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Aller au sommaire du numéro

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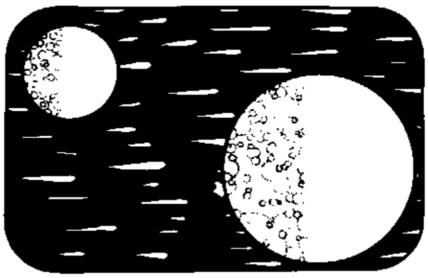

The Early History of the Earth

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This NATO conference was convened at the University of Leicester, April 5-11, 1975. It attracted approximately 130 delegates from 20 countries, including 23 from Canada.

The term "Early History" meant emphasis on the first half of earth history (> 2.5 b.y.). To a large degree, this was adhered to.

Two, three day field trips were held, one to the Scourie - Lochinver region of N. W. Scotland, the other to Lewis and Harris in the Outer Hebrides. Both trips were most ably led by J. Watson of Imperial College. An afternoon trip during the conference to Charnwood Forest allowed people to visit the local Precambrian and to walk amid some British History.

The opening session of the conference concentrated on the earth's formative stage, and its relationship to the origin of the moon. By analogy with lunar findings, J. V. Smith (U.S.A.) proposed that the earth's surface was unstable until about 4 b.y. ago, consistent with recent age measurements showing the oldest rocks to be 3.7 b.y. Prior to 4 b.y., the earth received severe bombardment from sun-orbiting projectiles. The earth's core formed very early in earth history, in thp first 100 m.y. (Murthy, U.S.A.). When compared with chondritic meteorites, the earth appears to be highly depleted in S, C and N (factors of 10^2 to 10^3), more so than in the halogens or in the stable isotopes of the noble gases. Eutectic melting and segregation of Fe-FeS liquids into the core is a plausible hypothesis that: (1) explains the core's density which is 15 per cent less than pure Fe-Ni, (2) explains the S deficiency, and (3) avoids the high temperatures necessary to segregate a pure Fe-Ni melt. The energy released during this core formation raised the temperature of the earth about 1200°C and led to the major geochemical differentiation at 4.5-4.6 b.y. Goetter (U.S.A.) pointed out that K is a siderophile element under strongly reducing conditions and may move into the core with the Fe-S melt. Rb may very well behave in a similar fashion and the decay of K^{40} and Rb^{87} could be a driving force for mantle convection (Hurley, U.S.A.). Shaw (Canada) presented his model for crustal development during the "pre-Archean" and "Proto-Archean". His notion of an early, thin anorthositic outer layer proved to be a controversial point. Jakês (Czechoslovakia) suggested that pressures may be too great for plagioclase formation. Instead, a spinel or garnet phase should form. To J. V. Smith, a more Na-rich plagioclase might be stabler, producing rocks such as tonalites and trondhjemites, common rock types in the Archean. To float plagioclase (Ca-rich) in an anhydrous melt would require a higher density than normal (from a high Ti content or high pressure).

The earth may have been heating up due to radioactive decay during the early Archean, and it was not until the later stages (3.3-2.5 b.y.) that abundant K-bearing granitic melts, generated below a 30 Km basaltic layer, were formed. For this early period then, there was no convective overturn because excess heat was not present, hence no necessity for plate tectonics (St. J. Lambert, Canada).

The advocates, Devil's advocates and agnostics of Archean Plate Tectonics began to emerge during the first day. The debate was to continue throughout the conference.

