Extraction of life-essential volatiles via melting of rocky planetary mantles of variable redox

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Secondary atmospheres of rocky planets are established largely by volcanic degassing. Mantle-derived partial melts act as the first agents to extract life-essential volatile elements such as carbon, sulfur, and water from the interior to the atmosphere. Our current understanding of relative extraction efficiency of various volatile elements from the mantle is based chiefly on volatile solubility and partitioning at present-day terrestrial mantle conditions. However, oxygen fugacity, fO_2 of rocky interiors is estimated to vary several log units both for the Solar System planets and exoplanets. Here we assess the influence of differences in the fO_2 of different planetary mantles on the volatile storage and degassing efficiency of individual volatile species.

Earth's shallow mantle is the only reservoir in the Solar System where carbon exists in oxidised form. In all other cases, graphite is likely the stable carbon-bearing phase, except in very reducing mantles, where carbon may also dissolve in Fe-Ni alloys or sulfides. For sulfur, sulfide is thought to be the chief repository for all planetary mantles although the composition of sulfide and its metal/sulfur ratio vary significantly with decreasing fO_2. Therefore, extraction of carbon and sulfur from a large swath of planetary mantles relies heavily on the carbon content at graphite saturation (CCGS) and sulfur content at sulfide saturation (SCSS) of basaltic melts at high P-T and especially as a function of fO_2. For water, however, the storage is expected to be mostly in nominally anhydrous silicates under all conditions. Combining the latest experimental models of CCGS and SCSS as a function of P-T-fO_2, we calculate how fractionated the life-essential major volatiles (C, S, and water) would be in mantle partial melts and as a function of extent of mantle melting. We will show that C/S ratio of mantle-derived melts and hence that of the secondary crust/atmosphere is expected to vary significantly from oxidised mantles of Earth to extremely reduced mantle of Mercury. C/S and C/H ratios of mantle melts for Earth also decrease with melting degree. Whereas the C/S and C/H ratios of low-degree melts start out low and increase with increasing degrees of melting for reduced mantles. This presentation will dicuss the control of variable redox on mantle-derived budgets of major volatiles with implications for surface habitability of rocky planets.