HYSTERESIS IN MELT NETWORK TOPOLOGY ALLOWS CORE FORMATION BY POROUS FLOW.
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Introduction: The differentiation that leads to the formation of metallic cores and silicate mantles is one of the most significant processes in the evolution of terrestrial planets and asteroids. Meteoritic evidence shows that many asteroids had metallic cores and geochemical evidence requires rapid core formation [1]. This suggests that large terrestrial planets formed by accretion of pre-differentiated plantesimals [2].

It is therefore important to understand the physical mechanism that allows the rapid segregation of core-forming liquids in planetesimals. Experimental studies of the microtexture of core forming melts have shown that they are not mobile in a solid silicate matrix at the relatively low pressures in planetesimals. The percolation threshold that is required by high dihedral angles between silicates and core forming melts is thought to prevent melt segregation by porous flow [3,4,5]. The absence solid state convection in planetesimals also prevents deformation assisted melt percolation that can be invoced in larger planetary bodies [6]. The physical mechanism that allows rapid core formation in planetesimals, other than complete melting, is therefore currently not understood.

Numerical Methods: We present first numerical simulations of grain-scale melt distributions in realistic irregular geometries. The initial solid configuration was obtained from x-ray diffraction contrast tomography [7]. The texturally equilibrated melt network topologies have been computed using a recently developed level-set method [8] and are shown in Figure 1. The permeabilities of these melt networks have subsequently been computed using a Lattice Bolzmann Method [9,10].

Hysteresis in Melt Connectivity: The simulations of melt network topologies presented here complement experimental work. In particular, they allow us to explore the evolution of the network during progressive melting and subsequent compaction. Simulations on irregular grains show that the percolation threshold at dihedral angles above 60 degrees is significantly larger than those previously reported for simple geometries. This explains why the percolation cut-off at 60 degress is such an effective barrier to porous flow at low porosities. For dihedral angles of typical core-forming melts, between 90 and 120 degrees, the percolation threshold is typically 15 to 20%.

Meteoritic evidence suggests that the porosities during the melting of core-forming liquids in planetesimals can reach 20 to 30% and therefore easily exceed

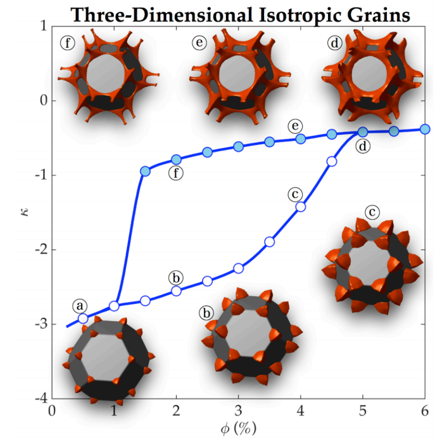

Figure 1: Computed melt networks in regular grains with dihedral angle of 60 degrees. Hysteresis in mean curvature as function of porosity. Upper branch represents connected draining melt.

this percolation threshold. Previous work assumes that only the fraction of melt above the percolation threshold is mobile so that only a fraction of the core-forming melts can segregate leaving the rest trapped in the silicate mantle, [6].

Our simulations show that this is not the case in an evolving texturally equilibrated system. Figure 1 shows that once the melt is connected at melt fractions above the percolation threshold, it remains connected during drainage due to hysteresis in the melt network topology. Only a very small fraction of 1 to 2% is trapped and left behind. This provides a physical mechanism that allows rapid early core formation in planetesimals without complete melting or deformation enhanced percolation. The trapping of a small fraction of iron may also provide and explanation for the 'excess siderophile problem', i.e. the observation that the concetrations of many siderophile elements in the mantle is larger than expected [11].

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