CHALCOPHILE ELEMENTS IN MARTIAN METEORITES INDICATE A LOW SULFUR CONTENT IN THE MARTIAN INTERIOR

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Introduction: The concentration of sulfur in the Martian core and mantle are critical to understand the origin of Mars' early magnetic field [1,2], the magmatic evolution and the early conditions of the Martian surface and atmosphere [3-5]. Because of the relatively high S contents (typically 1000-3000 µg/g) of some SNC meteorites and the abundance of sulfate on the Martian surface, it has long been assumed that Mars is rich in sulfur [6,7]. Heterogeneous accretion and core-mantle differentiation models also have yielded high S contents in mantle and core of Mars [4,7,8]. However, recent estimates of the sulfur content at sulfide saturation for plausible parent magmas of SNC meteorites hint that the maximum sulfur content of the Martian mantle may be only 700-1000 µg/g [9]. These are only maximum estimates and thus sulfur contents in Martian mantle sources remain poorly constrained. Moreover, contamination of Martian basaltic magma with crust, hydrothermal alteration on Mars and, probably in some cases, terrestrial alteration have led to variable changes of primary S contents in some SNC meteorites, further leading to difficulties to estimate the S content of the mantle.

Results and Discussion: We combine new and published data on the chalcophile elements S, Se, Te, Cu and the PGE in shergottites, nakhlites and ALH84001 to show that the parent magmas of these SNC meteorites formed and evolved at sulfide undersaturated conditions. This conclusion is consistent with the petrographic observation that sulfide precipitation in many SNC meteorites occurred at a very late stage during the cooling of trapped interstitial melt [3,10]. The observation that mass dependent δ^{34}S in young shergottites, which formed after early surficial S deposition did not result in significant shifts from chondritic values [11] supports the limited influence of crustal recycling on element and isotopic budgets of S in the Martian mantle. ALH8400l, which formed at 4.1 Ga also has very low contents of the strongly chalcophile elements PGE, Cu, Se and Te. Therefore, sulfide-undersaturated conditions may represent a secular feature of magma derived from the Martian mantle, which is not surprising, considering the inferred high FeO contents in the magmas. Negative correlations of abundances of Cu, Se, S and other incompatible chalcophile elements with MgO contents suggest that the sulfur content in the Martian mantle may be only 360±120 µg/g (1s). Such a low concentration of sulfur may be completely exhausted by a few percent melting [9], which, in particular for shergottites, resulted in chemical variations of chalcophile elements similar to sulfide-untersaturated terrestrial magmas (e.g., komatiites). Martian mantle inventories of S and Se were mostly established by core formation. Metal-silicate partitioning experiments have covered such conditions for S, and the factors affecting S partitioning have been constrained recently [4,12]. Thus it is possible to constrain the S content in the Martian core via estimated S contents in the mantle and core-mantle partitioning [12]. Metal-silicate partitioning data suggest that the Martian core likely contains a few percent of S only ($D^{metal\text{-}silicate}_S < 200$). From this it follows that the Martian interior should have a low sulfur content, which is also consistent with the relatively low abundance of the similar volatile element Zn suggested for the Martian mantle [13] and the lithophile to weakly siderophile nature of Zn [14]. We note that these results and their interpretation pose a dilemma as the low density of the Martian core determined from moment of inertia measurements require a larger fraction of light elements in the Martian core than in Earth's core [15]. Some of the alternatives (Si, O and C in the core) are no less problematic because they either require very reducing conditions or high temperatures during core formation [16,17]. Alternatively, the Martian mantle may have a heterogeneous composition and the parent magmas of SNC meteorites may not sample reservoirs representative of the Martian mantle [18].

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