Geophysical Research Abstracts
Vol. 14, EGU2012-11589, 2012
EGU General Assembly 2012

Lunar Orientale Basin Melt Lake: Depth and Differentiation

W. M. Vaughan (1), J. W. Head (1), P. C. Hess (1), L. Wilson (2), G. A. Neumann (3), D. E. Smith (4), and M. T. Zuber (4)

(1) Department of Geological Sciences, Brown University, Providence, RI 02912, USA (william_vaughan@brown.edu), (2) Lancaster Environment Centre, Lancaster University, Lancaster, LA1 4YQ, UK, (3) Solar System Exploration Division, NASA Goddard Space Flight Center, Greenbelt, MD 20771, USA, (4) Department of Earth, Atmospheric, and Planetary Sciences, MIT, Cambridge, MA 02139, USA

Impact melt emplacement and evolution in lunar multi-ring basins is poorly understood since impact melt deposits in basins are generally buried by mare basalt fill and obscured by subsequent impact cratering. The relatively young Orientale basin, which is only partially flooded with mare basalt, opens a rare window into basin-scale impact melts.

Depth of the Orientale melt lake. The smooth inner plains facies that fills the $\sim$350 km diameter central depression of the Orientale basin has been interpreted as a pure impact melt sheet. Recent Lunar Orbiter Laser Altimeter (LOLA) altimetry reveals that the $\sim$1.75 km average vertical subsidence of the central depression concentrates almost entirely along $\sim$25 km of marginal normal faults. This abrupt subsidence is not predicted by models that relate subsidence to thermal stresses resulting from impact-generated heat and uplift of crustal isotherms. However, since the fractured surface of the smooth facies suggests that it has undergone lateral shrinkage upon solidification and cooling, the vertical subsidence of the central depression could similarly result from solidification and cooling of the impact melt sheet. This end-member assumption constrains the depth of the Orientale melt sheet: a body of hot magma emplaced on the lunar surface should undergo $\sim$11-14% vertical subsidence upon solidification and cooling; $\sim$1.75 km average vertical subsidence is observed, implying the melt sheet may be up to $\sim$12.5-16 km deep.

Differentiation of the Orientale melt lake. The Orientale melt sheet (which, volumetrically, may be better described as a lake) is $\sim$350 km in diameter and may be up to $\sim$12.5-16 km deep, implying a volume of $\sim 10^6$ km^3, far greater than the largest differentiated igneous intrusions known on Earth. Could the Orientale melt sheet have differentiated? Previous work has argued that impact melt sheets do not differentiate since 1) few or no differentiated impact melt sheets are known on Earth; 2) impact "melt" sheets are better described as magmas carrying cold clasts, assimilation of which rapidly depresses liquid temperature. However, mounting evidence suggests that several large terrestrial impact melt sheets have differentiated (including the Sudbury Igneous Complex, Manicouagan, and Norokweng), and the volume of shock melt produced by an Orientale-size impact is so enormous that huge volumes of melt uncontaminated by clasts during crater excavation and modification seem likely to exist. We develop a simple model to predict the lithologies that might crystallize from the Orientale melt lake and other solidified multi-ring basin impact lakes based on 1) the bulk composition of the melt lake, 2) the operation of melt mixing in the melt lake, and 3) the chemical evolution of the resulting liquids on the An-Fo-Qz ternary. We investigate whether the resulting differentiates could explain puzzling lithologies observed in remotely-sensed data and the lunar sample suite. Young anorthosites could have crystallized from melt sheets. Mg-suite norites and troctolites could form in melt sheets, although their distinctive geochemical signature is hard to reproduce in this context. Mg-spinel lithologies could form from mixing of anorthosite and olivine-rich mantle liquids.