Thermal history of Earth and the modes of mantle convection

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Possible geodynamic regimes have may have prevailed in Earth's history are discussed on the basis of the energetics of plate-tectonic convection. Plate-tectonic convection, modulated by strong depleted lithosphere created at mid-ocean ridges, demands more sluggish plate tectonics when the mantle was hotter, contrary to commonly believed, more rapid tectonics in the past. This notion of sluggish plate tectonics can simultaneously satisfy geochemical constraints on the abundance of heat-producing elements and petrological constraints on the degree of secular cooling, in the framework of simple whole-mantle convection. The geological record of supercontinents back to 2.7 Ga is shown to be broadly consistent with the accelerating plate motion as predicted by the new model. Furthermore, the very fact of repeated continental aggregation indicates that thicker depleted lithosphere in the past needs to move more slowly to become negatively buoyant by thermal contraction and also needs to be strong enough to support resulting thermal boundary layer. The concept of many small plates covering Archean ocean basins is thus physically implausible. As a consequence of reduced secular cooling, mantle plumes were most likely weaker in the past. The chemical evolution of Earths mantle may have been encumbered considerably by sluggish plate tectonics and weak mantle plumes, maintaining its compositional heterogeneity at various spatial scales to the present day. Internal heat production probably played an important role in controlling plate dynamics in the early Archean, for which a different mode of mantle convection is suggested.