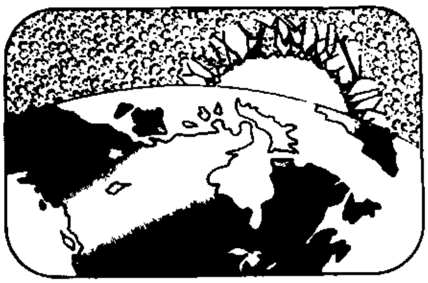

Presidential Address

Presidential Address to the Geological Association of Canada, Waterloo, Ontario

The Earth Sciences in Canada 1975

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I am not sure that a Presidential address is a very suitable forum for discussions of Science Policy or comparable matters - the audience of the day and the readers of the published version are always converts. Spurred to some extent by the 1974 report of the Canadian Geoscience Council, which tended perhaps to point only to weaknesses in the earth sciences in Canada, I thought it might be more fitting to turn to some aspects of what is excellent, and I am going to do this by weaving a tale around the activities of the two medallists for 1975, Dr. Irving and Dr. Walker. I appreciate there will be many gaps, but unless I merely catalogue, this is inevitable. To weave the tale in this manner gives me great personal pleasure, and you must not think that this arises solely because 15 to 20 years ago I studied in the same departments in England as they did before or after me. It arises rather because in the course of my graduate work I was involved in measuring the magnetic properties of sediments from the floor of the eastern Atlantic Ocean. The instruments I used had been left behind by Irving, and the sediments were in part turbidites from an abyssal plain, and we are all aware of Walker's devotion to such sediments.

Dr. Irving started his career by measuring the directions of magnetization of a variety of rocks, including, for example, the Torridonian, Precambrian sediments of northwest Scotland. You may recall that Sir Harold Jeffreys wrote in the third edition of *The Earth*, in 1952, some rather derogatory remarks about continental drift. He considered at some point Wegener's meteorological analogies, and wrote: "The ready acceptance (of meteorological) evidence springs mainly, I think, from the popular belief that meteorology is an easy subject; everybody knows when it is raining".

In spite of this discouragement, Irving was able to write three years later, in the mid-fifties: (1) that the earth's geographic pole has shifted relative to the continents, (2) that various land masses have moved relative to one another, and (3) that ancient latitudes deduced from paleoclimates and paleomagnetism are in agreement. He did hedge his bets one year later:

"Nevertheless," he wrote, "we are a very long way indeed from being compelled to believe that large scale polar wandering and continental drift as envisaged by Wegener has, in fact, occurred . . .". A motif, a theme, an insistence in this early work is care and attention to detail, in particular then to paleomagnetic "cleaning". "All results", he wrote, "must be based on good stability evidence . . . (or) it may be possible . . . to find results to support almost any point of view."

This same care to detail led fifteen years later to his group in Ottawa trying to "see through" the metamorphism of the Precambrian Shield. To attempt - with others such as Carmichael, Dunlop and Palmer - to find pole positions and their corresponding ages in the Archean and Proterozoic. And so we have now the beginnings of paths of Apparent Polar Wandering for the Shield, with hairpins reflecting orogeny, and disagreement concerning the status of the Grenville.

Irving's conversion to the Shield dates from about the same time as Roger Walker's; obviously a fatal infection, religious blight, whatever, struck English immigrants in about 1970. Walker, too, had worked with Phanerozoic rocks, and thought that sedimentology could help in the Precambrian. Let us see through the kyanite. He disliked his turbidites being called glacial varves, their only common feature being monotony, and persuaded Dr. Pettijohn that what Pettijohn had labelled "varves" in the Minnataki basin were in fact turbidites. Perhaps it is worthwhile at this point to ask "what sorts of questions do we - can we - ask of the Precambrian?"

Turner and Walker asked of the Archean greenstone belt of Sioux Lookout: what sequences of facies do we observe? They showed that continental deposits - alluvial fans - were followed by a resedimented association, including turbidites, a sequence unlike the one we are taught to expect as students (flysch followed by molasse: as described so elegantly by Eisbacher for the Cordillera). No shallow water facies were seen - no braided rivers, for example. No mix between continental and marine. Are these generalities to apply to all Greenstone belts? What do they tell us of "Greenstone processes?" What was the ocean like? How thick was the Precambrian crust?

Was the Archean crust of the Superior Province thin, as Goodwin suggests? Was this thinness, was the density, were the geothermal characteristics of this ancient crust the cause of extrusion of ultramafic flows - I ask, not only why did these ultramafic rocks melt, but what gave them their hydrostatic head? Isn't it hard to extrude such rocks if, following Baragar, the crust was a sodic granodiorite? The St. John's meeting last year was Plates and Metallogeny; we might, if the Abstracts this year are a guide, call this meeting "spinifex" and "komatiites". Such ultramafic rocks are being described by Beswick and Car, Frisch and Jenner, Gelinas and Brooks, Schwarz and Fujiwara, and Schau, among others. Cominco, through the Kretschmars, are using spinifex textures as indicators of tops, useful therefore in mapping.

What was the atmosphere like - that early atmosphere on which theories of the origin of life depend? It is on geologists that biologists such as George Wald depend. Hoffman has stromatolites two billion years old, presumably evidence of photosynthesis; how far back can we push them? Kimberley and Dimroth maintain that oxygen was available a longer time ago than popular accounts of life on earth would have one believe.

