

MAFIC CHARACTERISTICS OF LUNAR PYROCLASTIC DEPOSITS. Lisa Gaddis¹, James Tyburczy², and B. Ray Hawke³, ¹Astrogeology Team, U.S. Geological Survey, Flagstaff, AZ (lgaddis@usgs.gov), ²Department of Geology, Arizona State University, Tempe, AZ, ³PGD/SOEST, University of Hawaii, Honolulu, HI.

Introduction: The 5-band Clementine UVVIS data have been used to characterize 54 large and small lunar pyroclastic deposits (e.g., [1], [2]). We show that the large and small pyroclastic deposits have distinct spectral characteristics that are related to mafic composition. This work is part of an ongoing project to identify and characterize the primary volcanic or juvenile components of pyroclastic deposits on the Moon (e.g., [1], [3]).

Data: The Clementine data were obtained by the UVVIS camera at 5 wavelengths: 415, 750, 900, 950, and 1000 nm. Data used in this analysis for the pyroclastic deposits were derived from a reduced-resolution (~500 m/pixel) version of the final product of the USGS cartographic processing of the Clementine UVVIS data [4].

Background: More than 110 lunar pyroclastic deposits have been proposed (e.g., [5], [6]). They are observed all across the Moon, generally in the highlands near mare deposits and in association with probable volcanic vents. Large pyroclastic deposits (~10 in number) are of regional extent (up to several tens of thousands km²), whereas small deposits (~100 in number) are more localized, typically only several hundred km². The two types of lunar pyroclastic deposits are thought to have different modes of formation [7]: large deposits were probably emplaced via Strombolian-style fire-fountain eruptions [6], and the small deposits were formed via Vulcanian-style, intermittent eruptions [8]. The compositions of the large and small deposits are also recognized as different, although the systematics of those differences are not completely determined (e.g., [1], [2]). Many of the large deposits, such as those at Taurus-Littrow, Rima Bode, Aristarchus, Sulpicius Gallus, and Sinus Aestuum, may have a significant component of orange Fe⁺²-bearing volcanic glass beads (e.g., [6], [9], [10]). However, several of these deposits (Taurus-Littrow, Rima Bode, Sinus Aestuum) also contain significant amounts of black beads (the crystallized equivalent of Fe⁺²-bearing orange glass spheres) that are spectrally dominant. Both orange glasses and black beads were recognized as pyroclastic, with variations in cooling time in a fire-fountain probably resulting in quenched, crystallized, and/or composite droplets [2], [11].

Analyses of the compositions of the small pyroclastic deposits indicated that they could be classified into 3 groups, depending on the relative amounts of primary mafic material and presumably admixed highlands or mare materials [12]. Primary mafic or juvenile volcanic materials such as olivine and pyroxene in small pyroclastic deposits is thought

ene in small pyroclastic deposits is thought to have been mixed with highland or mare material as a result of entrainment of wall rock or caprock during explosive decompression and eruption. Group 1 spectra resemble those of lunar highlands, with feldspar-bearing mafic assemblages dominated by orthopyroxene. Group 2 spectra closely resemble mature mare deposits and are dominated by clinopyroxene. Group 3 deposits are dominated by olivine (as juvenile material) and orthopyroxene (from the wall rock) [12].

Recent work [1] has focused on using the Clementine UVVIS color ratio data to compare and contrast the compositions of 3 large [2] and 15 small pyroclastic deposits to evaluate both the character and distinctiveness of the two types of deposits and the validity of the previously observed compositional groupings. It was determined that: (1) The 3 compositional groupings of the small pyroclastic deposits continued to be observed, but they were not as clearly defined as in previous work. We proposed that, with additional data, these groups would likely aggregate into a single group representative of a continuum, with juvenile materials, highlands, and mare deposits as endmember compositions. (2) The color ratios of the large and small pyroclastic deposits overlap substantially, suggesting some compositional similarities. This result implied that complex mixtures of juvenile volcanic materials with highlands and/or mare materials (either during or following emplacement) may have been common to both types of deposits. It is likely that neither simple mixing of quenched versus crystallized volcanic glasses/beads as a formation mechanism for the large deposits [2], nor intimate mixing of juvenile and wallrock or caprock materials is strictly true for the majority of lunar pyroclastic deposits. (3) Volcanic glasses and beads may not be a common component in the small pyroclastic deposits. If this is true, then existing maturity, iron, and titanium mapping relationships [13] may be applicable to many of these deposits.

Discussion: In this work, we have increased the number of small and large pyroclastic deposits in our compositional analysis from 18 to 54, and we continue to characterize the mafic compositions of these deposits. The 8 large deposits are those at Aristarchus, Mare Humorum, Mare Vaporum, Montes Harbinger, Rima Bode, Sinus Aestuum, Sulpicius Gallus, and Taurus-Littrow. The 46 small deposits range from 3 to 3000 km², and they include sites such as Apollo Basin, Abel, Alphonsus, Atlas, Cleomedes, Compton (3 deposits), Cruger, Daguerre, E. Frigoris West and

MAFIC CHARACTERISTICS OF LUNAR PYROCLASTICS: L. R. Gaddis and others.

East, Franklin, Gambart, Gaudibert, Gauss, Grimaldi, Haldane, Humboldt (4 deposits), J. Herschel, Kiess, Lavoisier, Mare Smythii South (2 deposits), Mersenius, Messala, Montes Carpatius, Oppenheimer (3 deposits), Orientale, Petavius (2 deposits), Riccioli, Schluter A, Schrodinger, Southeast of Nectaris, and Tarantius [see Web site above for locations and citations].

