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The Generation of the Oceanic Lithosphere

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continental margin. Since 20,000 y BP to approximately 7000 y BP, the grounding line of the ice shelf has been retreating to its present position. A continuous retreat of the grounding line could cause a collapse of the West Antarctic ice sheet, and the volume of water added to the oceans would cause a six to eight metre rise in the global sea level.

Will increased atmospheric CO_2 advance this process? This question is difficult to answer because of the many uncertainties. There seems to be a consensus that increased CO_2 will have very little direct effect on the Antarctic ice sheet. The dynamics are more influenced by the position of the grounding lines of the ice shelves, which in turn are sensitive to the temperature of water and sea level along the continental margin.

Predicitions for the behaviour of the ice in Antarctica depends on computer modeling, which can give ambiguous results, if the baseline data is insufficient or poorly understood. The sparcity of basic data and the disagreement in the interpretation of this data was illustrated by arguments during the discussion period. For example, a question was raised pertaining to the stability of the Ross ice shelf due to tide cracks between the fast ice and the floating ice, which moves up and down with the changing tides. Because of this decoupling, there is a possibility that the buttressing effect of the fast ice is not great. An opposing view maintained that a heeling process takes place where cracks are being filled with freezing water from the sea below.

Comment

Usually scientists communicate new concepts and ideas to other scientists. The problem is that the lay public receives the news of scientific advances second hand and often outdated. In many cases, the public does not immediately grasp the significance of these new advances.

In the AAAS meetings, science news is tailored for the public and delivered by specialists. The significance is achieved by bringing together isolated advances to contribute to a problem or concern of a large scope. As a geologist with a concern for the environment, I find the discussions on nuclear waste and anthropogenic CO_2 accumulation in the atmosphere timely, although answers or solutions to these long-term, man-made problems seem to be still out of sight. These are new frontiers of science that demand new kinds of answers for new kinds of questions.

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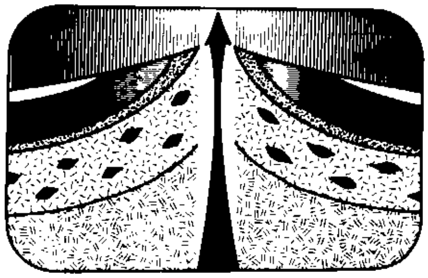

The Generation of the Oceanic Lithosphere

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AGU Chapman Conference, Airlie House, Virginia, April 6-10, 1981

With the abundance of geochemical data for deep sea basalts, the discovery of hydrothermal activity on the sea-floor and the arrival on the scene of high resolution geophysical and sonar techniques, this conference marked a milestone in the understanding of the oceanic lithosphere, and provided a platform for the formulation and diffusion of research objectives for the 1980s. Of particular interest was the possibility of geochemists and petrologists reaching a consensus with the geophysicists on models of magma generation and eruption, and hydrothermal activity at a ridge axis. This possibility was enhanced both by the idyllic setting of the Airlie House Conference Center in the Virginia countryside and by the format of the conference which allowed an equal number of oral and poster presentations; the latter were particularly effective in aiding the exchange of ideas since these sessions did not overlap with the oral presentations as is often the case in larger meetings. A total of 150 participants from nine countries presented 100 papers during the five day conference.

The introductory sessions dealt with the general nature of the crust and upper mantle at ridge axes. Talwani and Orcutt presented seismic models that demonstrated a narrow axial zone with the lithosphere rapidly attaining its maximum thickness. Their presentations were complemented by Lewis who presented gravity data from the Rose area which lead to the intriguing conclusion that a region of positive density contrast exists below the ridge axis; this provided some stimulus for the MgO-rich parental basalt proponents, who envisaged a column of dunite underlying the ridge axis! It is clear that we still have much to learn from gravity structure. A new perspective to the understanding of the upper mantle was given by the magnetotelluric data of Filloux. These data demonstrated a zone of conductive anistropy for the NE Pacific at 100 to 150 km which may represent a zone of partial melting; this technique, as yet in the development stage, has great potential for oceanic crust and upper mantle studies. These techniques represent one of the few tools for deep sounding and perhaps for answering the vital question as to the ultimate depth of ridge sources.