The second session on high grade metamorphic terrains centred on Greenland. Windley (U.K.) reviewed various such terrains from several shield areas. He pointed out that they are dominated by tonalitic gneisses containing remnants of supercrustals (older volcanic-sedimentary rocks) and by fragmented, layered, igneous complexes (dunites, peridotites, anorthosites etc.). An excellent series of outcrop slides demonstrated that original igneous features can be "streaked out" to give banded gneisses (Myers, Denmark). These photographs make one wary of any genetic interpretation of "paragneisses" in Precambrian areas, particularly those mapped on a reconnaissance scale. McGregor (Greenland) and Chadwick and Coe (U.K.), in separate papers, and on different field areas presented their views on the Amitsôq gneiss (3.6-3.7 b.y.), the Nûk gneiss (3.0-3.1 b.y.) and the Amerilik dykes (intermediate in age). McGregor believes that an augen gneiss of granodioritic composition and its associated dioritic gneiss are the oldest rocks in Greenland, older than the more abundant tonalitic rocks. Their chemistry appears unique in having high Fe/Mg, K and Ti contents. They fall on a tholeiitic trend. Chadwick and Coe believe the augen gneiss to be intrusive into the Amitsôq. McGregor believes that the Nûks were intruded as subhorizontal sheets (rather than diapirs) into thrust sheets of older Amitsôq. The parent material was derived from partial melting of a basaltic crust during subduction. Chadwick and Coe want extensive reworking of older material as well as introduction of new. Collerson *et al.* (Canada) convincingly demonstrated that the east coast of Labrador is the same as the west coast of Greenland. They reported an age of 3.6 b.y. by Hurst for the Uivak gneiss, certainly comparable to the Amitsôq. Hence Canada can now annex the North Atlantic craton to the Canadian Shield!

The presentation of extensive geochemical data on meta-volcanics and amphibolites (Rivalenti, Italy) and on gneisses (Tarney, U.K.) sparked considerable discussion *re* the usefulness and problems of interpretation of chemical data in highly deformed and/or metamorphosed ancient rocks. Gunn (Canada) pointed out that modern volcanics of pumpellyite grade have been open systems to K, Rb, etc. Caution is needed when interpreting Archean rock trends using modern day suites for comparison. Perhaps little weight should be placed on the alkalis. The REE and transition metals seem to be "relatively immobile" and may be better tracers of process (Arth, U.S.A.). This was the approach of Condie (U.S.A.) in his presentation on the evolution of greenstone belts. A comparison of rim and core of three pillow basalts proved Zr immobility, Rb loss and a slight increase in Sr^{87}/Sr^{86} ratios in the rim. There was no clear-cut relationship between Rb/Sr and the content of H_2O and CO_2 (Erlank, South Africa). J. V. Smith suggested that investigators turn to mineral analyses, particularly highly resistant ones. Why not look at zircons for trace elements as well as U/Pb dating? This problem of chemical analyses is a serious and continuing one. Surely common sense must prevail and rocks that are obviously altered (i.e., containing 2-4% H_2O or 3-4% CO_2) must be interpreted with a "grain of salt".

In the third session on greenstone belts, it was suggested that little andesite existed in the volcanic sequences. Instead they are dominated by basalt-dacite "pairs". Perhaps most rocks that chemically classify as andesites are a "mixed" assemblage (Arth). At Abitibi, basalt-dacite sequences are found on the flanks of volcanoes, but towards the centre, an orderly basalt-andesite-dacite sequence is found. The Superior Province volcanics as a whole seems to be 30 per cent andesite (Goodwin, Canada). Is it unique in this respect?

Are there greenstones and greenstones? At least two types appear to exist (Glikson, Australia). The "primary" ones are pre-granitic, ultramafic to mafic, oceanic tholeiites associated with chemical sediments (chert and iron formation). They show an age spread of 3.6-2.8 b.y. and formed a widespread crust. "Secondary" greenstones overlie both primary ones and Na granites, are mafic to acidic with minor ultramafics and have detrital sediments as well as chemical. The volcanics may be partially oceanic tholeiites in character, but seem to be most similar to island arc suites. These secondary greenstones form long linear features, or belts.

I felt a shortcoming in the greenstone session was the lack of any extensive discussion on Archean sedimentation. Some attention was given to chemical sediments (such as the Isua area by Allaart and Geto, Denmark) but there was essentially none on the well known graywacke, conglomerate sequences. These latter are an integral part of greenstone studies, certainly of Glikson's secondary type and must be considered in the formulation of any models.

