DIFFERENTIATION IN PLANETESIMALS: WHERE IS THE OLIVINE? Linda T. Elkins-Tanton, DTM, Carnegie Institution, 5241 Broad Branch Road NW, Washington, DC 20015 (ltelkins@dtm.ciw.edu).

Introduction: Differentiated planetesimals are thought to have accreted from primitive material within ~1.5 million years after formation of the first solids in the solar system (e.g., [1-9]). Sufficient ^{26}Al was present to melt the interior of planetesimals larger than ~7 km radius and allow a metallic core to differentiate from a silicate mantle. The planetesimal might be capped with a lid of either primitive unmelted material, or magmatic eruptions from the interior (Fig. 1), or it may melt all the way to its surface.

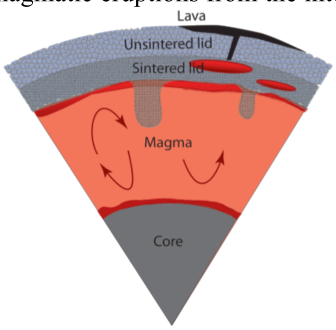

Fig. 1. Schematic cross-section of a molten planetesimal.

First minerals crystallizing from a planetesimal magma ocean: Fig. 2 shows a range of bulk chondritic silicate compositions that are candidates for the mantle magma oceans on planetesimals. At the low pressures in planetesimals, almost all would begin solidification by cystallizing olivine alone.

Why is the first crytallizing mineral of interest? It is the mineral most likely to settle to the core-mantle boundary. Settling requires low crystal fractions and sufficient time [10]. Thus, the first-crystallizing mineral is the one most likely to be in iron meteorites such as pallasites, if they represent samples of the core-mantle boundary. This simple magma ocean analysis shows that olivine is the likely mineral in the overwhleming number of cases.

Continued solidification of the planetesimal magma ocean: Over the ~0.5 kbar mantle pressure range of a planetesimal ~200 km in radius, the solidus will change by only about 10°C, and the adiabat by only ~2°C. As it cools, therefore, the entire depth of the magma ocean will contain some crystal fraction. The magma ocean will therefore have a high effective viscosity, perhaps in the range of hundreds to thousands of Pa s. Combined with the high heat flux of a small body cooling without an atmosphere, mineral grains would have to be large, perhaps several to 10 cm, to settle from the magma ocean.

Thus, only the earliest-forming crystals will settle, in the time before crystallinity rises. The rest of the planetesimal's mantle will solidify in bulk and *never produce an olivine cumulate*. This may be why we have no such samples in our collections.

Conclusions: The simplicity of the mineral assemblages in many iron meteorites supports successful olivine settling at the beginning of magma ocean solidification on a differentiated planetesimal. Processes such as impacts into silicate surfaces, or eutectic melts, would produce far more complex mineralogies. Later solidification would occur in bulk, and thus planetesimal magma oceans will not produce olivine + pyroxene cumulate, such as are predicted for the Moon.

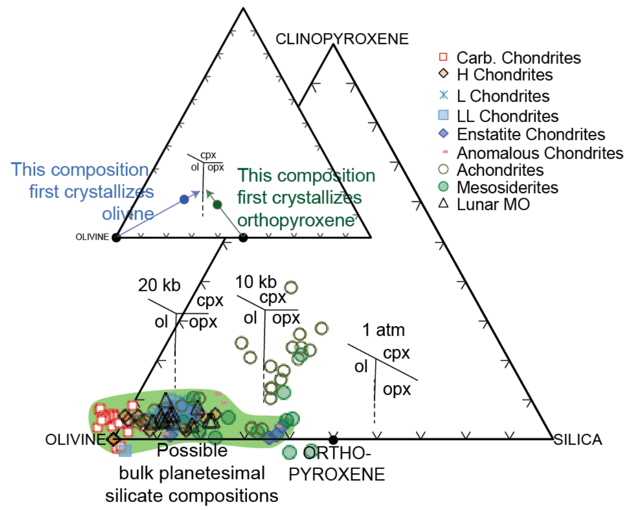

Fig 2. The silicate fraction of chondritic compositions [11] in a ternary diagram, in the green field. Possible lunar magma ocean compositions [12] also plot in the green region. Phase boundaries for solidification of a peridotitic magma ocean (an approximation of these chondritic comps) from [13]. Virtually all planetesimal compositions would begin to solidify by crystallizing only olivine.

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