Early mantle dynamics: depletion, plates and a revised cooling history

GEOFFREY F. DAVIES[1]

[1] Research School of Earth Sciences, Australian National University, Canberra ACT 0200, Australia; Geoff.Davies@anu.edu.au

Numerical models of the dynamics of the early, hot (1550°C) mantle, incorporating simulated plates, yield a strongly depleted upper mantle due to gravitational settling of denser subducted mafic crust through an upper mantle less viscous than at present. However mafic material remains suspended in the lower mantle due to its relatively higher viscosity, except for some accumulation at the base of the mantle. The upper mantle depletion would accord with the strong depletion of incompatible elements recorded in Nd and Hf isotopes from the earliest zircons and rocks. Subsequent cooling of the mantle would reduce the effect, thus also explaining why later observed depletions are not so strong.

This result can also explain why the depletion occurred before any record of significant continental crust, and it accords with geochemical tracers that indicate even the late Archean depletion was due more to basalt extraction than to the extraction of continental crust.

The strong mafic depletion of the upper mantle would reduce spreading-center melting and thus yield relatively thin oceanic crust, despite the high mantle temperature. Whereas a hot modern MORB source would yield oceanic crust about 30 km thick, the hot depleted mantle yields only 4-8 km of oceanic crust. It has been argued that a thick oceanic crust would inhibit plate tectonics, so the thinner crust of these models would make early plate tectonics more viable.

Less inhibited plates in turn would provide a mechanism to cool the early mantle, where no obvious mechanism has been evident. However efficient cooling would operate in two separate thermal regimes, very hot and cool. The result is that the mantle could 'hang' in a relatively hot state until radioactive heat production dropped below a threshhold that allows the cool-mantle regime to be viable, as illustrated (black curve; the grey curves show a conventional history and a mainly hot-history). While still conjectural, this revised thermal and tectonic history has intriguing potential.