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Mantle convection, plate tectonics and the thermo-chemical evolution of the Earth

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The coupled system of convection of the solid, rocky mantle of the Earth and plate tectonics is the main driver of long-term Earth evolution, being responsible for continental drift, earthquakes, volcanoes, crustal building, mountain building, heat loss from the core that drives the geodynamo, and outgassing/ingassing of volatiles to/from the atmosphere (particularly CO2 and water). The Earth started from a hot, molten state (magma ocean) and has been cooling since then, with radiogenic heating reducing the rate of cooling, although there is considerable uncertainty in the relative proportions of heat loss coming from radiogenic heating and cooling.

The mantle-plate system must be treated as thermo-chemical because there is continuous chemical differentiation caused by partial melting, which results in the production of oceanic and continental crust and has profound implications for the structure of the interior. Another complexity is that plate tectonics may not always have existed; there is much debate about what tectonic mode may have preceded it, and this has a strong effect on early thermo-chemical evolution.

Here, these various aspects are reviewed, uncertainties and important future research directions highlighted.

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