# VOLCANISM IN ALPHONSUS CRATER: EVIDENCE FOR COMPOSITIONAL VARIATION WITHIN LUNAR PYROCLASTIC DEPOSITS.

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**Introduction:** Dark-halo craters in Alphonsus crater (108 km diameter; ~13ºS/357ºE) are considered type localities of small lunar pyroclastic deposits (***Figure 1***). Head and Wilson [1] mapped the distribution and estimated volumes of materials in the pyroclastic cone deposits of Alphonsus. They concluded that primitive volcanic materials were present in many of the deposits. Earth-based spectral data indicated that these deposits were compositionally diverse and that several of the pyroclastic deposits may have olivine components [2, 3]. Recent results using Clementine UVVIS data were less conclusive, supporting the existence of compositional diversity among the Alphonsus and other pyroclastic deposits but not clearly identifying a juvenile mineralogic component [4-7].

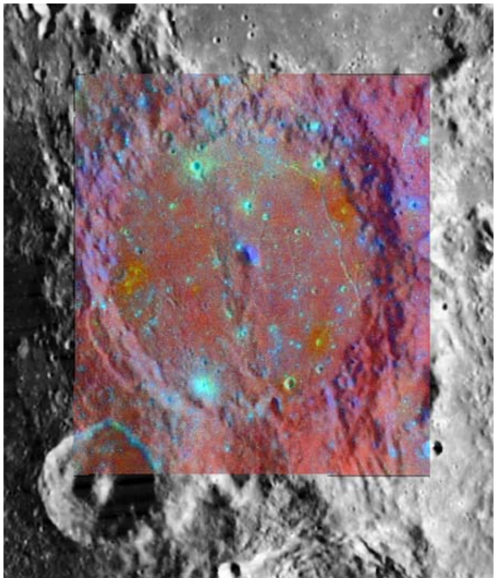

***Figure 1.*** *Coregistered Clementine color ratio data (R=750/415; G=750/950; B=415/750) and portion of Lunar Orbiter IV frame 108H2 showing Alphonsus crater (dia. 108 km). Yellow-orange colors in the crater mark locations of mafic materials in small pyroclastic deposits. Bright blue colors mark ~fresh impact craters.*

This study extends previous research by using Clementine 11-band multispectral data to study the compositions of volcanic materials in the Alphonsus pyroclastic deposits (with emphasis on juvenile mineralogic components) and to identify possible compositional variations within these deposits. Pyroclastic materials may include the best examples of primitive components (i.e., xenoliths) on the Moon and thus they are important in characterizing the lunar interior and as a constraint on the origin and evolution of lunar basaltic magmatism. Volcanic landforms such as those in Alphonsus crater may represent surface deposits of deep-seated and/or primitive lunar magmas that are accessible for future lunar landed exploration and sample collection. It is important to understand what minerals and elements may be found within such units.

**Data:** The Clementine global mosaic is available at 100 m/pixel for five ultraviolet-visible (UVVIS) wavelengths (415, 750, 900, 950, and 1000 nm; [8]) and 6 NIR wavelengths (1100, 1250, 1500, 2000, 2600, and 2780 nm; [9]) in the data holdings of the Imaging (IMG) Node of the Planetary Data System (PDS; see Garcia et al., this volume). The UVVIS and NIR mosaics are available at the PDS Map-a-Planet site (http://www.mapaplanet.org/explorer/moon.html). Mosaics of Clementine UVVIS and NIR data, as well as a global mosaic from Lunar Orbiter [Becker et al., this volume], have been warped to the latest lunar control network [10; Archinal et al., this volume] and are online at the USGS 'Planetary Interactive GIS on the Web Interactive Analyzable Database' (PIGWAD) site (http://webgis.wr.usgs.gov/pigwad/maps/the_moon.htm).

