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Contrasting styles of Proterozoic crustal evolution: A hot-plate tectonic model for Australian terranes

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Processes controlling lithospheric evolution on the early Earth are the subject of ongoing and often spirited debate. The popularity of uniformitarian principles has meant that, with the exception of the earliest Archaean, dynamic plate-tectonic models have largely prevailed. These models appear to be appropriate in many cases, including for the Palaeo-Mesoproterozoic evolution of North America and for the evolution of those Meso-Neoproterozoic terranes related to the assembly of Rodinia, including those in Australia. However, existing models for the Palaeo-Mesoproterozoic evolution of many Australian terranes do not fully account for a number of key observations. In particular: (1) repeated tectonic reactivation (both orogenesis and rifting); (2) large aspect-ratio orogenic belts; (3) mainly high temperature-low pressure metamorphism; (4) rifting and sag giving thick sedimentary basins; (5) the nature and timing of voluminous felsic magmatism, and (6) the general absence of plate-boundary features.

Here a more general approach to understanding crustal evolution is advocated. This is based on the recognition of critical observations from the geological record as well as an understanding of the chemical and physical properties of the lithosphere. The basic tenet of any tectonic model is that the crust will deform if the applied stress is greater than the average crustal strength, and this may occur where plate boundary forces are significantly amplified, or the crust is made sufficiently weak. One of the most outstanding features of Australian Proterozoic terranes is an extraordinary, but heterogeneous, enrichment of the heat-producing elements. The modern contribution of crustal heat sources to the surface heat flow is between 50-70 mWm^{-2}, and this value was at least 20-25% higher during the Proterozoic. This enrichment must contribute to significant long-term lithospheric weakening and, thus, we advocate a hybrid lithospheric evolution model with two tectonic switches: (1) plate-boundary-derived stresses and, (2) heat-producing-element-related lithospheric weakening. The Australian Proterozoic geological record of magmatism, metamorphism and sedimentation is therefore a function of the magnitude of plate-boundary derived stresses, the abundance and distribution of heat sources, and how both of these change with time. It has more in common with an early Earth hot-plate style of evolution, than the modern rigid-plate style.