Goldschmidt 2000
September 3rd–8th, 2000
Oxford, UK.

Journal of Conference Abstracts
Volume 5(2), 954

Influence of the Crystallization and Chemical Differentiation of a Lunar Magma Ocean on the subsequent Thermal Evolution of the Lunar Mantle

Dave Stegman (dstegman@seismo.berkeley.edu) & **Mark Jellinek** (markj@seismo.berkeley.edu)

Dept. Earth and Planetary Science, 307 McCone Hall, Univ. of California at Berkeley, Berkeley, CA 94720, USA

The dynamics, crystallization, and chemical differentiation of a lunar magma ocean (LMO) are revisited. The results of a few possible end member model outcomes are used as initial conditions for the subsequent subsolidus thermal evolution in the lunar mantle. The hypothesized moon formation due to the late stage collision of a planetesimal, possibly Mars-sized, with the proto-Earth likely results in the formation of an atmosphere of rock vapor with extremely high temperatures and for the impactor to loose most of its mass to the proto-Earth (Cameron, 1997). We consider that energies from such an event are large enough to favor a completely molten moon as a logical starting condition. Thus the cooling history of the LMO is revisited with the assumption that the LMO was over the full depth of the lunar mantle. Recent measurements of moment of inertial constrain the lunar core to have a radius between 220-450 km (Konopliv et al., 1998), which leads to a LMO depth of 1290-1520 km.

The subsequent LMO is cooled from above (to outer space) and such strong cooling is expected to have driven turbulent thermal convection. This regime of turbulent convection, appropriate for much of the solidification history, results in thorough thermal and chemical mixing. It is expected that crystallization was dominated by the internal nucleation and sedimentation of olivine-pyroxene-plagioclase assemblages. Whereas olivine and pyroxene crystals are predicted to settle to the CMB, plagioclase crystals are expected to float to the top of the LMO, forming a plagioclase-rich crust. Solidification is expected to have been dominated by the growth of an olivine-pyroxene crystal mush at the base of the LMO with ilmenite and magnetite joining the liquidus near the end of the solidification history. This is a consequence of significant crystal sedimentation, in situ crystal growth and the large flux of latent heat on crystal growth. The latent heat flux to the roof is expected to melt back any early-grown basaltic roof crust leaving behind an anorthosite-rich solid, which is consistent with current observations.

The resultant solid LMO is expected to be chemically stratified with a bulk density decreasing with height above the core until the position at which ilmenite, which is very dense, joined the liquidus. Most of the ilmenite is expected to be concentrated in the top quarter of the mantle. In addition, most of the highly incompatible elements, such as the radiogenic heat producing elements, are expected to be concentrated in a sandwich horizon near the top of the mantle, representing the last few percent of the LMO to crystallize.

This picture supports two end-member models: one in which the sandwich horizon is contained completely inside the ilmenite cumulate layer (as assumed by Hess and Parmentier (1995)) and one in which the sandwich horizon lies above the ilmenite cumulate layer. In either case, the ilmenite cumulate layer has a greater density than the underlying mantle and is therefore gravitationally unstable. The resultant Rayleigh-Taylor instabilities will transport the dense layer to the bottom of the lunar mantle. The results of analog experiments by Jellinek et al. (1999) show that this layer is likely to descend through the underlying mantle without mixing, forming a dense, cold layer above the core.

Sub-solidus convection of the lunar mantle is modelled in 3-D spherical geometry using the mantle convection code TERRA (Bunge et al., 1997). The initial conditions include different initial heterogeneous distributions of regions highly concentrated in radiogenic elements as suggested by the results of the crystallization models described above. The effects of these different initial heterogeneous distributions on the subsequent evolution of how regions highly concentrated in radiogenic elements are redistributed by convection is studied. More specifically, stagnant-lid convection is driven by top cooling, bottom heating and heterogeneous internal heating. Therefore, the evolution of such highly radiogenic regions is coupled to the heterogeneous initial conditions. For the end-member model in which the ilmenite cumulate layer, concentrated with radiogenic elements, gravitationally settles to surround the core and subsequently heats up enough to become buoyant (Zhong et al., 2000), the resultant instability is investigated in spherical geometry. This modelling provides an internally-consistent evolution which can be used as the starting point for investigating further lunar interior differentiation including the possible mechanisms for the genesis and distribution of Mare basalts as well as interpreting other geochemical data sets.

Bunge HP, Richards MA & Baumgardner JR, *Journal of Geophysical Research- Solid Earth*, **102**, 11991-12007, (1997).

Cameron AGW, *Icarus*, **126**, 126-137, (1997).

Hess PC & Parmentier EM, *Earth and Planetary Science Letters*, **134**, 501-514, (1995).

Jellinek AM, Kerr RC & Griffiths RW, *Journal of Geophysical Research- Solid Earth*, **104**, 7183-7201, (1999).

Konopliv AS, Binder AB, Hood LL, Kucinskas AB, Sjogren WL & Williams JG, *Science*, **281**, 1476-1480, (1998).

Zhong S, Parmentier EM & Zuber MT, *Earth and Planetary Science Letters*, **177**, 131-140, (2000).