**Geologic Setting:** Alphonsus is a Lower Imbrian-age crater located in the Fra Mauro highlands just east of Mare Nubium. The crater has a flat, heavily cratered floor, a central peak, and a broad, low rim. The crater floor is covered with Upper Imbrian mare basalts and these are dissected by north-south trending floor fractures. The 11 'dark-halo craters' of Alphonsus are located in and adjacent to the curvilinear floor rilles, indicating that the fractures likely provided conduits for volatile accumulation and subsequent pyroclastic eruption. These small craters are characterized by non-circular rims <2 km in diameter and dark halos that extend up to 6 km from the crater center [11]. Head and Wilson [1] modeled the eruption of these small pyroclastic deposits via the accumulation and explosive decompression of volatiles that collected beneath a caprock above a rising magma body.

Recent work focused on a morphologic analysis of Alphonsus pyroclastic deposits [11] using composite topographic models (10-25 m/pixel) created using scanned Apollo metric photographs. Results largely confirm previous results of Head and Wilson [1] but allowed refinements of volumetric assessments of possible juvenile contributions to these deposits. There are pronounced differences in likely amounts of juvenile materials erupted from the five major 'dark halo' craters or vents in the floor of Alphonsus crater.

Two UVVIS color ratios are commonly used for classification of volcanic soils on the Moon: the 950nm/750 nm ratio is interpreted in terms of strength of the 1-micron (a measure of $Fe^{2+}$ or mafic content of mature lunar soils) and the 415nm/750nm ratio measures the long-wavelength arm of the $TiO_2$ aborption band (loosely related to titanium content of mature lunar soils; see [12]). Analyses of Clementine color data for these deposits (***Figures 2, 3 and 4***) show that several of the larger vents (e.g., Soraya) exhibit color variations within the deposits. This supports earlier results of Robinson et al. [5] that pyroclastic deposits at Alphonsus, Atlas, and Schrodinger craters show intra-deposit spectral variations. Although outlying portions (cyan, yellow in ***Figure 4***) of the Soraya deposit appear to be mixed with highlands materials (possibly due to the thinness of these deposits), the homogeneous 'core' of the deposit (blue) is comprised of a spectrally 'red' (lower titanium?) unit with a relatively weak mafic band strength. Small portions of the central pit (vent?) of the Soraya cone show stronger mafic bands that may correspond to juvenile volcanic materials such as pyroxene, olivine, and/or iron-bearing glass. More detailed analyses of fresh surfaces within these deposits (such as in the ejecta of small, young craters or slopes of vents and crater walls that shed material) in the UVVIS and NIR data should help to eliminate the possible effects of maturity differences and allow us to identify mineralogic components within these deposits.

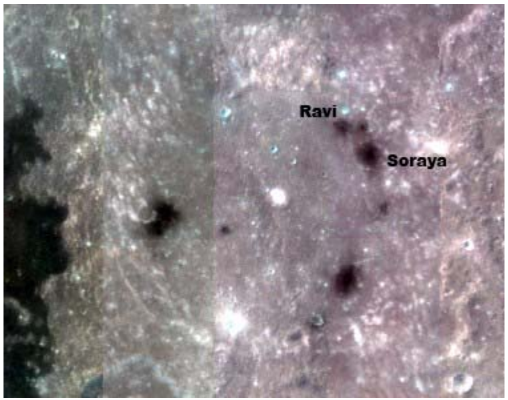

***Figure 2.*** *Clementine NIR enhanced color view (R=2000; G=1500; B=1100) of Alphonsus crater (dia. 108 km). Two of the largest 'dark halo' craters, Ravi and Soraya, are labeled at upper right.*

