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NEW PROSPECTS FOR ANALYZING LUNAR PYROCLASTIC GLASS

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Pyroclastic glass particles of diverse compositions are sparsely distributed in the lunar soil. Numerous suspected pyroclastic deposits have been pinpointed on the nearside. However, a dearth of pure samples large enough for spectral study, coupled with the kilometer spatial resolution of Earth-based telescope spectrometry, make it difficult to remotely analyze these deposits or tie most glasses to specific sources. Two developments should soon improve this situation. First, the technique of microscope photometry combined with microprobe analysis for the first time allows correlation of the reflectance spectra and chemical compositions of individual glass particles. Second, the Clementine spacecraft will provide multispectral images of pyroclastic deposits at much higher spatial resolution than is currently achievable. These developments, combined with traditional laboratory and telescope studies, should allow compositions of many pyroclastic deposits and sources of many soil particles to be determined.

Pyroclastic Glass. Lunar pyroclastic glass particles, tens to hundreds of micrometers in diameter, span a large range of chemical compositions. Delano (1) has identified 25 distinct glasses in lunar soil. Among these glasses, thin section colors range from green to yellow to orange to red with increasing TiO_2 content. Some of these compositions are also represented by devitrified black particles, darkened by myriad submicrometer ilmenite and spinel crystals.

Of these diverse glass types the reflectance spectra of only three are known (2,3). Sample 74220 is the high-Ti "orange soil" from Shorty Crater. Sample 74001 is a core dominated by almost pure concentrations of black glass, the devitrified equivalent of 74220. Sample 15401 contains predominantly low-Ti green glass. No other pyroclastic glasses have been found in sufficient quantity (10 mg ≈ 10,000 particles) to permit classical reflectance spectrometry (C.M. Pieters, personal communication).

If reflectance spectra could be correlated to chemical composition it might allow remote analysis of many lunar pyroclastic glass deposits. Such determinations could be ambiguous, however, if the deposits are heterogeneous. The extensive Taurus-Littrow dark mantle, for example, contains mainly black glass like 74001, mixed with orange glass similar to 74220. This determination was made based on telescopic measurements (4, 5) with 5-20 km spatial resolutions. Homogeneous deposits of smaller dimensions, if they exist on the Moon, cannot be identified by Earth-based measurements.

Microscope Photometry. We have for the first time collected reflectance spectra of individual pyroclastic glass spheres as small as ~20 μm in diameter. Measurements were made over the wavelength range of 380- to 800-nm relative to a $BaSO_4$ reference standard. Spectra were obtained by scanning over the wavelength range in 5 nm steps. Measuring apertures were optimized to individual particle diameters. Further details of the microscope photometric technique are reported by Bradley et al. (6).

Figure 1 shows typical spectra of ~ 100 μm diameter glass particles from samples 74220 (orange), 74001 (black), and 15401 (green). The orange glass spectrum is characterized by a gradual rise from the UV to around 600 nm, followed by a steep rise and a broad absorption feature longward of 700 nm. The green glass shows a rapid rise to approximately 560 nm, followed by a deep absorption feature centered in the infrared. These bands have been correlated with the abundances and oxidation states of iron and titanium in the glasses (7). The black glass spectrum is essentially flat throughout the measured range. The locations of absorption features closely match those measured for bulk samples (2,3), though the bulk samples exhibit more pronounced red slopes.

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The peak reflectivities of individual glass particles depend on size and degree of roughness, with broken particles having the most prominent spectral features. Values for green glass range from 7-16%, while orange glass ranges from 8-40%. In both cases slope trends and peak locations are similar among all particles. Black glasses all have nearly identical spectra.

Particles which have been measured by microscope photometry can subsequently be classified by chemical type using the electron microprobe. Thus, chemical compositions can be correlated with reflectance spectra even for extremely rare particles. We intend to use this combination of techniques to quantify the colors of the entire range of pyroclastic glasses, using individual particles picked from lunar soil samples.

Clementine. The Clementine spacecraft, due to map the moon from polar orbit in 1994, will carry four multispectral sensors. The high resolution camera, with an optimum resolution of 23 m, has been targeted to all identified pyroclastic deposits on the nearside. It will provide multispectral images through filters centered at 415, 560, 650, and 750 nm.

We analyzed our spectra of individual particles to determine if the three glass types could be distinguished using only data from the Clementine filter passbands. To emphasize spectral features and minimize albedo differences, reflectivity ratios among several bands were compared. Figure 2 shows a plot of 650/560 nm ratios vs. 750/560 nm ratios. This presentation was chosen to emphasize differences among the spectral types.

Figure 2 demonstrates a strong clustering of reflectivity ratios according to particle composition. We conclude that Clementine data would be adequate to differentiate among deposits of essentially pure orange, black, and green glass. With a resolution of 23 m, the Clementine high-resolution sensor could locate such concentrations in larger deposits which are heterogeneous at telescope resolution.

Determining the chemical compositions of pyroclastic glass deposits will significantly aid our understanding of lunar volcanism. Similarly, locating the sources of individual glass particles in lunar soils will place new constraints on models of regolith development.

References. (1) Delano, 1986, *PLPSC16*, D201 (2) Adams et al., 1974, *PLSC5*, 171 (3) Heiken et al., 1991, *Lunar Sourcebook*, p.211 (4) Gaddis et al., 1985, *Icarus, 61*, 461 (5) Hawke et al., 1991, *PLPSC21*, 377 (6) Bradley et al., 1994, this volume (7) Bell et al., 1976, *PLSC7*, 2543

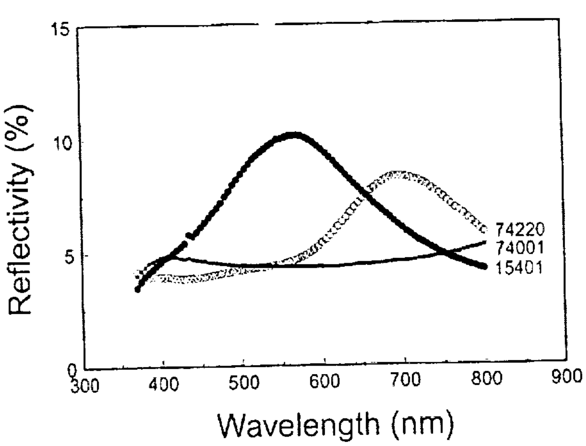

Figure 1. Representative spectra of individual pyroclastic glass particles ~100 μm in diameter

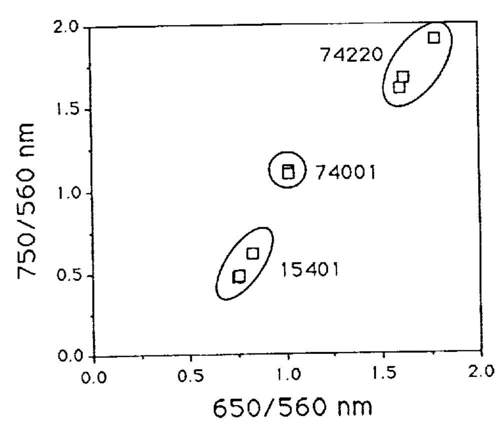

Figure 2. Pyroclastic glass particle color ratios using Clementine filter passbands