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Evolution of the Ancient Continental Margin of Western Newfoundland

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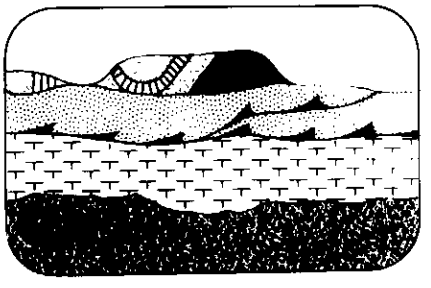
tends to resist erosion. The balance between concentration and physical energy can lead to mud belts on any part of modern or ancient shelves. McCave also challenged Miles Hayes' interpretation of the process by which hurricanes generate seaward-flowing bottom currents that result in graded storm layers on shelves. Moreton (I.A.S. Special Publication 5) has shown that hurricanes do not pile water up against the coastline to later flow seaward as the storm abates. Instead, there is a continuous bottom flow set up which may be directed either offshore or along shore. McCave favours this continuous flow as the mechanism by which storm layers are emplaced.

The most fascinating, and potentially most significant, aspect of this meeting was the general discussion of hummocky stratification. Philip Allen proposed three possible mechanisms for production of this poorly understood structure: 1. supercritical unidirectional flow; 2. intense oscillatory flows causing rolling-grain ripples; and 3. combined oscillatory and steady unidirectional flows with the waves propagated either with or against the current. Allen did not consider seaward-flowing density currents to be a reasonable alternative. After discussion of the problems associated with generation solely by oscillatory currents, he concluded that the best model for the production of hummocky stratification should be based on the combined effect of waves of moderate height and energy, and gentle steady currents. In the ensuing discussion, two additional mechanisms were suggested. Trevor Elliot noted that hummocky stratification resembles an interference pattern, and wondered if it might be produced by waves propagated at some angle to a steady bottom current. This model is remarkably like that suggested by Nick McCave on the basis of modern shelf studies. John Allen suggested that this structure could be the result of an attempt to form megaripples under waves. Chris Pound, in a later presentation, emphasized that the currents that produce hummocky stratification are commonly erosive, as scour and drape is the most commonly observed feature in the field. Clearly there is no agreement yet on the origin of hummocky stratification, but some of the suggestions presented at this BSRG meeting may yet supplant current explanations.

The 70 short papers, which were interspersed between the reviews, provided a complete cross-section of sedimentological topics, ranging from the practical (reservoir properties) to the academic (Zechstein subtidal stromatolites) and from ancient to modern. Most were well-presented and illustrated, and on time, so that a succession of chairmen, in what was largely a single-session meeting, were able to guide us through an almost bewildering variety of topics.

This meeting was an excellent 21st birthday party for the BSRG. Much of the enthusiasm seen in formal and informal discussions is due to the participation of young researchers and students, and the general acceptance of their views on a par with those of established experts. This format is different to that of many North American meetings, and certainly to that of most specialist meetings like Penrose Conferences and SEPM Research Conferences, where the major participants are predominantly from academia, industry or government agencies. We find the BSRG format very appealing and intellectually stimulating. Perhaps meetings of this type should be encouraged in the Canadian geoscience community.



Evolution of the Ancient Continental Margin of Western Newfoundland

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The 1983 spring meeting of the Newfoundland Section, Geological Association of Canada, took place from April 7-8. The program of 30 papers was organized by Chris Barnes and included all aspects of the Paleozoic geology of western Newfoundland. Registrants were provided with a formal program, including abstracts in GAC formt. Copies of these abstracts may be obtained from Chris Barnes, Program Chairman, Memorial University of Newfoundland.

Only two papers presented at the symposium broke away from the main theme. Phil Rice (Petro-Canada, CSPG Special Lecturer) presented a seismic journey through the modern continental-margin sequence of the Grand Banks, complete with aerial photographs of modern analogues of coastal and terrestrial ancient environments. Rice showed a novel three-dimensional seismic record depicting the upper surface of one of the Mesozoic reservoir sands. This intriguing technique allowed recognition of the form and plan-view features of a braided distributary complex. The perspective was much like that of an aerial photograph. Wayne Goodfellow (GSC, GAC Robinson Fund Special Lecturer) carefully documented the occurrence and genesis of lead-zinc deposits associated with starved basin sedimentation during rifting of the western Canadian Selwyn Basin. He stressed the importance of basement break-up faults in providing conduits for metalliferous fluids in their journey to a site of precipitation at the sediment-water interface.

