Origin of geochemical mantle reservoirs: Roles of subduction filter and thermal evolution of mantle

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Upwelling mantle melts at Mid-Ocean Ridges (MOR) to form basaltic igneous oceanic crust (IOC). IOC and overlying sediment (SED) descend into the mantle at subduction zones (SZ). The IOC, SED, and overriding mantle melt to form stable continental crust (CC) after crustal-level processing, whereas the residual slab is recycled into the lower mantle. We quantitatively explore the element re-distributions at MOR and SZ using numerical mass balance models, and we evaluate their roles in the Earth’s geochemical cycle. Our models of slab residues differ from previous ones by being internally consistent with geodynamic models of modern arcs and successful explanations of modern arc magma genesis, and by including element fluxes from the dehydration or melting of each underlying slab component. We find that the upper mantle potential temperature (T_p) was 1400–1650 °C from 3.5 to 1.7 Gyr before decreasing gradually to ~1300 °C today. Hot SZs with T_p ~1600 °C have a thermal structure like modern SW Japan where high-Mg andesite is formed that is like CC. Isotopically, residual IOC from hot SZ evolves to the HIMU OIB reservoir, residual SED to EMII, the residual base of the mantle wedge to EMI, and the residual top of the mantle wedge to the subcontinental lithosphere (SCLM) reservoir, after 1.7–2.5 Gyr of storage in the lower mantle. The Common (C) or Focal Zone (FOZO) reservoir is a stable mixture of the first three residues. Older recycled residues (~2.5 Gyr) form the DUPAL anomaly in the southern hemisphere, whereas younger ones (~1.7 Gyr) are in the northern hemisphere. These ages correspond to major CC forming events. We attribute the E-W heterogeneity of the depleted upper mantle (DMM) to involvement of sub-Gondwana SCLM except in the Pacific.

Keywords: Mantle reservoir, Subduction zone filter, Thermal evolution of mantle

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