PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY A MATHEMATICAL, PHYSICAL & ENGINEERING SCIENCES

General Discussion

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Phil. Trans. R. Soc. Lond. A 1976 **280**, 661-663
doi: 10.1098/rsta.1976.0019

Phil. Trans. R. Soc. Lond. A. **280**, 661–663 (1976) [661]
Printed in Great Britain

General Discussion

J. P. N. Badham (*University of Southampton, Department of Geology*). There is a general concensus amongst geologists today that the geotectonic evolution of Archaean 'greenstone' belts was causatively different to that of Phanerozoic orogens. That such a concensus seems not to have been reached for Proterozoic orogens is at first surprising. However, during the course of the discussion meeting it became clear that there is a fundamental difference in philosophy between those who work in the African, Laurentian or Baltic Shields and those who work on the Canadian or Australian shields.

Intercratonic mobile belts in Africa consist typically of highly deformed and metamorphosed sequences lying between cratonic basement. These belts are described as ensialic both because they contain remnants of the cratons and because sedimentary sequences can be traced from the craton into the mobile belt. The fact that they are eroded deeply while the surrounding cratons are not bespeaks of strong differential vertical movements, a fact that has been used to discriminate against a plate-tectonic origin, as have the absences from these belts of calc-alkaline igneous rocks and molasse. Finally the branching, arcuate pattern of Pan-African mobile belts has been contrasted with the pattern of interplate orogens.

I think that much, although not all, of the dichotomy arises because only the roots of the Pan-African belts are exposed. Most geologists would now accept the Newfoundland Appalachians as a classic continent-collision orogen. Yet in the south of the island collision was intense enough such that all we have preserved are the two cratons (Western Platform and Avalon Platform) separated by a narrow band of highly metamorphosed and deformed shelf and rise sediments (Fleur de Lys and Gander zones). Were it not for the preservation of higher levels of the orogen elsewhere, this zone might have been interpreted very differently.

Again, most people would accept the Coronation geosyncline as having formed on a continental margin. While Hoffman and I differ on the interpretation of the Wopmay orogen, we are both satisfied that it is a plate-tectonic phenomenon. We must conclude that the Proterozoic shield of Western Canada was at its present thickness – how else the remarkable preservation of the Bear and Slave provinces? If it was as thick, I see no difficulty in envisaging plate-tectonic processes.

However, the Wopmay orogen is important in this context, not only because of its age (near the Archaean–Proterozoic boundary), not because of its remarkable preservation, but because it plunges. Thus in the North platformal sediments, mobile zone and the high level Great Bear Batholith are superbly preserved. Progressively deeper levels are exposed to the South and the calc-alkaline rocks and molasse are eroded. Just before the whole complex disappears (conveniently?) beneath the Phanerozoic, the whole complex consists of keels of sillimanite-gneiss and amphibolite between granites and gneisses. There are marked similarities between this belt and the extensions of the Mozambique Belt from North (Dr Greenwood's plate-tectonic orogen) to South (Dr Kröner's mobile-belt).

The similarities may indeed be taken further. The Wopmay orogen is joined by the East Arm aulacogene, so brilliantly described by Stockwell and Hoffman. The sedimentary fill of this graben is preserved at a remarkably high level. (The same is true of the Bathurst aulacogene also.) There is Archaean basement to the North and Churchill (1750 Ma) basement to the

South. If the East Arm were eroded I would confidently predict that we would see a thin keel of gneisses and metasediments between the two cratons. The East Arm is without doubt an ensialic mobile belt: its geometry and relationships with the Wopmay orogen compare favourably with those between the Zambezi and Mozambique Belts.

Comparisons between the Slave craton and the Kapvaal craton are marked. Both are surrounded by younger mobile belts of various types. Erode the former more deeply and it would look like the latter. My point is not so much to propose that all mobile belts are of a plate tectonic origin, but to emphasize that if we are to understand the evolution of mobile belts and Proterozoic geotectonics, we must start by applying uniformitarian techniques in belts that are well exposed and preserved. It is futile to start at the bottom and to extrapolate upwards when top and bottom are preserved together elsewhere.

J. V. Hepworth (115 *Lower Road, Gt Bookham, Surrey*). The conclusion of two contributors (Shackleton and Kröner) that, in the African continent, there was no 'progressive cratonization' is noteworthy in marking the overdue end of a misleading paradigm which has persisted too long in the face of the evidence. One cannot keep wondering if there is not a danger of its being replaced by another equally misleading, again based on a single category of geophysical data, of a Proterozoic super-continent, subsequently disrupted and dismantled.

