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Non-equilibrium melting of partially differentiated asteroids: insights from partial melting experiments on L6 chondrite DAV01001

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Planetary differentiation in small bodies is believed to be ruled by several partial end-states that were dominated by low degrees of partial melting and melt segregation, before arriving at the formation of rocky planets. Having a better understanding of non-equilibrium melting processes in undifferentiated chondritic materials is critical to characterize planetary differentiation processes and the formation of rocky planets and differentiated asteroids. In this context, partial melting experiments of natural chondrites can provide unique insights into the petrological evolution associated with early planetary differentiation of planetesimals. For this study, we performed partial melting experiments using fragments from the ordinary chondrite DAV01001. Experiments were performed in a piston-cylinder at 1 GPa pressure, at temperatures from 1100 to 1300 °C and for 24 hours run duration. Reducing conditions were imposed by the use of graphite capsules. The experimental products were analysed using electron microprobe and synchrotron radiation computed microtomography (SR-μCT).

DAV01001 is an equilibrated L6 ordinary chondrite that has still visible relic chondrules and contains olivine (Fo_{75}), low-Ca pyroxene ($En_{77}Fs_{21}Wo_2$), high-Ca pyroxene ($En_{47}Fs_8Wo_{45}$), albitic plagioclase ($An_{13}Ab_{81}Or_6$), metal, troilite, chromite, and apatite. Upon heating, metal and troilite disappear at 1100 °C forming two immiscible phases, one made of pure metal with variable amounts of Ni, the other made of a metal-sulphide liquid of variable composition. Chromite starts melting at 1100 °C and disappears at 1300 °C. Silicatic melt forms already at 1100 °C as a result of the melting of plagioclase. With increasing temperature, the pyroxene and olivine begin to melt and shift the composition of the liquid towards trachy-andesitic (1200 °C) and basaltic trachy-andesitic to andesitic (1300 °C) compositions. Melting of olivine and pyroxene is accompanied by the crystallisation of both phases. The newly-formed olivine has a composition varying from Fo_{80} to Fo_{59}, becoming progressively enriched in Fe and Ca and depleted in Ni at increasing temperature. The newly-formed pyroxene has a variable Ca content, and is enriched in Al and Cr and depleted in Fe and Mn. The new-grown olivine and pyroxene crystals have a strong affinity with chondritic/primitive achondrites compositions, in contrast to the melts that have a good affinity to a bulk HED composition. Overall, the combination of melting and crystallisation fixes the

amount of silicatic liquid to a rather constant value of 10% vol.

SR-μCT was used to create 3D reconstructions of the experimental samples, in order to evaluate the efficiency of metal segregation at increasing degrees of partial melting. At increasing temperature, no change in the object density (number of 3D particles divided by the sample volume) is observed but only a progressive increase of the roundness and sphericity of the particles. This suggests that, even in presence of an interconnected liquid silicate phase (~10% vol), the coalescence of the metal phases does not occur spontaneously and other forces such as rotational spin or deformation are needed to segregate metal under these conditions.