Early planetary formation processes of Vesta evidenced by highly siderophile elements concentrations in eucrites

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Due to of their strong affinity for iron, the highly siderophile elements (HSE: Os, Ir, Ru, Pt, Pd, Re) partitioned into the metallic cores of telluric planets and smaller planetesimals during early differentiation, leaving behind silicate mantles depleted in those elements. The extent of the depletion is dependent on the silicate-metal pressure equilibration and the respective oxygen and sulphur fugacities during planetary formation. HSE can also be replenished in the mantle after core formation by impacts bringing exotic components. For the asteroid 4-Vesta, it has been proposed that diogenites did not experience post-core formation re-enrichment [1], while brecciated polymict and monomict eucrites and howardites show various degrees of exotic material contribution [2]. In addition, [3] suggested that while the low abundances of HSE in HED meteorites are consistent with highly efficient core segregation at low-pressure, their relative abundances may also reflect late chondritic HSE addition.

Recently, a suite of both cumulative and basaltic unbrecciated eucrites has precisely been dated using the Al-Mg chronometer for their crystallization ages, but also (model) differentiation ages [4]. It hence provides a detailed chronology for the silicate differentiation of Vesta. A systematic age discrepancy was observed between basaltic and cumulative eucrites that can be interpreted as the ongoing crystallization of the vestan crust contemporaneously to a vestan magma ocean. Here, we investigated the elemental systematics of HSE in the same basaltic and cumulative eucrites. We observe two different groups that encompass the distinction between cumulative and basaltic eucrites. The first group is strongly depleted in HSE and presents a fractionated pattern compared to chondrites. The second group has a flat chondritic-like HSE pattern, though 1000 times more depleted than chondrites. These low concentrations are still too high to be explained only by core segregation [3], as metal-silicate HSE partition coefficients increase dramatically at low pressure. Because the selected samples are unbrecciated, we can rule out chondritic secondary contamination by impact as observed in polymict eucrites [2]. We thus suggest that the distinction between the two groups is related to the progressive cessation of core segregation with a concomitant chondritic input during the late stage of the magma ocean on Vesta. While core segregation is ongoing, there is a competition between HSE depletion by metal segregation and HSE enrichment by chondritic input, resulting in a fractionated pattern. When the core segregation slows down, likely related to the progressive solidification of the magma ocean, the chondritic enrichment continues for a short amount of time and the HSE pattern becomes flat, though depleted compared to chondrites. Later, HSE addition by impact can also contaminate the vestan crust, with flat HSE patterns, but much higher concentrations [2]. Except for Re, the investigated HSE indicate a coherent addition of 0.1 % of chondritic material during the late stage of the magma ocean on Vesta. Even though not fully resolvable within error, this scenario is consistent with the precise dating performed on these eucrites [4].

References

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