THE LASSELL MASSIF — EVIDENCE FOR COMPLEX VOLCANISM ON THE MOON. J. W. Ashley[1], M. S. Robinson[1], J. D. Stopar[1], T. D. Glotch[2], B. Ray Hawke[3], S. J. Lawrence[1], B. T. Greenhagen[4], D. A. Paige[5], School of Earth and Space Exploration, Arizona State University, Tempe, AZ, 85287-3603, james.ashley@ser.asu.edu; [2]Department of Geosciences, Stony Brook University, Stony Brook, NY; [3]Hawaii Institute of Geophysics and Planetology, University of Hawaii, Honolulu, HI; [4]Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA; [5]Department of Earth and Space Sciences, University of California Los Angeles, Los Angeles, CA.

Introduction and Background: Understanding the occurrence, compositional range, volumetric and spatial extent, and timing of emplacement, of the Moon's crustal materials is important for constraining theories of lunar origin, thermal models of the lunar crust, and geologic evolution. Because they represent strong geochemical departures from primordial compositions, the presence and extent of Si-rich rocks on a planetary surface are indicators of internal processing, and are petrologic anomalies on the Moon.

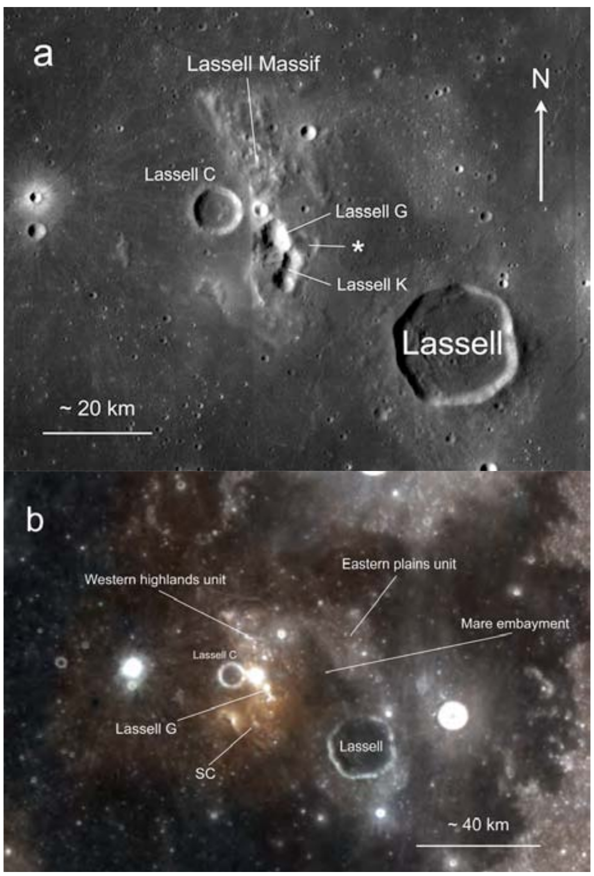

Figure 1a. WAC mosaic of Lassell Massif complex and surrounding region. 1b shows WAC VIS color using bands centered at 689, 415, and 321 nm. Note strong red (blue absorption) spot in the southern half of the Lassell Massif; and embayment of mare deposits, establishing relative timing of emplacement. Suspect cone feature is indicated as SC. Asterisk marks ancillary depression.

From both telescopic and orbital observations (Apollo Command Module pilots' visual descriptions [e.g., 1]), lunar 'red spots' have long been suspected to represent places of non-mare volcanism on the Moon [e.g., 2,3]. Some of these present anomalously high Th signatures in Lunar Prospector gamma ray data, consistent with evolved, Si-rich magma sources [4-6]. The Lassell complex, located in northeastern Mare Nubium near the center of the Alphonsus A basin (15°S, 8°W), is one such location. The complex consists of a ~25 x 46 km highland 'massif' that includes two conspicuous negative relief features (G [~5 x 6 km] and K [~5 x 7 km]), and an eastern plains unit [e.g., 3], all embayed by Imbrian-age mare deposits, which establish the timing of its emplacement as pre-mare (Figures 1a,b). The northern portion of the massif has been described as appearing mantled [2]. The northern portion of the massif has an optical maturity index (OMAT; [e.g., 7]) of 0.19 ± 0.01, similar to that of the eastern plains unit (0.15 ± 0.02).

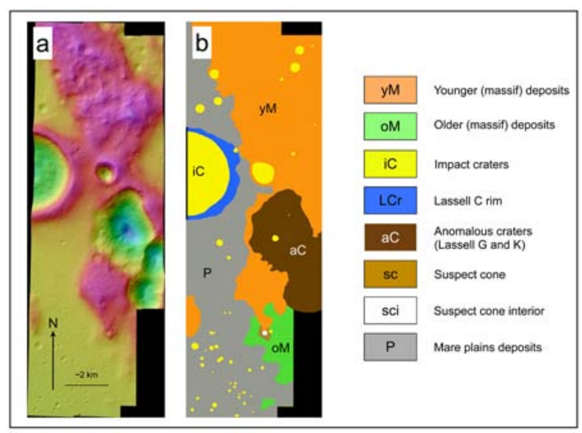

Figure 2a. DEM for the western two thirds of the massif construct. 2b is a geologic sketch map based on units identified within the DEM.