What was the earth's core like? Knowing how hard it is to locate the Mohorovicic discontinuity at the *present* time, and therefore being - improperly - sceptical of those who claim to locate the earth's core to a metre of two (or whatever it is) it may seem silly to ask this question. But we can ask: what processes for which the core is responsible do we observe in the Precambrian? Bingham and Evans have gone some way to answer this by their observation of a reversal of the earth's magnetic field in Proterozoic sediments some 1700 million years old. As the earth's field seems to be due to processes within the core, similar processes may have operated then as operate now. It would be nice to know the frequency of reversals in the Proterozoic.

One of the reasons those of us on the east coast appreciate Dr. Irving is his devotion to stratigraphy - magnetic reversal stratigraphy of the Mesozoic. He worked a number of years ago on igneous rocks from the Gulf of Aden, and before marine geophysicists arrived upon the scene, pointed to the likelihood that the Red Sea was once closed, and that the Arabian peninsula lay against the Horn of Africa. He looked, too, at rocks from Heard Island, in the southern Indian Ocean, showing how their magnetic properties could support ideas that Tuzo Wilson - another Logan medallist - was then developing. And by a lucky association he fell in with Loncarevic and Aumento, then studying the Mid-Atlantic Ridge at 45°N. You recall that over crests of mid-ocean ridges away from low magnetic latitudes one finds a large magnetic anomaly, which was then barely explained. He, with others in his laboratory, showed that weathering of basalts exposed to cold sea water could account for their reduced remanent magnetisation.

Far from the crests of mid-ocean ridges in the North Atlantic are found magnetic "quiet zones", where the amplitudes of magnetic anomalies are very low indeed. Charlotte Keen and D. L. Barrett have shown that - off Nova Scotia, at least - this is due to an extensive tract of normally polarised oceanic crust, in which there are a few - very few - reversals. We need a magnetic time scale based on observations from land, to see just what is the age of this ocean floor off the Nova Scotia continental margin - just when did the Atlantic open most recently? And Dr. Irving is providing this.

His studies of cold weathering - halmyrolysis - came at a time when others have begun to think of the interaction, hot and cold, between sea water and basalts. Dr. Fyfe spoke of this in St. John's last year, and Aumento and others drew upon their experience in Bermuda and in the laboratory at the Waterloo meeting. The matter is important to Precambrian geologists. Bernie Gunn has pointed out in the Abstracts that if oceanic basalts are so altered, it will often be difficult to say anything sensible about the chemistry of Precambrian basalts, thought to be oceanic. Modern oceanic crust is, of course, not only weathered, but thermally metamorphosed under high geothermal gradients; Einarsson points out that similar metamorphic grades are found in ophiolites in Newfoundland.

Perhaps a feature common to Walker's work and Irving's work is the attempt each makes to be quantitative and to be rigorous. Walker has looked at turbidites not merely as end results of *processes*, but in their total context. How big was the basin? Where did this resedimented clastic material come from? Such questions are important in establishing sizes of basins, and so on, in the Precambrian. He has recently spent his time looking at proximal turbidites, clastics resedimented near their source - which those who work at sea associate with submarine fans and their channels such as the Laurentian Cone off the Grand Banks. Many turbidity currents travel long distances - abyssal plains are very flat. Reinhard Hesse has traced individual turbidites through a great length of a Cretaceous flysch sequence in the Alps.

Sedimentological studies help us in many ways. For example, Hoffman's studies of the Coronation geosyncline point to a boundary of the Shield in Proterozoic times, and suggested to him that some of the processes which we now ascribe to the interaction of plates started in the early Proterozoic, some two billion years ago. Lajoie, Heroux and Mathey have defined the edge of the Shield in the Late Precambrian and early Paleozoic by their studies of the provenance of sandstones of the south shore of the St. Lawrence. But other techniques can be used. Bennett, Clowes and Ellis undertook refraction studies in the Rocky Mountain Trench, and with this work and the magnetic survey of the Earth Physics Branch to hand, they define the hidden western margin of the Shield within the Cordillera.

Hoffman drew our attention to the development of aulacogens - sediment filled rifts created at rifted margins. Mesozoic and Tertiary examples are numerous along our eastern seaboard, and are perhaps obvious in northern Baffin Bay where the Sounds of the eastern Arctic enter the Bay. What evidence is there of rifting in the history of the Shield? Baragar has pointed to plateau basalts within Canada which may mark attempts to open a new ocean - successful or not. Obvious Mesozoic examples are the Triassic basalts of Nova Scotia, but Baragar points to those of the Aphebian - the Matachewan-Keewatin dykes, and numerous younger examples. Whilst these indicators of rifting *may* be real indicators we certainly do not know what *initiates* rifting, and the only work of which I am aware in Canada directed to this problem is Wayne Cannon's at York University. He has pointed to possible interactions between the wobble of the axis of symmetry of the earth about the axis of rotation - the Chandler wobble - and the decrease in length of the day. At some time in the past the annual driving force and the Chandler wobble would have coincided, and a lot of energy would have had to be dissipated within the earth. Cannon puts the time at some 185 million years ago, and speculates that this caused the breakup of Pangea. Now, we don't have to believe Cannon. My point is that so much interest lies in possibilities of sea-floor spreading in the Precambrian, that we can only applaud someone who looks at its origins.

You will appreciate as well as I that this talk could have been prepared in a variety of ways. I have tried to span, so very briefly, the Archean to the Recent, very theoretical geophysics to very practical mapping, the present crust and the Precambrian core. Others would do this differently - perhaps span the gamut of applied geophysics, mining geology and applied geochemistry. The point I leave you with is this: that there is a lot of excellent work being undertaken in the earth sciences in Canada, and it must be nurtured and applauded.