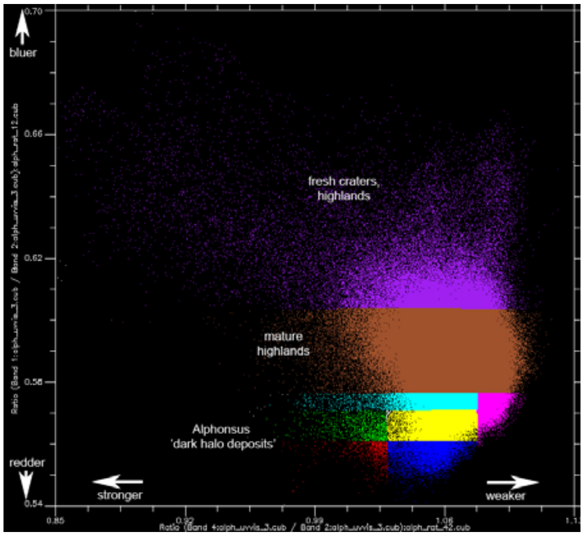

***Figure 3.*** *Clementine ratio parameters (Y=Band 1/Band 2 or 415/750; X=Band 4/Band 2 or 950/750) showing classification of units in Alphonsus. The major 'dark halo deposits' are highlighted near the bottom of the data cluster (red, blue, green, yellow).*

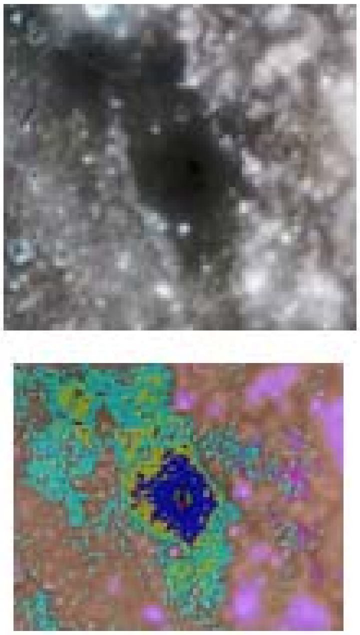

***Figure 4.*** *Clementine views of Soraya 'dark halo' crater in Alphonsus crater. 750 nm albedo image (top) shows dark pyroclastic deposits; classification map (bottom) shows intra-deposit compositional variation. Views are ~20 km across.*

**Summary:** These analyses confirm that morphologic and topographic information can be used to search for deposits of possibly juvenile volcanic materials and, when supported by color information, to map their location, distribution, and compositional relations. Addition of the recently released Clementine NIR data [9] to these analyses will help to distinguish among the primary mafic components (e.g., pyroxene, olivine, iron-bearing glass) that have absorption features near 1 and 2 microns. When available, hyperspectral data from the Moon Mineralogy Mapper (0.7 to 3.0 microns, ~70 m/pixel; [13]) and color data from the Lunar Reconnaissance Orbiter cameras [14] are expected to support detailed compositional analyses of lunar pyroclastic and other volcanic deposits, assisting in unraveling primary from secondary basalts, contamination from nearby units and mixing relationships, soil maturity variations, etc.

**References:** [1] Head and Wilson (1979) PLPSC 10$^{th}$, 2861. [2] Hawke et al., 1989, PLPSC 19th, 255. [3] Coombs et al., 1990. PLPSC. 20$^{th}$, 339. [4] Shoemaker et al., 1994, Science 266, 1851. [5] Robinson et al., 1996, LPS XXVII, 1087. [6] Gaddis et al., 2000, JGR, 105, 4245. [7] Gaddis et al., 2003, Icarus 161, 262. [8] Eliason *et al.*, 1999. [9] Gaddis, Lisa et al., 2008 (in review), The Clementine NIR Global Lunar Mosaic, PDS Volumes USA_NASA_PDS_CL_5001 through 5078. [10] Archinal et al., 2007, LPS XXXVIII, 1904. [11] Skinner, et al., 2005, LPS XXXVI, abs. #2344. [12] Lucey et al., 2006, Ch. 2 in Rev. Min. Geochem., 60, pp. 83-219. [13] Pieters et al., 2005, LEAG, 1576. [14] Robinson et al., 2005, LPS XXXVI, 1576.