The petrological data for the oceanic crust led to a series of arguments concerning the presence of normal crust. Thompson introduced a series of papers on the Kane Fracture zone which has been classified as normal oceanic crust due to the lack of high iron or alkaline basalts. Dick argued from the phase mineralogy of oceanic peridotites that the oceanic mantle and deep oceanic crust are remarkably heterogeneous but distinct from most ophiolite assemblages; the latter, he argued, reflect island-arc or back-arc material. This led to a series of interventions related to the probability that the sample of the deep oceanic crust is biased since more than 90% of the samples are from fracture zones.

The isotopic and geochemical presentations broached the problem of oceanic mantle heterogeneity. The isotopic arguments of Zindler and Anderson stressed the problem of Pb-isotopic heterogeneity; both presentations invoked a crustal component to explain the anomalous values, leading to the speculation that "wet spots" rather than "hot spots" control oceanic island volcanism. Machado presented Nd-isotopic data indicating small-scale, long-lived heterogeneity in the oceanic mantle, and questioned the contention that the oceanic mantle is well mixed. Although the papers were well presented and provocative, the discussions were tempered due to the absence of certain European and West Coast U.S.A. geochemists. However, all the models invoking mantle heterogeneity were questioned by O'Hara, who, in his own style, explained geochemical variations by mixing and contamination by assimilation in high level magma chambers. Using major elements, Langmuir showed the mantle to be undepleted and homogeneous. However, the large variations that exist in the FeO content for oceanic basalts of similar MgO content were ascribed to variable geothermal gradients, resulting in the speculation that a thermal regime more complex than envisaged by most geophysicists exists within the oceanic mantle.

A series of conferences were presented on the experimental evidence for the nature of primitive oceanic basalt magmas. This session had the potential for a lively interchange between the high and low MgO and high CaO + Al_2O_3 protagonists. However, despite the convincing arguments presented by the high MgO group, namely Stolper, Elthon and O'Hara, the discussion never reached the anticipated level and each author seemed content with his particular parental magma - no one seemed willing to admit that all types may exist!

Perhaps the most convincing evidence for high MgO liquids, or at least their absence from most dredge hauls, was given by Huppert and Sparks who presented a film demonstrating the behavior of a hot, dense, high MgO liquid when intruded into cooler, more fractionated liquid. It was very evident that, on reaching the magma chamber, a high MgO liquid would be erupted with extreme difficulty and would eventually be mixed totally in the magma chamber. This model led to interventions concerning komatiite generation and the problem of excess olivine-rich material in ophiolites. As a complement to the Huppert-Sparks model, Walker demonstrated that Soret separation in a magma chamber with an above liquidus density gradient may result in liquids ranging from picrite to andesite composition. The possible superposition of Soret and crystal fractionation complicates models of magma chamber evolution considerably! Walker's experiments are dramatic for very high thermal gradients but much work is needed to evaluate this infiuence.

A series of presentations compared fast and slow, and Atlantic and Pacific spreading centers. Petrologically, the principal difference recognised was the abundance of Fe-basalts in the fast spreading ridges. Hey and Sinton interpreted this in terms of ridge propagation resulting in ridge jumping and magma isolation at the propagating ridge front. Hopson was one of the few scientists to compare ophiolites and "normal" horizons and thin volcanic horizons of the Oman ophiolite as characteristic of fast spreading ridges such as the East Pacific Rise, whilst the coastal range ophiolites, with incomplete gabbro and peridotite sections and thick volcanic horizons, were compared to slow Atlantic type spreading centres. The study of fast vs. slow ridges has been accelerated by the introduction of multi, narrow-beam sonar techniques. Francheteau presented a detailed bathymetric survey of the East Pacific Rise which demonstrated the zone of lava extrusion to be limited to a narrow, 0.5 to 1 km valley at the ridge crest. Within the central valley, the volcanics are covered by a thin sediment coating that may reflect wide scale, steady state, hydrothermal activity. The relatively simple morphology of the East Pacific Rise is in marked contrast to that described by Atwater for the FAMOUS and AMAR regions of the Atlantic. In these areas the magma chambers are transitory features resulting in a wide zone of lava extrusion of limited longitudinal extent. A similar model was evident from side-scan sonar data presented by Laughton for the Rekjanes ridge. The new sonar data presented showed fault structures of similar amplitude at both fast and slow spreading centres. Seismic data indicating the presence of magma chambers at ridges are still inadequate.

