Origin of geochemical mantle components: Role of spreading ridge, subduction zone, and thermal evolution of mantle

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We explore the element redistribution at mid-ocean ridges (MOR) and subduction zones (SZ) using a numerical model to evaluate the roles of decompression melting at MOR and fluxed melting at SZ of the mantle in Earth's geochemical cycle, with focus on the formation of the depleted and enriched mantle components. Our model uses a trace element mass balance based on an internally consistent thermodynamic-petrologic computation to explain the composition of MOR basalt (MORB) and SZ magmas and their residual mantles and slab components. Model results for MORB-like basalts from 3.5 to 0 Ga indicate a high mantle potential temperature (Tp) of 1650–1500°C during 3.5–1.5 Ga before decreasing gradually to ~1300°C today. The source mantle composition changed from primitive (PM) to depleted as Tp decreased, but this source mantle is variable with an early depleted reservoir (EDR) mantle periodically present. We examine a two-stage Sr-Nd-Hf-Pb isotopic evolution of mantle residues from melting of PM or EDR at MORs. At high-Tp (3.5–1.5 Ga), the MOR process formed extremely depleted DMM. This event coincided with formation of the majority of the continental crust (CC), the sub-continental lithospheric mantle (SCLM), and the enriched mantle components EM1, EM2, and HIMU formed from the slab components at the Archean to early Proterozoic high-Tp SZs and stored in the lowermost mantle now found in ocean island basalts (OIBs) through plume upwelling. During cooler mantle conditions (1.5–0 Ga), the MOR process formed most of the modern ocean basin DMM. Changes in the mode of mantle convection from vigorous deep mantle recharge before ~1.5 Ga to less vigorous afterwards is suggested to explain the thermochemical mantle evolution. These EM and DM components appear to form large domains forming N-S hemispheric lower mantle EM and E-W hemispheric upper mantle DM structures, respectively. Mantle convection appears to be sluggish for these mantle components perhaps due to density stratification of the source materials.