Revisiting Late Accretion

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Late accretion, also known as "the late veneer", is typically defined as the addition of materials with generally chondritic bulk compositions to planetary mantles after core formation has largely ceased. It is a concept that was created in the 1960's to explain the apparent overabundance of highly siderophile elements (HSE) in Earth's mantle relative to what would be expected from metal-silicate partition known at the time. In the case of Earth, the total mass of late accreted materials would need to equal or exceed ~0.5 wt.% of Earth's mass to account for the HSE present in the mantle. The concept has strengthened somewhat since then as Os isotope and relative abundances of HSE projected for the bulk silicate Earth (BSE) appear to be within the range of chondritic meteorites. Retaining chondritic ratios in BSE by invoking other processes, such as high pressure/temperature metal-silicate partitioning, is problematic. Despite the strong evidence for late accretion, it is valuable to occasionally re-assess the concept with new data and ideas.

Osmium isotopes continue to be the strongest evidence for late accretion. They leave little wiggle room with respect to the precisely chondritic relative abundances of Re-Pt-Os in the BSE. Conversely, Ru/Ir and Pd/Ir ratios estimated for the BSE are not good matches to chondritic meteorites, and may indicate that either our ability to estimate BSE ratios from upper mantle materials is not as good as believed, or that additional processes have have been involved (e.g., Hadean matte). Alternatively, these ratios may also mean that late accretion was not the process that dominated their abundances in the mantle.

Comparative Earth-Moon mantle abundances of HSE, together with the difference in $^{182}W/^{184}W$ between the two bodies provides evidence for stochastic late accretion, whereby late accretion to Earth was dominated by a small number of Pluto mass bodies. This conclusion, coupled with recent dynamical modeling of impactors of that size, suggests that late accreted materials may have been forcefully injected into the mantle with mantle and cores separating, and should not be thought of as having formed a "veneer".

Some studies have argued that late accretion consisted largely of oxidized, carbonaceous chondrite-like materials, potentially delivering substantial water and organics to Earth. Although Os isotopes have long weighed against the involvement of carbonaceous chondrite-like material during late accretion, recent Ru and Mo genetic isotope data for the mantle definitively rule out any substantial contributions.