Figure 1 shows Clementine color ratio data for the 54 pyroclastic deposits. In Figure 1(a), the ratios 415/750 nm versus 950/750 nm are shown for comparison to earlier work [1]. These color ratios are related to relative titanium content of mature lunar soils (415/750 nm; high Ti=higher ratio; low Ti=lower ratio) and mafic content (950/750 nm; larger ratio=weaker mafic band) of mature mare soils. Several aspects should be noted: (1) The 8 large pyroclastic deposits form a distinctive and strongly linear trend with a positive slope. Orientale, an unusual large deposit, falls outside this trend (to the lower right). The deposits that consist of substantial fractions of black devitrified beads (e.g., [6], [9], [10]), including Taurus-Littrow, Rima Bode, Sinus Aestuum, and Mare Vaporum, all plot in the upper right (high Ti, shallow mafic band). (2) The 46 small deposits have a broad, diffuse pattern surrounding a moderately dense central cluster. The greatest variation is observed in 950/750 nm, and a slightly smaller variation in 415/750 nm. Within 3-group classification, the single Group 3 deposit at J. Herschel is no longer isolated at the lower left in the plot; deposits nearby include Montes Harbinger, Schrodinger, Aristarchus, and Compton. Many of the new data points plot in the range of Group 1.

Figure 1(b) allows us to examine the compositional data for the large and small deposits in more detail. All large pyroclastic deposits, whether inferred to have glass or devitrified beads as the dominant components, have distinctively low reflectance at 750 nm. Most of the small deposits are brighter than the large deposits, and the groupings are better defined. Discriminants may include primary compositional differences (glass/beads versus fragmented basalt), particle size variations, and secondary mixing effects due to deposit size. The 415/750 versus 750-nm albedo data serve both to discriminate large and small pyroclastic deposits and to clarify compositional relationships among the small deposits.

Future Work: The Clementine 100-m/pixel UVVIS global data will be used to further expand a compositional database for lunar pyroclastic deposits (<http://www.flag.wr.usgs.gov/USGSFlag/Space/LunPyro>).

References: [1] Gaddis et al., 1999, *JGR*, in press; Gaddis et al., 1997, *LPS XXVIII*, 398-390. [2] Weitz et al., 1998, *JGR*, 22725-22759. [3] Gaddis et al., this volume. [4] Eliason et al., 1999, Mission to the Moon, The Clementine UVVIS Global Mosaic, PDS CL_4001-4078. [5] Gaddis et al., 1998, *LPS XXIX*, 1807-1808. [6] Gaddis et al., 1985, *Icarus*, 61, 461-488. [7] Wilson and Head, 1981, *JGR*, 78, 2971-3001. [8] Head and Wilson, 1979, *PLPSC 10th*, 2861-2897. [9] Pieters et al., 1973, *JGR*, 78, 5867-5875. [10] Adams et al., 1974, *PLPSC 5th*, 171-186. [11] Heiken et al., 1974, *GCA*, 38, 1703-1718. [12] Hawke et al., 1989, *PLPSC 19th*, 255-268; Hawke et al., 1990, *PLPSC 20th*, 249-258. [13] Lucey et al., 1998a, *JGR*, 103, 3679; Lucey et al., 1998b, *LPS XXIX*, #1356.

Figure 1. Clementine color ratio data for lunar pyroclastic deposits.

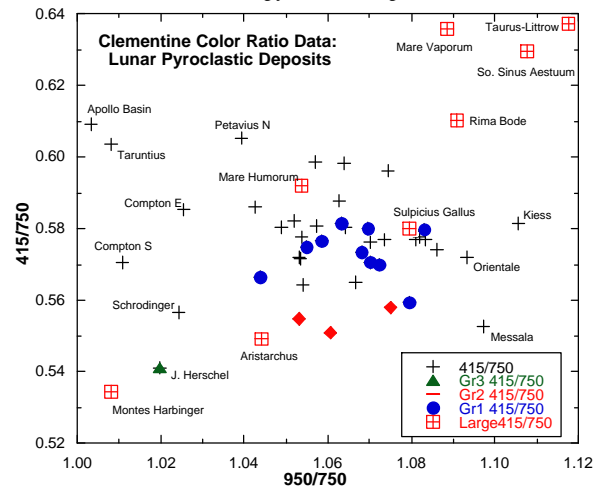


Figure 1(a). 415 nm/750 nm versus 950 nm/750 nm.

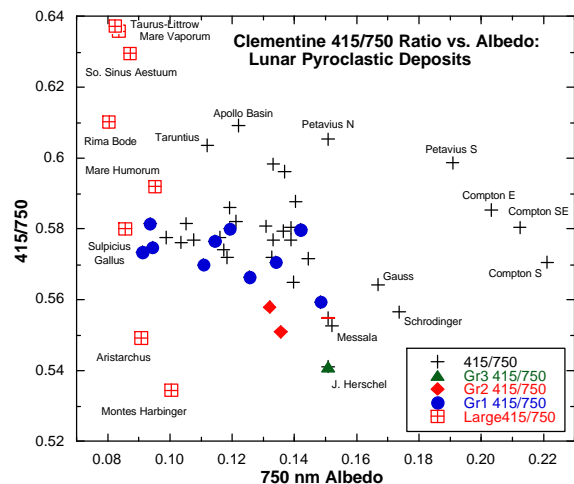


Figure 1(b). 415 nm/750 nm versus 750 nm.