Of particular interest to the petrologists were the geophysicists models for magma genesis in the upper mantle. Most models favoured small scale diapir rather than the more traditional large scale mantle upwelling below the rise. Turcotte described a model of magma generation by pressure release melting and segregation of liquid over a depth range of tens of kilometres. Udinistev considers that structural inhomogeneity may reflect the irregular character of lithosphere generation and concluded that the presence of mantle diapirs of limited size was the most reasonable explanation. Shouten reached a similar conclusion for the Atlantic ocean based on magnetic data. In his model he speculated that small ($\leq$50 km) lengths of ridge, separated by transforms, have remained isolated for the entire history of the Atlantic ocean resulting in a steady state model of diapir generation beneath each segment.

The discovery of hydrothermal activity of the sea floor has led to a proliferation of research in this area. However, only a half-day session was dedicated to this subject. Von Damm presented chemical data for the 21°N East Pacific Rise hydrothermal vents, for the more conservative elements the mass fluxes were demonstrated to equal the fluvial input from the continents. Similarly, Hart demonstrated that the oceanic crust as a whole is a major sink for the alkaline elements. In addition, Hart demonstrated that dating of secondary minerals from old sea-floor may yield a reasonable age as most secondary alteration processes in the volcanic pile are complete within 10 m.y. of crust formation. Mottl and Delaney showed large variations in the FeO/MgO of chlorite associated with hydrothermally altered rocks. These variations were related to the water/rock ratio: the Fe-rich chlorites relate to the deep discharge zone of a hydrothermal system where temperatures are high and water/rock fluxes low; the Mg-rich chlorites relate to the downflow zones in the volcanic pile where lower temperatures and high water/rock fluxes predominate. Mehegan presented details of the secondary mineralization of the Icelandic research project drill. These data show how land based drilling can aid in understanding hydrothermal systems in oceanic regions. The proposed drill programme in the Troodos complex (Robinson and Hall, Dalhousie) should provide an ideal opportunity to study a fossil oceanic hydrothermal system. As yet geophysical studies of the hydrothermal areas are inconclusive. Riesdesel showed seismic data from which he estimated a 2 to 3 km depth range for the hydrothermal system. With the discovery of new hydrothermal vents on the East Pacific Rise and the study of the Atlantic regions such as the TAG field the paucity of geophysical data will no doubt be rectified.

In summary, the conference marked a rare opportunity for ocean floor geologists from various subdisciplines to exchange ideas. However, it is difficult to find areas in which a major consensus was reached. The geophysical models of upper mantle magma generation seem to favour kinematic flow related to small diapirs beneath each ridge segment. This is consistent with geochemical models which propose small-scale mantle heterogeneity. Most petrologists seemed too ready to eliminate ophiolite complexes as candidates for oceanic crust and upper mantle. Our sample of deep oceanic crust is limited to fracture zones; we have very little idea of the nature of the oceanic crust between two transforms. If some geophysical models are correct the centre of each rift segment represents the axis of an upwelling diapir and must have a different crustal and upper mantle structure from the transform. Several research areas were evident as candidates for providing significant advances for the 1980s. The most notable were the high resolution bathymetric data from the French and British groups and geophysical techniques such as magnetotelluric studies of stable oceanic crust and fan seismic arrays across newly formed crust.

Financial support is obviously becoming harder to find for expensive programs such as deep ocean drilling, but the land based deep drilling projects proposed to the early 1980s will no doubt aid in interpreting the mass of data obtained for the ocean basins during the 1970s. As stressed in the conference resume, laboratory funds are limited and collaboration with industry based research teams which are often technologically more advanced must be viewed as a means of supporting ocean research in the 1980s. There is perhaps need for concentrating the sparse systems of observation in fewer places to obtain less ambiguous data.