The Paleozoic talks were preceded by two general keynote papers. Chris Beaumont, Steacie Fellow from Dalhousie University, provided a stimulating discussion entitled "Rifting, collision of plates and the formation of sedimentary basins", as an introduction to the mechanisms of basin formation at both passive and convergent continental margins. He emphasized that the mechanical properties of the lithosphere can largely account for various aspects of basin development, including subsidence history. Thick, cool lithosphere acts like a stiff spring and flexes for a greater distance away from the continental margin than does thinner, hotter lithosphere. The peripheral bulge associated with flexure during emplacement of thrust sheets at active continental margins is found furthest from the margin when the lithosphere is thickest. If true, then the width of foreland basins produced by flexure would be a function of lithosphere thickness, and indirectly a function of the time interval between rifting to form a passive continental margin and subsequent destruction of the margin. Although in Phanerozoic orogens we commonly have good biostratigraphic control on the timing of these events, this relationship between foreland basin width and "age" of the passive margin could be useful in unravelling the timing of Precambrian continental-margin tectonics and in estimating the properties of the Precambrian lithosphere. It might also be possible to calculate from such data the approximate width of Precambrian oceans. Beaumont illustrated his talk with examples from the Scotian Basin, the western Canadian foreland basin and the Appalachian foreland basin. In the latter example, Beaumont considered interaction with nearby intracratonic basins. When the peripheral bulges associated with foreland and intracratonic basins overlap, intermediate arches are elevated, and when the bulges pass by one another, as a result of increased thrusting and widening of the foreland basin, the

arches subside and the intracratonic basin becomes yoked to the foreland basin. This dynamic model was used by Beaumont to explain the observed geologic history of deposition on the Findlay Arch and Nashville Dome, both located between the Appalachian foreland basin and two adjacent intracratonic basins, the Michigan and the Illinois.

Beaumont also suggested that the sub-Middle Ordovician (sub-Table Head) unconformity in the Appalachians may be the result of migration of a peripheral bulge across the margin as thrust sheets were emplaced further east. This hypothesis is intriguing because it suggests an alternate and testable explanation for regional (but not world-wide) unconformities, and also predicts that such unconformities would be diachronous.

James Lee Wilson (University of Michigan, CSPG Special Lecturer), in his paper entitled "Patterns of carbonate infestations controlled by tectonism", provided a spectacular visual tour through the variety of carbonate platform margins found in the Mesozoic of western Canada, Texas, Mexico, Morocco, Tunisia, the eastern edge of the Arabian Shield and the Alps. Wilson emphasized the fundamental control that basement faults play in the location and orientation of carbonate platforms. Bob Stevens, in a later presentation, noted that uncertainty still exists as to whether the deep-water Cow Head Group is allochthonous or autochthonous, even though the carbonate platform terrain from which it was derived is found both to the west and to the east of the present Cow Head outcrops. If, as Wilson claims, passive margins are commonly characterized by detached, small carbonate banks on fault blocks, then suggestions that the Cow Head Group may be in place must be given serious consideration. This problem may be no less serious than that of locating the root zones of sedimentary and ophiolite klippen in the northern Appalachians.

A third keynote paper was presented by Noel James, recent AAPG Special Lecturer and Steacie Fellow. Noel provided a comprehensive stratigraphic framework for many of the subsequent talks in the program, with a detailed discussion of the Cambro-Ordovician platform sequence of western Newfoundland and southern Labrador. The stratigraphy was interpreted in terms of early extensional tectonics (passive margin) followed by post-Early Ordovician compressional events (convergent margin). There still does not seem to be a good explanation for the relative thinness of the passive-margin sequence in western Newfoundland (Ca. 2.0 km), particularly when Beaumont's models for passive-margin subsidence would predict a thicker miogeoclinal sequence. Perhaps the carbonate platform margin in this region was located unusually far from the actual continental margin and closer to the hinge-line about which the marginal subsidence took place.

The remaining shorter papers presented on the first day were grouped into three themes, namely, the carbonate platform, the coeval slope succession, and aspects of regional correlation. The more important contributions are discussed below. Our comments on these and on other papers will only mention the names of the speakers, even though many papers had multiple authorship. Detailed analysis by Ian Knight of the Middle and Upper Cambrian package on both sides of the Great Northern Peninsula convincingly demonstrated the west to east change from a middle shelf facies belt to an outer shelf facies belt. Within this sequence, Doug Boyce recognized an important faunal hiatus caused by a major Early Ordovician regressive-transgressive event. In discussion, Chris Beaumont stressed the possible link between this unconformity and peripheral-bulge tectonics.

Slope sediments of the Cow Head Group were described in terms of conodont paleontology (Chris Barnes), gravity-induced sediment slides (Mario Coniglio) and debris flow geotechnical properties (Rick Hiscott). Snouts and projecting blocks associated with the Cow Head debris flows suggest strengths like those reported for modern subaerial flows. Bottom slopes calculated from debris strengths and bed thicknesses are consistent with the common occurrence of sedimentary slides and slide-induced shear zones in the Cow Head sequence.

