Timing and nature of late accretion

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There is overwhelming evidence for varying amounts of late accretion additions of the highly siderophile elements (HSE: Re, Os, Ir, Ru, Rh, Pt, Pd, Au) after core formation to fully differentiated inner Solar System planetary bodies. HSE abundances in rocky mantles of planets point to the cessation of core formation and continued accretion of broadly chondritic materials as a key process during the final stages of planet formation. Here I consider the fundamental relationships between late accretion additions, their timing, and potential correlations of HSE abundances with mantle oxidation state and volatile contents. On Earth, there is direct access to upper mantle materials, albeit these sample sets may not be completely unbiased. There is also the possibility that some diogenites represent lower crustal or mantle samples from their parent body. Because of a lack of definitive mantle samples from most fully differentiated bodies, establishing estimated HSE abundances of mantles occurs though derivative melts. A means for estimating mantle HSE abundances is to utilise the compatible behaviour of the HSE and MgO. Using this method, it is possible to estimate mantle HSE abundances for Earth, the Moon and Mars at ~0.009 ±0.003, ~0.0002 ±0.0001, ~0.007 ±0.004 (2σ), respectively. Using these mantle estimates, apparent correlation between HSE abundances and fO_2 in planetary bodies breaks down.

It has been shown that the petrology of diogenites are consistent with HSE being set within these meteorites during crystallization, within ~2-3 Ma of Solar System initial (SSI). The timing of post-core formation accretion to diogenites contrasts with timing constraints from Mars, within the first 100 Ma of SSI, and with the Moon within the first ~150 Ma as defined by crystallization ages of the oldest ferroan anorthosites. Constraints on post-core formation accretion for Earth are less well constrained, but must have been set prior to 4 Ga. These results suggest that, in some manner, parent body size exerts influence on post-core formation late accretion. Simplistically, smaller-sized bodies melt, differentiate and cool faster than larger-sized bodies, inpart because of more limited accretion of increasingly massive impactors. Thus HSE abundances in rocky planets reflect the timing of cessation of core formation, as well as the degree to which planetary mantles are able to convect and homogenise the HSE. As planetary mantles become more convectively sluggish, additions of HSE will lead to increasing mantle heterogeneity.

Highly siderophile element constraints on intraplate magmatism

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Ocean island basalts (OIB) and continental flood basalts (CFB) represent volcanic rocks that are unassociated with conventional plate tectonic boundary magmatic processes and that may require anomalous thermo-chemical and/or tectonic conditions to induce small- to large-scale melting of their mantle sources. Studies of the highly siderophile element (HSE) geochemistry of these and other forms of intraplate magmas have the potential to provide answers to questions regarding mantle sources and potential core-mantle interactions, if the effects of assimilation, fractional crystallization and melting processes can be elucidated.

HSE (Os, Ir, Ru, Pt, Pd, Re) abundance and $^{187}Os/^{188}Os$ data for OIB and CFB illustrate the importance of sulphides during both mantle partial melting and modification of primary melts during transit through the lithosphere. The interplay of partial melting and lithological/mineralogical heterogeneity of the mantle source are also important, with lower degrees of partial melting resulting in sampling of more fusible materials (e.g., grain-boundary sulphides [1]). This relationship suggests that intraplate magmas derived from large degrees of partial melting will provide a broader mantle sampling than those derived from lower degrees of partial melting. Alkalic HIMU (high $^{238}U/^{206}Pb$) OIB with high-Os abundances (>50 ppt) that have elevated $^{187}Os/^{188}Os$ (ratios up to 0.175), and hence long-term (>1 to 2 Ga) Re/Os fractionations, have $^{186}Os/^{188}Os$ within the range of abyssal peridotite compositions. Likewise, enriched mantle (EM) OIB that have $^{187}Os/^{188}Os$ that dominantly reflect contributions from peridotite with only minor contributions from recycled sediment or continental crust and/or lithospheric mantle materials lack evidence for long-term Pt/Os fractionations. In contrast, some Hawaiian picrites have $^{186}Os/^{188}Os$ ratios consistent with a mantle source with high time-integrated Pt/Os with respect to average upper mantle composition [2]. Evidence for long-term Pt/Os fractinations retained in higher-degree tholeiites may implicate radiogenic outer core contributions, or sampling of isolated mantle source reservoirs that have evolved with supra-chondritic Pt/Os over >2 to 3 Ga time-scales.

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