The conference was organized by Dean Presnall and Anton Hales of Texas and Fred Frey of M.I.T., all of whom are to be congratulated for putting together a stimulating program.

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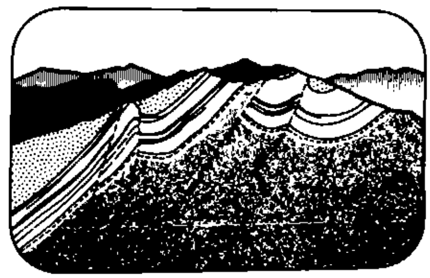

Workshop on the Geology of Southeastern British Columbia Coalfields

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Introduction

The workshop was held February 11 and 12, 1981 in Fernie, B.C., the weatherman smiled and 100 geologists interested in coal were treated to a technically and socially well organized workshop on southeastern B.C. coalfields. In general, the talks were of high caliber and well illustrated. David Grieve, District Geologist in Fernie for the Ministry of Energy, Mines and Petroleum Resources, did an excellent job of organizing and orchestrating the meeting.

The meeting opened with a general session on the stratigraphy and sedimentology of the Jurassic-Cretaceous Kootenay Group. The depositional environments were portrayed by Dave Gibson, maceral compositions and their significance by Alex Cameron, and palynology by Art Sweet, all with the GSC in Calgary. Dave Grieve zeroed in on stratigraphy of the coal seams, and Peter Daignault illustrated some of the difficulties in correlating seams at Fording Coal.

The afternoon session painted a picture of the structural setting of the deposits. Pete Gordy of Shell Oil led off with a rapid-fire structural tour around the coalfields. Dave Pearson, a consultant, outlined the usefulness of coal rank studies in determining tectonic history. Marc Bustin of UBC followed with a meticulous description of small and large scale tectonic features in Crowsnest Pass area coal deposits. Dave Grieve gave a brief overview of the Flathead Coalfield then detailed papers were given for the Lillyburt deposit by Brian McKinstry of Crows Nest Resources, and for the Sage Creek property by Owen Cullingham of Pan Ocean.

The evening featured a prime rib dinner followed by a slide tour entitled "Coal liquefaction plants I have known", humorously and energetically delivered by Dave Pearson.

The second day of the meeting concentrated on detailed property reports. The morning was devoted to the Crowsnest (Fernie Basin) Coalfield and Coal Mountain. After a brief overview by Dave Pearson, the Michel area was outlined by Lynn Taylor of B.C. Coal (formerly Kaiser Resources) and Tom Cole of Crows Nest Resources described the Lodgepole property. The geology of the Dominion Coal Blocks and Coal Mountain were well described by Neil Ollerenshaw of the GSC and Marc Bustin respectively. The afternoon was devoted to the Elk Valley Coalfield. After an overview by Dave Grieve, the Line Creek mine (by Ted Hannah of Crows Nest Resources), the Greenhills property (by Sam Samuelson of B.C. Coal), Fording Coal properties (by Ken Komenac) and the Elco property (by Gary Lawrence), were described.

Selected Highlights

The difficulty of correlating coal seams in an area of rapid facies changes and complex structural history was continuously stressed. However, to a non-expert like myself, it was equally clear that work to date has partially succeeded in outlining criteria for successful correlation within individual properties.

As Dave Gibson explained, sediments in the Kootenay Group were derived from the west and transported by meandering and braided streams toward the Fernie Sea. As a result facies reflect alluvial fan, alluvial plain, coastal plain, and beach environments within wave-dominated deltaic systems.

The sedimentary rocks are time-transgressive; they young eastward and northward and rapid lateral facies changes are the rule. The components of the Kootenay Group, from oldest to youngest, are the basal Morrissey Formation sandstone, the coal-bearing Mist Mountain Formation and the Elk Formation. The overlying Cadomin Formation of the Blairmore Group is interpreted to be either a braided plain or a sediment lag deposit.

Maceral composition in the coals is controlled by the source vegetation and the rank. There are a staggering number of subdivisions of maceral type but they fall into three broad groups: vitrinite, exinite and inertinite, and of prime interest in assessing coal quality is the vitrinite to inertinite ratio. Alex Cameron described variations that occur in modern peat environments and their applicability in