The papers dealing with regional relationships summarized earlier work, and will not be specifically discussed here. Hank Williams closed the first day's proceedings with a keynote paper that humourously tallied territorial losses and gains sustained by continents bordering the modern Atlantic Ocean during earlier orogenic events. Northern Africa lost substantial ground to eastern Canada (i.e., Avalon and Meguma Zones), whereas the northward extension of the ancient eastern continental margin of North America was expropriated by the British Isles during formation of the modern Atlantic.

The morning of the second day was devoted to collision and obduction processes. Mike Searle introduced this session with a visual extravaganza on ophiolite obduction and thrust sheet emplacement in western Newfoundland, Oman, the United Arab Emirates and the Himalayas. Searle discussed the problems in structural analysis and construction of balanced cross-sections even in orogenic belts as well exposed as the Oman Mountains and the Himalayas. To perform such analysis, it is essential to know the original thickness of rock units involved in thrusting; the fold style must also be concentric for production of truly accurate cross-sections. Such information is not available in most parts of the Appalachian Orogen, particularly in the north. This creates serious roadblocks to any attempts at palinspastic restoration of transported terranes. As pointed out in the talk by Bob Stevens, application of models involving emplacement of large thrust sheets to western Newfoundland is a recent phenomenon. Many problems in detailed interpretation still remain. Bob reminded us that this meeting was being held on the 20th anniversary of the Rodgers and Neale publication that first pointed out the presence of allochthonous terranes in western Newfoundland.

Most of the remaining papers of this session described structural and stratigraphic relationships in the allochthons of western Newfoundland, based on recent field studies. Highlights included Beckie Jamieson's assertion that the apparent prograde metamorphism toward the peridotite contact in the aureole beneath the St. Anthony Ophiolite Complex is simply the result of fortuitous preservation of relict high grade assemblages within a greenschist facies shear zone. If true, then earlier explanations of the "aureole", including thermal models, must be re-examined. Papers by Greg Dunning and Derek Wilton closed this part of the meeting with a firm rejection of the idea that rocks east of the Cape Ray Fault in southwestern Newfoundland represent basement from the eastern side of Iapetus. These rocks are ophiolitic, with locally gneissic Ordovician tonalite intrusions produced by partial melting of sediments of the Fleur de Lys type. Derek presented structural, geochemical, and Rb-Sr age-date evidence that the fault itself is not a cryptic suture, but only a more modest, though large, shear zone.

The last session of the meeting dealt mainly with paleomagnetism, and Late Paleozoic geology and strike-slip tectonics in the northern Appalachians. Garry Quinlan set the stage with a general discussion of the production of pull-apart basins. The lithospheric responses are much like those involved in formation of rifts. The observed Carboniferous stratigraphy of the Magdalen Basin can be explained by two phases of extension and thermal subsidence. The second phase accounts for an increase in subsidence rate prior to deposition of the Windsor Group. Discussion after this talk included some criticism of the coarseness of the stratigraphic subdivisions that had been used to constrain the calculated subsidence curves, although the procedure certainly is promising.

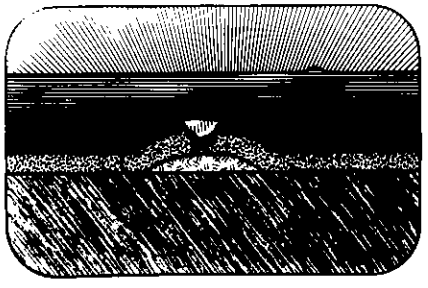
Dick Hyde presented geological results from the Carboniferous Deer Lake Basin

that demonstrated clearly the importance of dextral strike-slip movements during the early (Anguille) stages of deposition. The major evidence is structural (e.g., fold axes oriented obliquely to master faults) and not sedimentological.

The paleomagicians (and their detractors) held the spotlight for the final talks of this session. Ernie Deutsch re-evaluated paleomagnetic data from the British Isles, and combined this information with other geological evidence to calculate an absolute width for the Iapetus Ocean of 3600 ± 2200 km! If the uncertainty in the position of modern Newfoundland was so great, then the current dispute with the federal government over offshore petroleum resources might involve Colonel Khaddafi rather than Pierre Trudeau.

