A multiple-system study of the geochemical evolution of the mantle with force-balanced plates and thermo-chemical effects

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Mantle convection models taking into account oceanic crust extraction and recycling are used to study a multiple-system chemical evolution of the Earth's mantle. The dynamical models are based on high-resolution cylindrical calculations with force-balanced plates and variable chemical density. The dynamic results have a convective vigor similar to that of the present day Earth as measured by surface heatflow and average plate velocities. The importance of the recycling of oceanic crust in the form of dense eclogite is confirmed using the isotope geochemical evolution in the U-Th-Pb, Sm-Nd, Rb-Sr and Re-Os systems. The extraction of continental crust is found to be essential for the formation of all isotope end-members including HIMU. Our analysis indicates that EM-I may be generated purely from the enrichment by ancient oceanic crust without the addition of sediment. This suggests that EM-I is indicative of mantle enrichment before about 2.5 Ga while HIMU is formed by more recently extracted oceanic crust. We find that it is difficult to maintain a true DMM isotopic end-member in Sr-Nd when significantly enriched end-members are present. This may suggest a higher sensitivity of the Sr-Nd system to mass exchange between the upper and lower mantle.

Reading the clues recorded in chemical and textural depth profiles in critical zone systems

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The Critical Zone is defined as the zone from the outer vegetation canopy to the lower limit of groundwater. In that zone, bedrock formed at depth equilibrates to surficial conditions through chemical reactions that are accelerated by biota. These weathering reactions are documented by the gradients in concentration of i) elements in the solid regolith, ii) minerals, and iii) solutes in porefluids. The interpretation and modelling of profiles of such concentrations versus depth elucidate controls on denudation. For example, geomorphologists consider total denudation of some landscapes to be limited by the rates of chemical weathering reactions: in such "weathering-limited" regimes, chemical gradients are expected to show only partial depletion of parent mineralogy at the land surface. In such landscapes, steady state systems develop when porefluid chemistry couples rates of erosion at the land surface to the regolith advance rate at depth. In contrast, "supply-limited" landscapes are those where total denudation is not dependent on chemical weathering rates. For these landscapes, regolith is largely depleted of parent minerals; steady state can only develop when regolith grain size couples regolith advance rates at depth to erosion at the surface. Understanding such effects requires quantification of not only chemical gradients but also gradients in pore and grain size versus depth. Models are being developed to quantify depth profiles for elemental concentrations and textural characteristics to reveal histories of weathering.