Instrumentation and data products: We used Lunar Reconnaissance Orbiter Camera (LROC) Wide Angle Camera (WAC; 100 m/p) three-band visible color and Narrow Angle Camera (NAC; 0.5 m/p) images, together with LRO Diviner Lunar Radiometer Experiment (Diviner) mid-infrared emissivity data. A high-resolution (2 m/p) digital elevation model (DEM) was derived from NAC stereo observations for the western two thirds of the massif highland structure (Figures 2a, 3). While Diviner data are typically used to model the silicate Christiansen Feature (CF; [e.g., 8]) position, this cannot be done for highly silicic surfaces, which have CF positions outside of Diviner's spectral range. Instead, we determine the presence of highly silicic materials based on the concavity of Diviner 3 point spectra [e.g., 9,10]. The Diviner data were used to generate a CF map coprojected with WAC and NAC DEM base maps (Figures 3,4). Diviner pixels with anomalously concave spectra were set to have CF values of 7.0 μm.

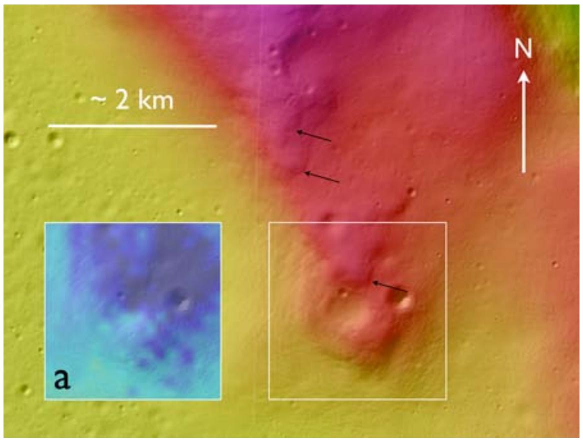

Figure 3. Detail of NAC DEM, showing southern margin of Lassell Massif highland structure. Arrows indicate lobate flow structures in 'stair-step' arrangement. The features superpose a suspect volcanic cone structure (white box). Inset (a) shows the Diviner CF overlay for this area registered to cylindrically projected NAC shaded relief base image. Note correspondence of superposed highland terrain visible in DEM to Si-rich signal (dark blue) in the inset.

Observations: DEM and image analysis shows a stair-step series of lobate margins, suggestive of multiple viscous flow events, along the southern flank of the massif (arrows in Figure 3). A feature resembling a small volcanic cone is seen underlying these deposits at the extreme southern end of the massif (Figure 3 box and inset). This feature has inner rim slopes of ~5°, outer flank slopes of 4-10°, and a height of ~60m. It is similar in height, base diameter (1850m), and summit diameter (740m) to a cinder cone, but may be a degraded, ancient impact crater. Portions of the Lassell G and K (unit aC in Figure 2b) pit walls exhibit low-reflectance streamers suggestive of pyroclastic dark mantle deposits, similar to those observed at Sulpicius Gallus [e.g., 11]. The unit aC negative relief features lack the morphologies typical of impact craters (raised rim, obvious ejecta blanket, etc.), and may represent explosive pits or collapse feature. A possibly related, ancillary depression is indicated in Figure 1a by the asterisk.

The CF map (Figure 4) identifies a region of high-Si materials centered on the Lassell G and K depressions, with outlying areas coincident to small craters, which appear to have excavated and exposed a Si-rich subsurface from beneath a regolith or other mantling deposits of lower Si composition. The southern portion of the massif appears to superpose the northeast portion of the suspect cone feature, and has a Si-rich signature, while the 'cone' itself appears to be less silicic (Figure 3, inset).

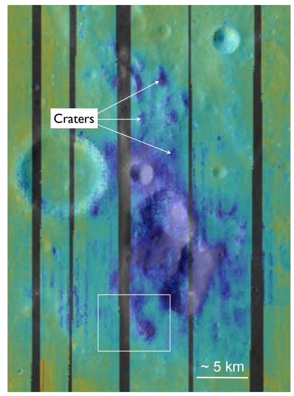

Figure 4. Diviner CF map coprojected with WAC mosaic for comparison to large-scale morphologic features. Dark blue pixels indicate silicic compositions. Note areas of crater excavation exposing high-Si deposits. White square depicts area shown in Figure 3.

Interpretation: The Si-rich Lassell complex Diviner signatures correlate well with morphologic features across the Lassell Massif highland deposits. Indications of both high-Si and dark mantled deposits in a variety of stratigraphic relationships, with possible caldera collapse, and viscous flow structures, support a complex volcanic history in Mare Nubium, possibly comparable to that seen at Compton-Belkovich [12]. Expanded DEM coverage will permit volumetric calculations of regional deposits that will help determine whether the Lassell G and K negative relief features are the result of explosion, collapse, or impact.

References: [1] Whitaker E. A. (1972) *Apollo 16 Prelim. Sci. Rpt. NASA SP-315*, pp. 29-104 to 29-105. [2] Wood C. A. and Head J. W. (1975) *Conf. on Origins of Mare Basalts,* Lunar Sci. Inst., Houston, TX. [3] Müller A. B. et al., (1986) *LPSC XVII*, 577-578. [4] Hagerty J. J. et al., (2006) *JGR* 111(E06002). [5] Hawke B. Ray et al., (2001) *LPSC XXXII*, Abs. #1241. [6] Glotch T. D. et al., *GRL* 38, L21204. [7] Lucey P. G. et al., (2000) *JGR* 105(E8), 20,377-20,386. [8] Logan L. M. et al., (1973) *JGR*. 78, 4983-5003. [9] Glotch T. D. et al., (2010) *Science* 329, 1510-1513. [10] Greenhagen B. T. et al., (2010) *Science*, 329, 1507-1509. [11] Head J. W. et al., (1980) *LPS XI*, 418-420. [12] Jolliff B. L. et al., (2011) *Nat. Geo*. 4, 566-571.