Papers presented by Bill Morris and Dave Strong (co-authored by Ted Irving) addressed the question of Late Paleozoic strike-slip motions in the northern Appalachians. Both papers presented arguments against major movements of the magnitude suggested by Van der Voo, Kent and Opdyke, etc. Morris surveyed existing paleomagnetic data for Devonian and Carboniferous movements, and concluded that the data are the result of Permian lateritic weathering or Hercynian metamorphism, and have nothing to do with primary rock magnetism. Strong presented new data gathered from Carboniferous rocks in eastern and western Newfoundland. These data are consistent for all localities, and yield a paleolatitude of about 20 degrees south. This latitude is 40 degrees different than supposed Carboniferous cratonic data (Mau Chunk, Barnett and St. Joe Formations), and on this basis other workers have suggested major wrench movements. Strong and Irving, however, obtained identical data from the Deer Lake Basin of western Newfoundland, which on the basis of field relationships was deposited directly on the craton! There are no major faults between these sediments and the interior of the craton. The reason that the discrepancy in paleopole positions exists is not due to real strike-slip movements. Rather, it is the result of a strong Permian overprint which has been successfully filtered from the Appalachian data, but which has been erroneously ascribed to Carboniferous magnetization on the craton. The implications of this discovery are clear and profound. Proponents of major sinistral strike-slip movements in the Appalachians during the Late Paleozoic will have to return to the drawing board and begin anew by obtaining true Carboniferous paleomagnetic data from the craton! Geologists working on the ground in eastern Canada will be pleased with this turn of events, as all hard geologic data have indicated Late Paleozoic dextral, not sinistral, movements, usually of minor magnitude. As many of us suspected, the true test of theories that suggest major plate movements is to be found in outcrops on the ground. The paleomagnetic hypothesis has, in this case, failed the test.

This meeting left all participants with a better understanding of the rock sequences and problems associated with the ancient continental margin of eastern North America in western Newfoundland. Clearly this resulted from the inclusion in the program of papers from many fields in the earth sciences, including crustal geodynamics, sedimentology, stratigraphy, structural geology, geochemistry and paleomagnetism. The program chairman, Chris Barnes, is to be congratulated on his success in putting together such a multidisciplinary symposium.



The 12th Arctic Workshop

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Introduction

The 12th Arctic Workshop was held in Amherst, Massachusetts, March 16-18, 1983 and was sponsored by the Institute of Arctic and Alpine Research (INSTAAR). The workshops normally bring together about 70 people engaged in cold region environmental studies, including biology, geology, physics and history. Thus, the workshops are interdisciplinary, an event at which palynologists, glaciologists, botanists and marine geologists may find it interesting to listen to each other mainly because of the many overlaps in their work and the comraderie that normally develops between those who work in remote areas.

During the three days of this workshop a total of 28 papers and one afternoon devoted to poster sessions touched upon a wide range of topics. Although interaction between subdisciplines was very strong, the major topics could be ranked as follows: glacial geology, climate, botany, paleoceanography and paleoclimate, history of polar research and anthropology. In this report we discuss the main points of ten papers which are most relevant to our own interests in Arctic geological research.

The First International Polar Year

This year's workshop was held against the background of the centennial of the First International Polar Year, 1882-1883. Fittingly, the first paper, by W. Barr, University of Saskatchewan, dealt with some of the pioneer geomorphological investigations that took place during the First International Polar Year. At that time 14 polar expeditions were undertaken with eleven countries participating. This was the first truly international scientific investigation of polar regions and, although intended to focus on meteorology, terrestrial magnetism and auroral studies, a number of participants made geomorphological observations that remain significant, considering their early date. For example, an excellent description of pingoes and tundra polygons in the Lena delta region was made by the members of the Russian expedition (1881-1884). To date, this has been the only published mention of pingoes in the Lena Delta, although they are similar to those described for the Mackenzie Delta. In northern Labrador, Dr. K.R. Kock from the German expedition (1883) noticed a sharp contact between the shattered felsenmeer of the upper slopes and the heavily glaciated lower slopes of the Torngat Mountains. He concluded that the higher peaks of these mountains had escaped the last glaciation.

The Marine Environment and Climate

Three papers dealt with the ocean as a climatic modifier and as a source for ancient climatic paleosignals. P.M. Kelly, University of East Anglia, discussed a scheme devised by the Soviet Union to direct the flow of a number of Siberian rivers to the south for the purpose of land irrigation. The project would involve the diverting of up to 200 to 300 km^3 of water per year by the middle of the next century. The interference with the Arctic hydrologic system at this magnitude could have profound climatic effects. For example, it is believed that Siberian river runoff is a major factor in maintaining a strong pycnocline that favours the formation of sea ice over the Arctic Ocean and its marginal seas. The runoff also apparently reduces the rate of heat exchange between the deeper intermediate Atlantic water and the seasonal layer at the sea surface. This simple runoff-ice cover relationship is controversial because some evidence suggests a direct dynamic relationship between the volume of the warmer Atlantic water entering the Arctic