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Compositional analyses of small lunar pyroclastic deposits using Clementine multispectral data

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Abstract. Clementine ultraviolet-visible (UVVIS) data are used to examine the compositions of 18 pyroclastic deposits (15 small, three large) at 13 sites on the Moon. Compositional variations among pyroclastic deposits largely result from differing amounts of new basaltic (or juvenile) material and reworked local material entrained in their ejecta upon eruption. Characterization of pyroclastic deposit compositions allows us to understand the mechanisms of lunar explosive volcanism. Evidence for compositional differences between small pyroclastic deposits at a single site is observed at Atlas crater. At all sites, compositional variation among the small pyroclastic deposits is consistent with earlier classification based on Earth-based spectra: three compositional groups can be observed, and the trend of increasing mafic absorption band strength from Group 1 to Group 2 to Group 3 is noted. As redefined here, Group 1 deposits include those of Alphonsus West, Alphonsus Southeast, Alphonsus Northeast 2, Atlas South, Crüger, Franklin, Grimaldi, Lavoisier, Oppenheimer, Orientale, and Riccioli. Group 1 deposits resemble lunar highlands, with weak mafic bands and relatively high UV/VIS ratios. Group 2 deposits include those of Alphonsus Northeast 1, Atlas North, Eastern Frigoris East and West, and Aristarchus Plateau; Group 2 deposits are similar to mature lunar maria, with moderate mafic band depths and intermediate UV/VIS ratios. The single Group 3 deposit, J. Herschel, has a relatively strong mafic band and a low UV/VIS ratio, and olivine is a likely juvenile component. Two of the deposits in these groups, Orientale and Aristarchus, are large pyroclastic deposits. The third large pyroclastic deposit, Apollo 17/Taurus Littrow, has a very weak mafic band and a high UV/VIS ratio and it does not belong to any of the compositional groups for small pyroclastic deposits. The observed compositional variations indicate that highland and mare materials are also present in many large and small pyroclastic deposits, and they suggest that volcanic glasses or spheres may not be dominant juvenile components in all large pyroclastic deposits.

1. Introduction

Lunar pyroclastic deposits are volatile and metallic element (Fe and Ti) enriched remnants of ancient volcanic eruptions on the Moon, and they provide clues to conditions in the early lunar interior [e.g., *Papike et al.*, 1998] and to the distribution of potential resource materials for future exploitation [*Hawke et al.*, 1990]. Studies of lunar pyroclastic materials, especially the primary or juvenile picritic glasses, provide unique information on the composition of the mantle [e.g., *Delano*, 1986] and on the nature and origin of associated volatile elements in an otherwise volatile-depleted environment [e.g., *Heiken et al.*, 1974]. Possible fundamental differences between picritic glasses and mare basalts [e.g., lesser fractional crystallization and greater depth of origin for glasses; *Shearer and Papike*, 1993; *Papike et al.*, 1998] support their identification as the best examples of primitive materials on the Moon and attest to their importance in characterizing the lunar interior and as a starting place for understanding the origin and evolution of basaltic magmatism on the Moon. Remote-sensing analyses of these deposits have helped us to identify the characteristic components of some of these deposits [e.g., *Adams*, 1974; *Pieters et al.*, 1973, 1974; *Gaddis et al.*, 1985; *Lucey et al.*, 1986; *Hawke et al.*, 1989; *Coombs et al.*, 1990], to begin to constrain the distribution of lunar volcanic deposits [*Head*, 1974], and to understand the styles of eruption and emplacement of basalts on the Moon [*Wilson and Head*, 1981; *Weitz et al.*, 1998].

Previous analyses have established the general distribution, composition, and eruptive styles of lunar pyroclastic deposits, but many fundamental questions remain. The higher-spatial-resolution (~100 m/pixel) views of the Moon presented by the Clementine ultraviolet-visible (UVVIS) data allow scientists to (1) develop a more complete picture of the global distribution of lunar pyroclastic deposits [*Gaddis et al.*, 1998], (2) identify previously unrecognized pyroclastic deposits [*Shoemaker et al.*, 1994; *Morrison and Bussey*, 1997; *Rosanova et al.*, 1998; *Yingst and Head*, 1998], (3) characterize the range of pyroclastic material compositions [*Gaddis et al.*, 1997b; *Weitz et al.*, 1998]; the nature, extent,

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