STRATIGRAPHY AND EVOLUTION OF THE LUNAR HIGHLAND CRUST: A SAMPLING OF VERTICAL AND REGIONAL HETEROGENEITIES C. M. Pieters, Geological Sciences, Brown University, Providence, RI 02912

The Apollo and Luna programs have gradually provided lunar scientists, after extended and meticulous analysis, with a sufficient variety of samples to suspect the evolution of the lunar crust is considerably more complex than the simple differentiation of a magma ocean proposed during the first blush of Apollo exploration (1). The chemistry and mineralogy of the select small group of pristine rocks (2), which escaped much of the transformations incurred during the high impact flux of early lunar history, indicate that the evolution of the lunar crust is likely to have involved several differentiation events separated either spatially or temporally. Discussed below are remotely acquired new mineralogical data for unsampled lunar regions, that begin to document the heterogenieties of the lunar crust and provide tantalizing evidence for a very varied lunar crustal evolution. The full lunar coverage and high spatial resolution of the LGO mapping spectrometer (VIMS) will provide a more complete assessment of lunar mineralogy and distribution of crustal rock types required for crustal evolution models .

Near-infrared reflectance spectroscopy is particularly sensitive to the mafic mineral composition and content of surface material. Spectra of pyroxenes exhibit paired absorption bands (3): the first band for low-Ca orthopyroxenes occurs at 0.90 - 0.93 μm and for high-Ca clinopyroxenes at 0.96-0.99 μm. Olivines exhibit a distinct broad multiple band centered beyond 1.0 μm. Assessment of mineral abundance from reflectance spectra requires modeling of known or suspected components in a multicomponent system (e.g. 4). For lunar highland materials, noritic compositions are easily distinguished from gabbroic by identification of the dominent type of pyroxene composition present and its abundance, troctolites and dunites are distinguished by identification of abundant olivine, and anorthosites by the absence of significant amounts of mafic minerals. Each of these compositions has been detected at different lunar locations using telescopic near-infrared reflectance spectra (see review in 5). Although current data are limited and only include nearside regions, the composition of the megaregolith has been shown to be dominated by a variety of anorthositic norites, while deeper crustal material (from 5-10 km depth and exposed in the central peaks of large craters) exhibit a much wider range of rock types including gabbros, norites, troctolites and anorthosites (5).

With spectroscopic measurements of sufficient spatial resolution on the surface (earth-based telescopes currently obtain spectra for areas 3-5 km in diameter), the stratigraphy of the crust can be studied at individual regions using an understanding of the systematic excavation and deposition of material from depth during a major impact event. By analyzing the composition of surface material in a spatial context around a crater, the local stratigraphy can thus be reconstructed. Briefly, the deepest material forms the central peaks; material from higher stratigraphic zones is deposited on the rim or forms the walls.

Presented in Figures 1a - 1h are residual reflectance spectra (after removal of a continuum estimated as a straight line) for a few small areas associated with several large impact craters on the nearside. Based on the nature and positions of observed absorption features, the following inferences can be made about the general composition of the upper and lower stratigraphic zones for the first ~10 km at each site (upper/lower): <u>Copernicus</u> -- noritic/troctolitic; <u>Eratosthenes</u> -- noritic/gabbroic; <u>Lansberg</u> -- noritic/noritic; <u>Bullialdus</u>-- gabbroic/noritic; <u>Tycho</u> -- gabbroic/gabbroic; <u>Arzachel</u> -- noritic/noritic; <u>Theophilus</u> -- noritic/anorthositic; <u>Aristarchus</u> (6) -- (gabbroic + troctolitic)/gabbroic.

Discussion: Unlike the megaregolith composition, only three of these craters exhibit noritic compositions at depth, emphasizing the heterogeniety of crustal materials below the megaregolith. In addition, more than half exhibit varying compositions with depth. Although subsurface cumulates of a given composition must be several tens of kilometers in extent (in order to form the large central peak mountains of distinct mineralogy), compositional stratigraphy or zoning is clearly not uniform across the nearside. For example, Copernicus, Eratosthenes and Lansberg, separated by only a few hundred kilometers, each exhibit a noritic upper crustal composition but have distinctly different lower stratigraphic compositions (troctolitic, gabbroic, and noritic, respectively). Each of these eight craters display a different compositional

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stratigraphy and rich geologic history. Major advances in our understanding of the lunar crust and its evolution are anticipated as more detailed information on surface composition becomes available from remote measurements and is analyzed in terms of regional geology and crater history. Lunar evolution, often considered an end-member in planetary science studies, is not likely to remain as simple as originally envisioned from the first phase of lunar exploration.

