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Constraining the Depth of the Martian Magma Ocean during Core Formation using Element Partitioning

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The depth of a planetary magma ocean places first order constraints on the thermal state of a young planet. For the Earth, the depth of the magma ocean is mostly constrained by the pressure-temperature conditions at which Fe-rich metal last equilibrated with the bulk silicate Earth (BSE). These equilibration conditions are thought to correspond to the conditions at the terrestrial magma ocean floor, as this is where the metal ponds before sinking to the core. This depth is estimated by combining the BSE contents of siderophile (iron-loving) elements with metal-silicate partition coefficients (D) at high temperatures and pressures [e.g. 1].

The extent and depth of a magma ocean on Mars are hotly debated. In the case of Mars, the sulphur content of the core is significantly higher than for Earth (10-16 wt% sulphur [2]). The presence of sulphur has been shown to have an effect on the metal-silicate partitioning of some siderophile elements [3], but the current data set is insufficient to be of use for direct application to Martian conditions. We have started an experimental programme to constrain siderophile element partition coefficients for Ni and Co between metal and silicate as a function of temperature, pressure and sulphur content in the metal-alloy. For the silicate composition we used a newly proposed bulk silicate Mars (BSM) [4]. We chose the above-mentioned siderophile elements because their BSM concentrations are reasonably known from studies of Martian meteorites. Our aim is to derive new constraints on the depth of the Martian magma ocean and the chemistry accompanying Martian core formation.

Experimental methods: The starting material consisted of a 1:1 mixture of silicate glass + quench crystals in the FeO-CaO-MgO-Al2O3-SiO2 (FCMAS) system with a composition based on [4], and metal consisting of FeS, Fe, Ni, Co, FeP3. Four different metal compositions were used with sulphur contents of 0, 5, 15 and 25wt% respectively. Experiments were made in an end-loaded piston-cylinder using graphite-lined Pt capsules. Experiments were performed at 1, 2 and 3 GPa, and at temperatures of 1600 and 1650 °C, for 5hrs. Electron microprobe was used to determine the concentration of major and minor elements in each phase.

Results: Preliminary results show that the sulfur content has an effect on the siderophile element partitioning, even within this small range of pressures and temperatures. With these experiments made with realistic conditions for a Martian magma ocean, we will present a new parameterization of metal-silicate D (Ni and Co) depending on pressure, temperature and sulfur content.

References: [1] Righter (2003) Ann. Rev. Earth Planet. Sci. 31, 135-174 [2] Schubert (1990) JGR 95, 14095-14104. [3] Jana and Walker (1997) GCA 61, 5255-5277. [4] Khan and Connolly (2008) JGR, 113, E07003.