Canada Basin.

Ruth Jackson (AGC) also pursued the analogy with oceanic plateaus. She noted that the Manahiki Plateau in the south-west Pacific Ocean had similar sediment-filled troughs and grabens, with magnetic anomalies following topography in the long normal-polarity interval of the late Cretaceous. The possible high-velocity lower crust was in contrast to surrounding continental areas but similar to other oceanic plateaus. In terms of the tectonic history of the basin it was important to draw a distinction between the structure that was produced by a "hot-spot" in pre-existing oceanic crust and the product of an "enhanced" spreading centre active near a "hot-spot". In the formation of the Canada Basin, a number of triple plate junctions may have existed. Triple junctions are now thought to be associated with at least some of the Pacific oceanic plateaus.

Nancy Van Wagoner (Acadia U.) argued that the basement sample from Alpha Ridge indicated alkaline volcanism in shallow water with associated hydroclastic eruptions. Such volcanism rarely occurs at subduction zones or mature spreading centres and is indicative of incipient rifting, aseismic ridges and hot-spots. She proposed that the Alpha Ridge was formed as an aseimic ridge during Canada Basin development in association with a major hot-spot plume near the continental margin. The tholeiites of Strand Fjord and the break-up of the continental margin would also have been associated with this.

Larry Sobczak (EPB) speculated that the hypothetical fracture proposed from filtered gravity anomalies that runs from south-east to north-west across the US could be continued northward in a major arc that would coincide with the margin of the Canada Basin. He noted that magnetic trends in the southern Canada Basin were still indeterminate but that there was a clear difference in the gravity field between the north and south Canada Basins. A "wiper-blade" opening of the Canada Basin from a point near Ellesmere Island still seemed a feasible process for its evolution. Jack Sweeney (Pacific Geoscience Centre (PGC)) summarizing the session on the Alpha Ridge, reviewed some of the basic data on the age of the Ridge. He distinguished the principal phases in the region: (1) the creation of the Canada Basin (79-118 Ma), and (2) the creation of the Eurasia Basin (starting 63-53 Ma). The Alpha Ridge, Lomonosov Ridge and Makarov Basin could be associated with either of these phases or have been formed at some time between. The constraint of uniform magnetization could suggest the periods 83-118 Ma, 70-79 Ma or 63-68 Ma for Alpha Ridge creation. On balance, because of the pre-Maastrichtian fossils recovered from the sediments on the Ridge, he preferred an age range of 73-118 Ma.

The workshop concluded with a Panel discussion on future directions for Arctic geoscience. The panel was introduced by Jim Tanner and consisted of Art Grantz (Alaska Branch, USGS), Leonard Johnson (Office of Naval Research (ONR), US), Allan Judge (EPB) and Jack Sweeney (PGC). The Moderator was Mike Dence (EPB).

Leonard Johnson (ONR) felt that as the Ice Island facility now existed, Canada should make the best possible use of it. With luck it would move off the shelf into the Beaufort Sea and Canada Basin and a firm multi-disciplinary science plan should be established to take advantage of any opportunities that might arise. A particular challenge for the Arctic would be coring and drilling. The technology to drill sea-bed cores from moving ice seems near impossible but the evolution and paleoclimatic history of the Basin will be difficult to reconstruct until such data are available. He noted that international programs were very desirable and that to his knowledge, the Danish Government would be very interested in joint investigations in the Lincoln

Sea. From the floor, Fred Roots (former Director of PCSP) commented that although planning where there are no obvious opportunities for support can be a depressing exercise, the process of planning can itself prove to be useful. Art Grantz (USGS) began by stressing that the US had never managed to mount programs in the Arctic that had been as successful in terms of size and productivity as CESAR and LOREX. For tectonic targets there were a large number of areas to aim at, particularly between the ridges. In terms of exploration methods, he would like to see the advent of deep reflection seismic and more seismic profiling where it could be towed from ships. US and Russian ships, and perhaps the new Canadian Icebreaker, should be able to offer increased opportunities for profiling and bottom sampling. Greater coverage of aeromagnetic surveys was urgently needed (Canada has recently completed a new survey in the Beaufort Sea) and in the future, airborne gravity might offer a tool for both gravity and bathymetry. He felt that the Ice Island should not only have a basic program but a well-organized visitor program for national and international teams that might wish to come in for a short period to solve particular problems. Alan Judge (EPB) felt that detailed studies such as CESAR still lacked the regional context, broader data sets are always needed to interpret local studies. The Ice Island may not achieve this and may not provide the scientific stimulus of expeditions such as CESAR. Nevertheless the drilling problem should perhaps be addressed as a priority and funded through the Federal Government's Unsolicited Proposal program. Among targets for new initiative expeditions, he included the basins between the Alpha and Lomonosov Ridges, the western part of the Alpha Ridge and the Nansen-Gakkel Ridge system and stressed the need for paleoclimatic data. Jack Sweeney (PGC) agreed that drilling should be attempted. He also pointed out that the neo-tectonics of the Arctic must be looked at, in particular, detailed seismicity which would determine which parts were now active. The long-term evolution of the Canadian Arctic Margin had implications for the Arctic Basin and should not be neglected.

