A tale of two cratons: Speculations on the origin of continents

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Abstract

The origin of continents is not well understood, perhaps because each of the two usual ways of addressing the problem has methodological difficulties. Isotope geochronology has enabled the condition of the early Earth to be reconstructed from the direct evidence of successively older rocks, working backwards in time. But, since a point is reached where there are no older rocks available, much speculation about the immediately pre-geological history of the Earth (the period when its identity was well established but of which no direct trace remains in the form of existing surface rocks) has come from planetology; and its approach has been, properly, to work forwards in time, starting from some preferred model of accretion. This paper is an attempt to bridge these two approaches, by focusing on what characteristics of the earliest rocks actually need to be explained by the planetological models.

The restriction of these oldest rocks to a small number of core areas within early cratons, of which the Kaapvaal Craton (KC) of southern Africa and the Pilbara Craton (PC) of Western Australia are taken as typical, is first noted. The closely parallel evolution of both of these Cratons starts at about the same time, with the sudden appearance of vast quantities of evolved silicic magma (now orthogneisses), accompanied by the deposition of thick successions of mixed, mainly volcanic, rocks differing in only a few respects from those that have continued to come from the Earth's interior; although the early Earth must have been hotter, this is not reflected in the metamorphism of the oldest strata. Following this abrupt beginning, these protocontinents grew steadily through continuous, but diminishing, magmatic activity, manifest as both silicic plutonism and bimodal eruption.

All of these features are consistent with the following simple model of the early Earth. A completely molten immediately pre-geological Earth had, outside its metallic core, a pattern of huge, polygonal, convection cells with ascending central plumes and descending peripheries; there were possibly as few as 12 such cells, forming a pattern of irregular pentagons, with 20 main centres of convective descent (COCDs) at their triple junctions. Before the continents formed, the thin skin of cooled and solidified material, formed on the surface of each cell during radial surface flow, was carried down at the margins and remelted as it descended. Such melting produced, by well known petrogenetic processes, a variety of differentiated magmas which during rapid early convection were carried down and remixed with their parent materials. As the whole Earth cooled, and the rate of convection slowed, a point was reached where the buoyancy of these silicic magmas enabled them to rise faster than the descending columns below the COCDs, resulting in the appearance at the surface of a plug of orthogneiss.

The subsequent geological development of the KC and PC, jointly taken as archetypes of the early continents, fits comfortably with a concept that later continental growth was a simple response to maintenance of the same large-scale convective system which remained in force long enough to establish, below the oldest parts of the continents, the very deep roots for which there is increasing evidence. At some stage of lateral growth, possibly associated with both a change of global convective patterns and the development of a layered mantle, the early continents became unstable and were subject to break-up and relative displacement over the Earth's surface. The existing areas of oldest rocks are not simply the few surviving remnants of some early (but not earliest) continental crust that covered the whole Earth, but really do represent both the initial and sole centres of continental growth.

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