In the fourth session, on tectonic styles, K. Burke (U.S.A.) proposed that "permobile" deformation dominated. He envisioned smaller plates and/or longer ridges coupled with a lack of any ridged deformation at collision or rupture. He believed that movement of the plates was relatively rapid so that the higher heat contents of that time could be dissipated. A fine example of detailed structural studies in polyphase areas was presented by Coward *et al.* (U.K.) on the Limpopo belt. Ermanovics (Canada) emphasized the ambiguous age relationships in areas such as Cross Lake in Manitoba. Such detailed studies as these are essential before any meaningful geochemical and petrological studies can be done.

The fifth session on the Evolution of the Archean Crust began with A. M. Goodwin's "fixist" model. Drawing on lunar history for comparison, he called for impact development along asymmetric, crescentric patterns. A global convection system followed along the same path. Sialic differentiates aggregated to form continents that finally became Pangaea, a crescentric land mass following the primitive impact outline. The sialic material was added gradually from 3.7-2.6 b.y. St. J. Lambert *et al.* argued for a secular change with time, especially for K, Pb, Rb and K/Na. Tonalitic diapers appear to be more Mg-rich than ancient gneisses, a point also made by McGregor. Archean rocks were depleted in U with K/U ratios as high as 4×10^4 to 10^5, rather than the normal value of 10^4. Moorbath (U.K.) believes that two major events occurred in Archean time - at 3.7-3.8 (Greenland, Minnesota) and at 2.5-2.8 (worldwide). The 3.5-3.6 events recorded in Rhodesia and Norway may well represent a third. It appears that ancient crust is more common than thought, with ages >3.3 b.y. now found in most shields. Hurley *et al.* reported new ages up to 3.4 b.y. from South America. Moorbath further argued that Pb and Sr isotopic ratios dictate that younger material (2.5-2.8, 3.1 b.y.) was not derived from older sial (3.6-3.8 etc.). The Pb data is compatible with a μ value (U^{238}/Pb^{204}) of approximately 7.6 consistant with single stage (or two stage) evolution from mantle material. He stressed that short periods (about 50 m.y.) of crustal growth occurred. Sr isotope ratios in seawater during geologic history mirror K/Na age trends for continental crust and reflect three dominant tectonic regimes - an ensimatic "greenstone belt" type during the Archean followed by ensialic "mobile belt" in the Proterozoic and finally ensimatic "plate tectonics" in the Phanerozoic (Veizer, Canada).

A brief session on metallogeny consisted of a review paper by Watson and a paper on gold deposits in Rhodesia (Fripp, South Africa). Fripp believes vein or lode deposits form from Au chloride brines under greenschist facies metamorphic conditions and that stratiform Au in sulfate and carbonate iron formation was deposited from a different brine during periods of quiescence in the earlier Archean. Major points brought out during the discussion were: (1) the Ni ores in the Yilgan block were concentrated during metamorphism of komatiitic volcanics or ultramafic intrusives (Binns, Australia); (2) porphyry Cu, Mo and Au deposits exist in Archean rocks, but are not economic, hence little known (W. Walker, Canada); (3) there is little Pb in Archean deposits, in sympathy with the low K contents (Glikson). In this session there was too little devotion to ore deposits in relation to basic studies on the origin of Archean rocks. There still exists the isolation of "economic geology" among many, but not all, Archean workers.