In discussion from the floor, it was established as unlikely that ODP drilling would be attempted in the Arctic Basin. It was also suggested that satellite altimetry for bathymetry had promise and emphasized that whatever is attempted, navigation remains a major hurdle for Arctic operations. Fred Roots stressed that Arctic programs have to be "sold" both nationally and internationally and urged scientists to go out and promote their ideas through international Arctic Committees. In a final comment, Larry Sobczak pleaded for continuing efforts to try and release the confidential and "strategic" geophysical data which undoubtedly exist over the Arctic Basin.

For this observer, the workshop showed clearly that the Alpha Ridge is most likely to be tectonically and geologically comparable with the oceanic plateaus of the Pacific Ocean or with "hot-spot" related structures such as Iceland. These tend to be the least understood of oceanic features and it is hardly surprising that the small data sets available for the Arctic have proved so difficult to interpret. The lack of regional data plus the lower latitude bias of most map projections make the synthesis of Arctic Basin tectonics a continually elusive exercise. Barriers to Arctic work are physical, economic and political. They are formidable and any progress has to be supported on at least the national, and probably international, level. For Canada, the new Ice Island and a political awareness of Canadian sovereignty in the North, provide opportunities which the geoscience community cannot afford to ignore.

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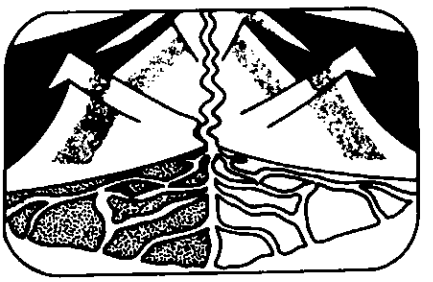

International Symposium on Foreland Basins

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Syn- to post-orogenic sediments in continental foreland basins (molasse) have been studied intensively for many years because they contain significant hydrocarbon and coal reserves, and provide a detailed record of the tectonic events which created the orogen supplying the sediments. As a result, the International Symposium on Foreland Basins, which was held in Fribourg, Switzerland, from 2-4 September, 1985, attracted considerable interest, with over 200 participants from 21 countries. This important meeting, which was sponsored jointly by the International Association of Sedimentologists and the Society of Economic Paleontologists and Mineralogists, consisted of 43 oral presentations, supplemented by 40 poster displays. As might be expected from the sponsoring organizations, sedimentary geologists predominated, although there were a few geophysicists and structural geologists present.

The first half-day of the symposium was devoted to general presentations on the broader geophysical, structural, sedimentological, and hydrocarbon aspects of foreland basins. The following $2^1/_2$ days consisted of case studies (including several significant reinterpretations), subdivided into sessions on the basis of geography and age: Paleozoic and Archean Foreland Basins (13 contributions); Asian and Australasian Foreland Basins (3); Himalayas and Siwaliks (7); Pyrenées and Ebro Basin, Spain (7); Swiss Alps and Molasse Basin (7); French Alps and Apennines (11); the Rocky Mountains (13); and 10 miscellaneous presentations describing examples from Chile and Argentina, Svalbard, the Persian Gulf, the Greek Hellenides, Turkey, and southern Spain. Over 80% of the contributions were on Mesozoic and Cenozoic fold belts, but the examples ranged in age from the Archean Fig Tree and Moodies Groups of South Africa (Eriksson and Harris, Virginia Polytechnic, Blacksburg, VA) to the presently-active foreland basins of western Taiwan (Covey, Exxon, Houston), the Timor-Tanimbar Trough (Audley-Charles, University College, London, UK), the