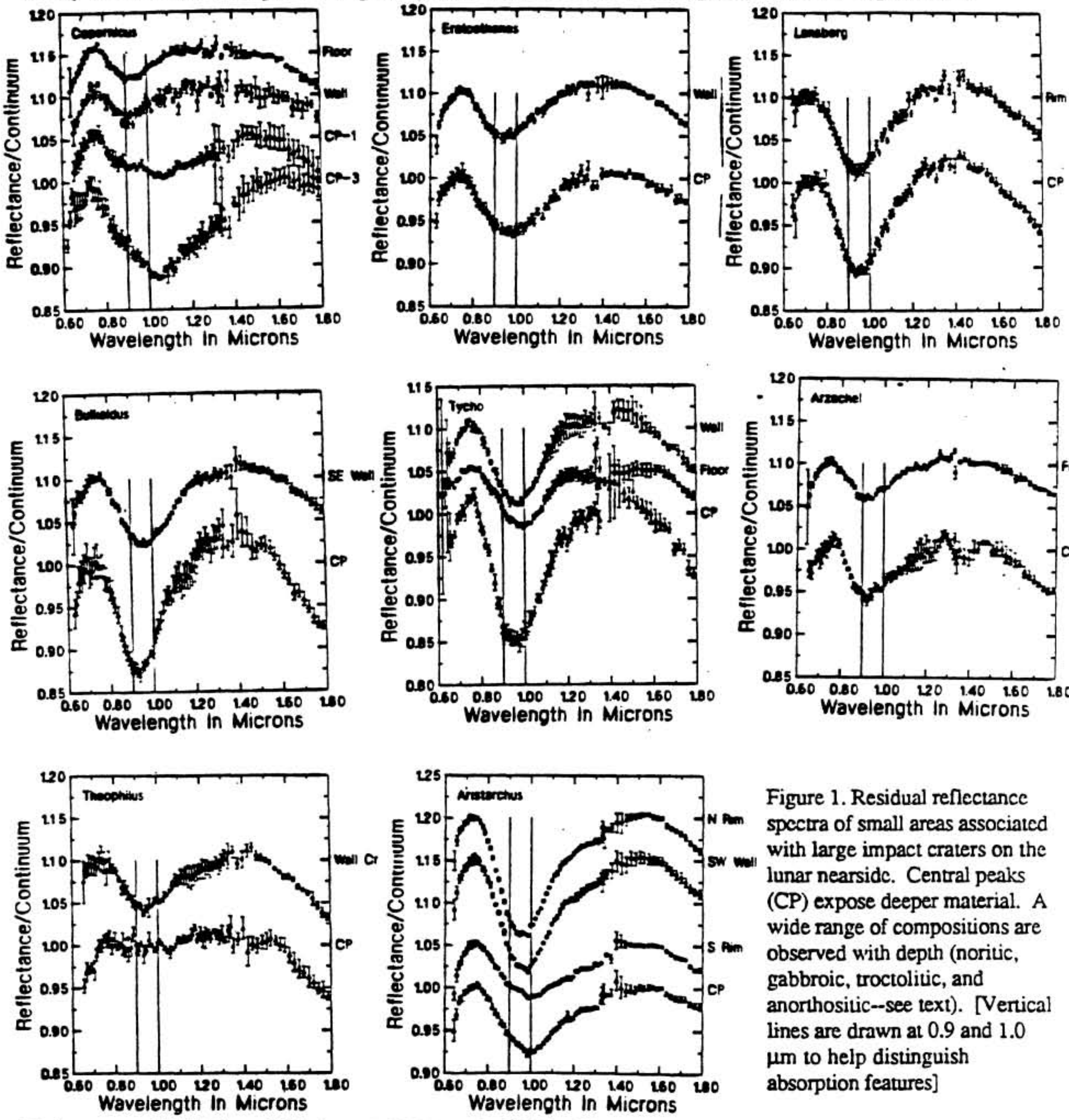

Figure 1. Residual reflectance spectra of small areas associated with large impact craters on the lunar nearside. Central peaks (CP) expose deeper material. A wide range of compositions are observed with depth (noritic, gabbroic, troctolitic, and anorthositic--see text). [Vertical lines are drawn at 0.9 and 1.0 µm to help distinguish absorption features]

References: (1) Walker, 1983 *Proc. LPSC 14*, B17-B25; Warren, 1985, *An Rev. Earth & Plan. Sci. 13*, 201-240. (2) Warren and Wasson, 1977, *Proc. LPSC 8th*, 2215-2235; Warren and Wasson, 1980, *Proc. Conf. Lunar High. Crust*, 81-99; James, 1980 *Proc. LPSC 11th*,365-393. (3) Adams, 1974 *JGR*, 79, 4829-4836. (4) Mustard and Pieters, 1987, Proc. LPSC17. (5) Pieters, 1986, *Rev. Geophys.*, *24*, No2, 557-578. (6) Lucey et al., 1986, *Proc. LPSC16th*, *JGR*, *91*, D344-354.