The concept of African cratonization germinated from one category of geological data (radiometric age dating) which, totally inadequate in density in relation to area, largely irrelevant to the early history of the rocks in question (predominant K-Ar determinations), and largely anticipating systematic mapping, grow out of all proportion to its validity into the 'Pan-African Orogeny'. Palaeomagnetic determinations appear to the writer to be occupying a precisely analogous position at the present moment. This may be partly because we are still failing to distinguish between one facet and the orogenic process as a whole, in this case supposed continental break-up tending to be regarded as synonomous with orogeny.

For these reasons the writer appealed for a more uniformitarian approach to the problem, by which he does not mean a blinkered attempt to force facts into a restricted model but one which embraces the full range of realities within Plate theory as far as it is at present (imperfectly) understood. Thus it appears that much of the information available about the actual tectonics of two great Proterozoic domains is as yet undervalued. A. J. Baer's simplified picture of Grenville structures ('little blue worms') are not 'impartial' representations of trends too complex to unravel, but crude approximations: similarly, in a considerable part of the Mozambique Belt it is possible to produce an initial analysis of significant structural elements at a reconnaissance level: for example, the references made by contributors to 're-worked basement' within both Grenville and Mozambique Belt in fact depend upon these broad-scale reconnaissance studies for its recognition.

Wynne-Edwards' analysis of the Grenville did *not* depend upon a slavish translation of trend directions into categories but involved many other analytical factors. In the Mozambique Belt whatever interpretation may be put upon the axial fold structures and lineations which plunge transversely from the region of the predominantly cataclastic 'front' into and across the Belt, at least two minimum conclusions can be drawn with regard to the tectonics: the initial process in 're-working' of the floor or basement was one of 'attenuation' or 'thinning' (thanks be to Professor J. V. Watson, this Symposium) of individual elements and stretching in the transverse direction. This phase was succeeded by buckling about north–south axes

(main orogenic belt trend) of such elements as the mullioned gneisses. While it may not be permissible to erect a vector system, nor to refer to the initial phase as 'opening' or the late phase to 'collision' we can see the outlines of deformation within the deep levels of a (presumably) ensialic orogenic belt. My reading of the Grenville, in simplest terms, is similar.

It is very difficult to identify the re-worked gneisses of the basement within the Belt and it would not be safe to absolutely deny the existence of supracrustal eugeosynclinal volcanics, nor of sutures, although these have not been recognized within the Belt. One may also wonder how far it would be possible to do so within the present day Alpine Belt at similar tectonic levels and whether it would not be termed (by an imaginary geologist) 'ensialic'. Enough is known, however, to answer Dr Greenwood's query as to whether the Mozambique Belt represents a great transcurrent fault system. The answer is 'No', but it is of interest to observe that there is a crude similarity between the generally north–south trending orogenic direction of the Mozambique Belt and the transverse, associated Zambezi and Ubendian (and possibly Limpopo) mobile belts: is it possible that this is the continental expression of the well-perceived ridge/transform fault pattern equivalent in the oceanic crust?

It is also worth remarking that however one interprets the transverse lineation and stretching within the Belt this extends across the cataclastic front into the foreland which also displays similar 'stretch' structures – it was not entirely rigid in the orogeny.

Having made the point that a considerable amount is known regarding the gross tectonics of two great 'Proterozoic' orogenic belts, and making the appeal that these should be related to gross Plate motions postulated from palaeomagnetic data, it is worth emphasizing that even these reconnaissance studies are small in relation to the vast areas which have been designated 'Pan-African' and 'Grenville'. Professor Baer's masterly synthesis of the Grenville, in which he stated the extent of knowledge in each category and clearly attributed the status of the 'front' and other elements to their conceptual origins, emphasizes the necessity of doing the same for the 'Pan-African'. It should be realized that the greater part of this vast, postulated entity (as illustrated in the Symposium) is still based upon the single parameter of radiometric age determinations and, requires to be rigorously examined on a continental scale before it deserves to be accepted as an integral part of a global or continental tectonic system. A similar analysis of all data relating to the supposed Pan-African orogeny would, I suspect, destroy it as a concept, as Dr Kroner's account of the regional tectonics seemed to confirm.

Although it would be foolish to ignore the many lines of evidence that point towards some kind of major change in crustal history in the Proterozoic I am even more impressed by the apparent similarity of crustal development processes such as we have recently established in the Botswana sector of the Archaean Kaapvaal craton, by Dr Greenwood's account of the evolution of the southern part of the Arabian shield, and the similarity of both of these to Phanerozoic crustal evolution.

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