Understanding Earth using highly siderophile and chalcophile elements

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The highly siderophile elements (HSE; Re, Os, Ir, Ru, Pt, Rh, Au, Pd) - which are characterized by low-pressure metal–silicate distribution coefficients of more than 10^4 - and the highly chalcophile elements (HCE: S, Se, Te, Pb), have characteristics making them ideal for understanding a range of Earth processes. Two long-lived radioactive isotope decay schemes occur within the HSE ($^{187}Re \rightarrow ^{187}Os$ $T_{1/2}$ = 41 Ga; ^{190}Pt-^{186}Os $T_{1/2}$ = ~450 Ga), with the $^{187}Os/^{188}Os$ chronometer finding wide application, from geochronology, to studies of mantle heterogeneity, or the record of continental weathering. During condensation of elements at the formation of the Solar nebula, siderophile and chalcophile elements sequestered in refractory metallic alloys, or into FeS, depending on volatility. Early Earth differentiation led to siderophile elements being extracted into the metallic iron core, and corresponding depletion in Earth's silicate mantle and crust. Abundances of siderophile elements in bulk silicate Earth are higher than expected from low-pressure metal-silicate partitioning. This overabundance in Earth's mantle has been attributed to 'late accretion' of materials with generally chondritic bulk composition after core formation ceased, to account for the chondrite-relative abundances of the HSE, with the HCE suggesting volatile-rich accretion in some instances. Some siderophile elements have decreased metal-silicate partition coefficients at high pressure suggesting that core-mantle equilibration may account for the siderophile element abundances in the bulk silicate Earth. However, any model must account for both the abundances of these elements and the long-term ratios of Re/Os and Pt/Os that are within 5-10% of chondritic values deduced from $^{187}Os/^{188}Os$ and $^{186}Os/^{188}Os$ in mantle rocks. Asteroids, which underwent metal-silicate partitioning at low pressures, show HSE and HCE abundances in broadly chondritic proportions, indicating that late accretion was ubiquitous in the Solar System. Late accretion is a natural consequence of planetary growth, whereby the end of core formation and metal-silicate partitioning enables build-up of siderophile elements in planetary mantles, in broadly chondritic abundances. For Earth, late accretion of approximately 0.8% by mass of a carbonaceous chondrite component is required to explain HSE and HCE in the mantle. For other planetary bodies, the amount of late accretion is less certain, but is likely to be strongly tied to the timing of cessation of core formation and metal-silicate equilibration.