The final day-and-a-half centered around the evolution of the atmosphere, oceans and the beginning of life. The growth of free O_2 received considerable attention. N_2 and the noble gases built up over time while CO_2 has always had approximately "modern values" because of marine silicate equilibria. Free O_2 began with the photosynthesis of organic matter, perhaps as far back as 2.9 b.y. Iron formations were a huge sink for storing O_2 and until this system was saturated, no free O_2 occurred (Schidlauski, Germany). Free O_2 certainly existed back into the late Archean, because pyrite is *not* common in sediments of this age and there is no real evidence of reduced carbon compounds or "primordial oil slicks" in littoral deposits (Dimroth and Kimberly, Canada). If the PO_2 was about one per cent of today's value (about 0.002 atm.), UO^2 could survive and be transported as detritus material. Allowing this modest amount of free O_2 in the early atmosphere, helps explain $Fe(OH)_3$ and Fe_2O_3 present in iron formation as far back as the 3.7 b.y. old Isua iron-formation. PO_2 was low because of high heat production and rapid weathering, i.e., demand exceeded supply. Ocean chemistry has not varied much over the past 3 b.y. Dolomite is common in Archean rocks because of the relatively high PCO_2 produced by extensive, early degassing of the earth (Holland and Kimberly, U.S.A. and Canada). J. Walker (U.S.A.) suggested that the composition of the primitive atmosphere depends on the model one assumes for earth formation. If the primitive earth was homogeneous, with metallic Fe at depth, the early atmosphere would contain highly-reduced species such as CH_4. If instead the earth formed according to the inhomogeneous, accretion model, whereby a veneer of volatile-rich, low temperature condensate provided the material for the crust and upper mantle, its oxidation state was approximately the same as today. Then the primordial atmosphere would resemble the modern one with the addition of some H_2 and the removal of all O_2.

According to J. W. Schopf (U.S.A.), the evidence for Archean life is "meager". All well preserved fossils are Proterozoic or younger. A continuum exists back to 2.3 b.y. and Proterozoic biostratigraphy seems possible. On the other hand Muir and Grant (U.K.) found flat-lying laminations of amorphous organic matter in black chert bands, preserved microfossils similar to younger Precambrian ones and small domical "stromatolites" in the Onverwacht group in South Africa. These authors are quite convinced that life existed 3.4 b.y. ago. Cloud (U.S.A.) urged extreme caution in calling unusual Archean structures, fossils. He pointed out that the original meaning of stromatolites was a laminated rock with upward convexity, but now seems to apply only to structures made by blue-green algae. Similar structures of non-biologic origin are possible, such as those created in hot spring areas or in Mn pavements. He stressed that one must look for the microfossils associated with stromatolite beds. He felt the presence of kerogen (a main component of humic acids) is a good indicator of life forms. The antiquity of life remains an open question.

Overall, this was an excellent conference, extremely well organized in every way by Brian Windley and his associates at Leicester. The papers are to be published as a book by John Wiley and Sons, Inc., within the next year. Finally, there was abundant opportunity for free exchange of ideas both at the end of each session and during the informal "bull sessions" before lunch, supper and in the evening. Here one could make his (her) point by gently poking a friend's chest with a mug of best British beer.

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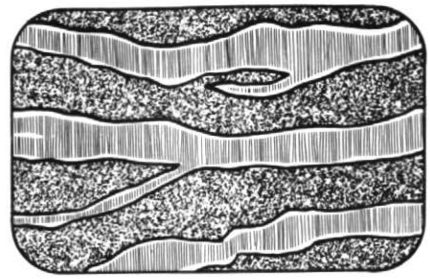

Third International Conference on the Physics and Chemistry of Asbestos Minerals

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Introduction

The Third International Conference on the Physics and Chemistry of Asbestos Minerals was held at Université Laval, Quebec City, from August 17 to 21, 1975. Over 150 participants, representing 20 countries from all continents, listened carefully for four solid days, as world (and some local) experts on the various aspects of asbestos delivered their respective technical papers. The previous two international conferences on asbestos were held at Oxford, England, in 1967, and at Louvain, Belgium, in 1971.

Following the tradition of international scientific meetings, the language chosen by all the speakers was English, even though French was also an official language at the conference. Many of the talks were well prepared and well delivered. However, as is often the case at such conferences, the very high professional competence of several speakers was not always matched by the quality of their exposé. This leads one to wonder if, one day, scientists - and particularly those who are ultra-specialized - will cease underestimating the importance of verbal communication at scientific gatherings.

One of the best things about this international event was the fact that there was only one session going on at any given time for the duration of the whole conference. This enabled