Persistence of isotopic domains in the upper mantle: evidence from mantle circulation models

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Ocean-scaled geochemical differences across the upper mantle have been known since the '80's (e.g. [1,2,3]), with definition of the DUPAL and SOPAL anomalies. Furthermore, the depleted, Indian Ocean MORB signature, synonymous with the DUPAL anomaly, has been documented in Neo-Tethys and Paleo-Tethys MORB prior even to the formation of the Indian Ocean (e.g. [4,5]). Whilst such observations have been documented, it is not clear how isotopic anomalies can persist in the upper mantle through successive plate re-organisations. We explore this question using 3D spherical numerical mantle circulation models embedded with the latest geological paleo-tectonic reconstructions and ground-truthed with new Hf-Nd isotope data. We find that the geographic patterns of chemical variations around the Earth's mantle endure within largely isolated cells defined by the positions of subducting plates. We find compelling evidence that large-scale convection cells constrain the overall mixing pattern within the upper mantle, producing a dominantly 'up-down' convective pattern, where material at the core-mantle boundary (CMB) is returned to the upper mantle geographically above it. The models fit global patterns of isotope data and can explain long-lived features such as the DUPAL anomaly and differences between Indian and Pacific Ocean crust. Indeed, our new geochemical data suggests this mode of convection could have influenced the evolution of mantle composition well beyond the timeframe of the mantle circulation models, potentially since at least the start of the Paleozoic.

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