Rapid core segregation in planetesimals: Results from in-situ X-ray microtomography

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Differentiation of the terrestrial planets into silicate mantles and metallic cores is one of the most significant events in their history. Although a magma ocean scenario is often used to explain this event for large planets such as Earth, smaller planets and planetesimals likely never achieved the high temperatures necessary for such wide scale melting. In these smaller bodies, ^{26}Al decay is thought to contribute enough heat to melt only the core forming metallic phase, and leave the silicate as a solid phase. W-Hf isotopic signatures in meteorites suggest that some planetesimals differentiated within just a few million years [1]. Achieving core segregation on this time scale by a percolative flow mechanism whereby core material drains though a solid silicate mantle via an interconnected network of melt faces two major problems: (1) in a hydrostatic situation, the *percolation threshold* is above 5 vol% melt, so the process would lead to inefficient core formation, and several vol% of core material would remain stranded in the mantle, which is not supported by observations (2) the *permeability* of fully connected melts at microstructural equilibrium is low enough that some planetesimals may still not be able to differentiate on the short time scale that is required [2]. It has been suggested that shear deformation can cause isolated melt pockets to become connected even at low melt fractions [3,4].

Here, we have measured the change in permeability of core forming melts in a silicate matrix due to deformation. Mixtures of San Carlos olivine and FeS close to the equilibrium percolation threshold (~5 vol% FeS) were pre-synthesized to achieve an equilibrium microstructure, and then loaded into the rotational Drickamer apparatus at GSE-CARS, sector 13-BMD, at the Advanced Photon Source (Argonne National Laboratory). The samples were then pressed to ~2GPa, and heated to ~1100°C. Alternating cycles of rotation to collect X-ray tomography images, and twisting to deform the sample were conducted. Qualitative and quantitative analyses were performed on the resulting 3-dimensional x-ray tomographic images to evaluate the effect of shear deformation on permeability and migration velocity. Preliminary results from Lattice-Boltzmann simulations show a marked increase in the permeability with increasing deformation, which would allow more rapid and efficient core formation in planetesimals.

[1] Kleine et al. (2002) *Nature* **418**, 952-955. [2] Watson and Roberts (2011) *Phys. Earth. Planet. Int.* **186**, 172-182. [3] Bruhn *et al.* Nature **403,** 883-886. [4] Hustoft and Kohlstedt (2006) Geochem. Geophys. Geosyst. **7,** Q02001 doi:10.1029/2005GC001048

Large-volume silicic magma genesis at Yellowstone, Heise, and Caetano: Isotope and geochronology insights from three supervolcanoes in the western U.S.A.

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Large caldera "supervolcanoes" are fed by silicic magma chambers that may reach thousands of km^3 in size. We investigate the processes and time scales by which voluminous silicic magmas are generated by combining laser ablation/fluorination O isotope analyses of major phenocrysts with ion microprobe U-Pb dates and O isotope analyses of accessory zircon. We compare these for three supervolcanoes in the western U.S.A.–Yellowstone (Wyoming, 2.1-0.64 Ma), Heise (Idaho, 6.6-4.5 Ma), and Caetano (Nevada, 34 Ma). Yellowstone and Heise are multi-cyclic caldera complexes that produced large volumes of crystal-poor, anhydrous, high-silica rhyolites, many with low-δ^{18}O signatures diagnostic of remelting large volumes of hydrothermally altered rock in the shallow crust (δ^{18}Omelt=0-4‰). U-Pb ages and δ^{18}O compositions for doubly fingerprinted zircon spots reveal that caldera-wide batch assembly of heterogeneous melts with unique δ^{18}O compositions occurs over short time scales (~0.1-0.3 Ma) prior to voluminous tuff and lava eruptions at Yellowstone and Heise. Caetano is a single caldera that produced large volumes of crystal-rich, hydrous (biotite- and hornblende-bearing), low- and high-silica rhyolites with exclusively normal-high δ^{18}O signatures (δ^{18}Omelt=10-11‰). U-Pb ages of Caetano Tuff zircons range from within error of sanidine ^{40}Ar/^{39}Ar eruption ages to ~3 Ma older, indicating a prolonged period of magma assembly and growth. In addition to having different crustal sources, magma assembly time scales, and petrological characteristics, Caetano is also disparate from Yellowstone and Heise in that it has not produced any large-volume pre- or post-caldera rhyolite lavas. However, two resurgent granitic plutons intrude the intracaldera Caetano Tuff, providing clear evidence for magmatism postdating caldera collapse. U-Pb zircon ages, sanidine ^{40}Ar/^{39}Ar eruption ages, whole-rock major and trace element geochemistry, and O isotope signatures indicate a genetic connection between the Carico Lake resurgent pluton (δ^{18}Ozircon= 8.2±0.1‰) and the Caetano Tuff (δ^{18}Ozircon= 8.3±0.1‰), supporting the model of linked volcanic-plutonic components in caldera settings.