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

Introductory Remarks

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Introductory remarks

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In the past decade or so several major advances have significantly increased our understanding of continental crustal evolution. First, there is widespread recognition that the Wilson Cycle of plate opening and closure was responsible for the formation of Mesozoic–Cainozoic orogenic belts. Indeed the application of this plate tectonic scenario has been so successful that it is now possible to interpret the deformation of most Palaeozoic and several Proterozoic orogenic belts by accretionary or collisional processes. Secondly, there has been a surge of multidisciplinary research activity on Precambrian rocks, and especially on those formed before about 2.5 Ga B.P. during the Archaean. In the light of these advances, we are now beginning to understand the evolution of the continental crust in a continuous, long-term perspective with a global tectonic model that seems to be increasingly applicable to a wide range of young and old environments.

This meeting report highlights one of the principal current controversies regarding continental crustal evolution: how much crust was created during, and by the end of, the Archaean, and how much subsequently? This question is directly related to the controversial role of secular recycling of crustal materials. According to one view (Armstrong), based mainly on isotopic and continental freeboard arguments, the total mass of continental crust was differentiated early in the Earth's history, perhaps before 3.7 Ga B.P., with negligible crustal growth since that time. This 'steady-state' model clearly implies efficient recycling of the bulk of eroded continental materials through the mantle throughout geological time.

In contrast, many isotope geologists (for example, O'Nions & Hamilton) argue that early rapid growth of the bulk of the continental mass during the period 3.5–2.5 Ga B.P. was followed by a decline in growth rate to the present, concomitant with the overall decrease in terrestrial radiogenic heat production. Rare-earth element evidence on sedimentary rocks, too, is consistent with a low continental growth rate in the earliest Archaean, a massive increase in growth rate (to about 70% of the total crust) between about 3.0 and 2.5 Ga B.P., and a slow decrease until the present day (Taylor & McLennan). Dewey & Windley calculate rates of continental growth based on this general viewpoint.

Within the general framework of this controversy, it is important to attempt to distinguish clearly between selected element recycling and bulk return of continental material to the mantle. It appears that recycling of crustal materials into the zone of magma genesis and mantle may well have been limited to the subduction of some pelagic sediments and altered oceanic crust (Karig & Kay).

A subject that cannot be avoided when considering continental evolution is uniformitarianism. Can Lyell's doctrine be strictly adhered to, or has it no relevance for deciphering the early geological record? Has modern-style plate tectonics operated through Earth history, or was some modified version responsible for early crustal growth, or did some different form of 'ensialic' orogenesis involving no lateral plate motion operate in the Precambrian? Reference to these questions will be found in several papers of this report. There is an increasing awareness that the higher radiogenic heat production in the distant past must be related to increased tectonic activity, and in turn that some form of rapid plate accretion and destruction was responsible for the rapid crustal growth rate in the period 3.5–2.5 Ga B.P. On this view, the earliest thermal régime was intense enough to inhibit the production of continental crust before about 3.7 Ga B.P. (the age of the oldest true continental crust). Before this, the relatively thin, basic, terrestrial proto-crust was easily disrupted and recycled back into the mantle by efficient convection, perhaps aided before about 3.9 Ga B.P. by intense and concentrated impacting by planetesimals (Smith). It was only when these early, basic unstable proto-plates became thick enough to interact in a manner akin to intraoceanic plate tectonics that localized nuclei of true continental crust could begin to differentiate and stabilize.

Another factor brought out by several contributors (Brown; Dewey & Windley; Dickinson; Tarney & Windley) is that crustal growth in the past most probably took place by some form of arc/Cordilleran activity at destructive continental margins. Only this tectonic environment enables those processes to take place that are capable of producing new continental crust on a massive scale. It has only been realized recently that the geological record provides good evidence of island-arc-, Cordilleran- and Himalayan-type activity since the early Proterozoic in a manner not so different from that of today (Barker *et al.*; Dewey & Windley; Dickinson; Hamilton; Tarney & Windley). These relationships support the view that modern-style plate tectonic processes began at least 2.5 Ga ago.

Three papers (Thorpe *et al.*; Barker *et al.*; Brown) are devoted to the subject of andesites, tonalites and granites, which have been three of the principal crust-generating rocks since the early Precambrian. It is essential that the tectonic and geochemical constraints on the evolution of the relevant parent magmas are fully worked out if we are to understand their roles in continental evolution. Advances in trace-element and isotope geochemistry, in particular, allow the determination of the history of partial melting and fractional crystallization processes in magmas, of the relative magnitude of crust and mantle contributions, and of the degree of depletion of mantle sources (Hanson; O'Nions & Hamilton). A further paper (Wells) discusses new, interrelated tectonic and thermal models for the production and emplacement of massive amounts of new continent-forming magmas from mantle source regions and their subsequent metamorphic and geochemical differentation, within a framework based on the concept of episodic, short-lived continental accretion episodes. The possible long-term effect of continental crust formation on the nature and thickness of the sub-continental lithosphere ('tectosphere') is another relevant and much debated problem (Jordan).

Two papers deal with various aspects of the relative movement of continental masses. Further advantages have been made in palaeomagnetism (Dunlop) which, in the construction of apparent polar wandering paths, enable the movement of continental plates to be followed for the last 2.5 Ga, as well as in the study of palaeoclimates and lithofacies distribution in relation to ancient environments (Ziegler *et al.*).

Finally, the evolution of continental crust is intimately related to the development of atmosphere and hydrosphere. The interaction between endogenic and exogenic processes during the course of Earth history is discussed by Holland.

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Our aim in convening this Discussion Meeting was not to review the latest field results, nor to concentrate on syntheses of specific time periods or orogenic belts, because there have been several recent conferences on these subjects. Instead, the objective has been to emphasize the principles and processes that have controlled the formation and evolution of the continental crust throughout geological time.

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