Evidence for carbon rich cores in asteroids and terrestrial planets

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The light element compositions of planetary and asteroidal cores play a significant role in setting the resultant Hf/W ratios of their silicate mantles. During core formation the metal/silicate partitioning behaviour of W, a moderately siderophile element of 6^{+} valence, is dominated by the prevailing oxygen fugacity of core. Additionally, W exhibits strong positive interactions with S in the metallic phase, resulting in siderophile W partitioning much less strongly into the metallic liquid if the core is S-rich. The large, S rich core of Mars coupled with the high FeO content of the mantle (~18wt% FeO) results in bulk silicate Mars having low Hf/W ratios of ~5. In contrast the Earth, with lower FeO content in the mantle (8wt%FeO), and higher pressures of metal/silicate equilibration exhibits Hf/W contents of ~25.

Vesta is enigmatic. It has an oxidised mantle with a Mars-like FeO content (14 – 18wt%FeO), whilst its small size means that peak pressures of metal-silicate equilibration are very low. This makes the elevated, Earth-like, Hf/W ratio of 19 surprising and leads to the obvious question – how can W be so strongly partitioned into Vesta's core? The presence of cosmochemically abundant carbon during Vesta's differentiation is a likely explanation. Carbon dramatically increases the siderophile behaviour of W. The implication is that Vesta's Hf/W can only be explained if its core is carbon rich and W is preferentially partitioned into the metallic phase. Hence, we show that to explain the mantle abundances of W in silicate Mars and Vesta, light element core contents must be dramatically different.