CENTRAL PEAKS OF LUNAR IMPACT CRATERS: NEW VIEWS FROM CLEMENTINE S. Tompkins and C.M. Pieters, Dept. Geol. Sci., Box 1846, Brown University, Providence, RI 02912

INTRODUCTION: While the Moon's crust has been shown to be compositionally heterogeneous on a 10's of km scale (e.g., 1), a better understanding of the extent and character of this heterogeneity would be valuable to test and modify petrologic models of lunar crustal evolution. The Clementine mission, which has provided digital multispectral images for the entire Moon, will contribute substantially by allowing spectrally distinct units within lunar impact craters to be mapped spatially, thus providing geologic context. Impact craters on the Moon have proved useful as tools for examining the near-surface stratigraphy of the lunar crust. The central peaks of complex craters are believed to have uplifted material from depths of approximately 0.10 - 0.15 times the crater diameter (e.g., 2). In part based on the clarity of spectral features, these central peaks are thought to remain lithologically coherent, despite the forces acting upon them during the impact process. Previous studies of craters using telescopic near-infrared (NIR) spectra provided high spectral resolution information for a single location selected by the observer (e.g., 1). The recently acquired Clementine UVVIS camera data adds spatial information to this view of central peaks. Initial examination of the data has shown that the central peaks are compositionally far more heterogeneous than previously recognized.

DATA REDUCTION AND CALIBRATION: UVVIS camera multispectral images were analyzed for five nearside complex craters: Copernicus, Tycho, Bullialdus, Eratosthenes, and Piccolomini. Initial calibrations were performed as described in 3 and 4.

CRATER CENTRAL PEAKS: Each of the five sets of peaks represents a different compositional category based on the mineralogical interpretation of NIR spectra (1). These compositional units (listed in Table 1) are assumed to have been excavated from depths of ~ 2 - 10 km, for craters ranging from 20 - 100 km in diameter. However, the spectrum for each location represents an average for the area within the telescope's field-of-view, which ranges from 4 - 10 km in diameter.

Clementine multispectral images, while lacking the spectral resolution for detailed mineralogical estimates, provide high-spatial resolution data that allow lithologic units to be examined in geologic context. A summary of initial interpretations of these data is provided in Table 1. Perhaps the most unusual of the five craters is Eratosthenes, the stratigraphic marker for the Eratosthenian Period, which is discussed in more detail below as an example of the compositional and geological interpretations that are now possible. The NIR telescopic spectra for this crater indicated peaks of brecciated gabbro, with additional unknown components. The Clementine images indicate that the peaks of Eratosthenes in fact contain multiple and distinct lithologic units.

ERATOSTHENES: Located adjacent to the Apennine Mountains at their southernmost point, Eratosthenes is a 58-km crater whose central peaks have uplifted material from depths of 8+ km (2). It is likely that the crater has uplifted deposits from the Imbrium Basin in part or all of its central peaks, as well as in the north wall. This region of the Moon is also known for an abundance of dark mantling deposits (DMD) (e.g., 5) and it is possible that Eratosthenes has excavated DMD as well.

While absolute compositional interpretations cannot be made with these Clementine data, spectral parameters such as the 415 nm/750 nm ratio (which is sensitive to soil maturity) and the 750 nm/950 nm ratio (related to the strength of the 1 μm mafic absorption feature) may be used to estimate the compositional characteristics of geologic units. A linear mixing model (e.g., 6, 7) was also used to investigate the distribution and interaction of spectrally distinct "end-member" units. It is clear that Eratosthenes' central peaks are heterogeneous at the scale of the Clementine pixels (~200 km/pixel for this image). There are four spectral units, whose distribution is mapped in Figure 1, and whose spectral characteristics are listed in Table 2. Unit 1 has the highest albedo, the "bluest" (least positive) 415-750 nm slope for the peaks, and no indication of a mafic absorption near 1 μm, as estimated from the 750 nm/950 nm ratio. While the lack of an absorption band could be associated with maturity, the blue UVVIS slope and the high albedo indicate the opposite. This unusual combination of spectral characteristics strongly suggests that this unit is predominantly anorthositic. Unit 2 is of intermediate albedo, has a relatively blue 415-750 nm slope, and exhibits the strongest mafic absorption feature for the central peaks. This unit may represent basalt or gabbro, norite (the Apennines are generally noritic, (e.g., 8)), or some type of DMD. Compared to Unit 2, Unit 3 has a lower albedo, a redder UVVIS slope (the reddest of the four central peaks units), and a weaker mafic absorption. This unit may represent downslope runoff from the peaks, i.e., a mature combination of Units 1 and 2. On the other hand, the strong red slope could also be associated with impact melt. Either interpretation is consistent with the physical distribution of the unit at the base of the peaks (Figure 1). Unit 4 is the darkest, but is bluer and less mafic than Unit 3. It is associated with two of the central peaks in particular, as well as the crater floor. The flat dark spectrum may be due to maturation, or to the presence of opaque minerals. One possibility for the strong correlation between floor material and these particular central peaks is that the floor material represents (in part) a shallower pre-impact layer, and the peaks represent a more deep-seated unit of similar composition, or possibly even a dike feeding the shallower layer. This explanation would favor a Ti-rich basalt or DMD being the dominant composition in Unit 4.

SUMMARY AND FUTURE WORK: The complexity of the central peaks at Eratosthenes is a specific example of the view that Clementine multispectral images provide of the lunar crust at 2 - 10 km depth. The new spatial perspective demonstrates clearly the crust's km-scale heterogeneity. The character and diversity of this heterogeneity remain to be explored when the calibration of Clementine data and integration of its multiple datasets are complete.

Table 1: Telescopic NIR Interpretations and Clementine UVVIS Observations of Crater Central Peaks

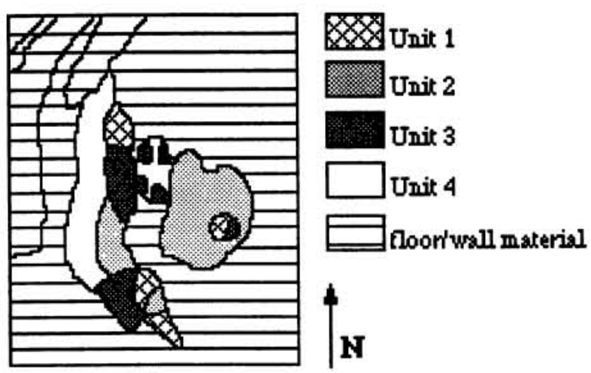
Crater	Compositions from NIR	Clementine Observations
Copernicus*	Troctolite, with a different relative abundance of olivine and anorthosite (an.) noted for different peaks (1).	Consistent with NIR (3).
Tycho*	Gabbro (cpx + an.) (1, 9).	Consistent with NIR (3).
Bullialdus*	Norite (opx + an.) (10) [two distinct compositions apparent from analysis of telescopic images (7)].	Consistent with telescopic images, although additional stratigraphic units are apparent.
Piccolomini	Shocked Anorthosite (1).	Small rings of more mafic material at the base of the peaks, a possible indication of stratigraphic layers.
Eratosthenes	Gabbroic Breccia with unknown additional components (1).	Several lithologies are suggested, including anorthosite, basalt and/or DMD, and impact melt.

*These craters have been suggested to have excavated layered mafic plutons, which could be Mg-Suite sources.

Table 2: Relative Optical Properties for Eratosthenes Central Peaks Units

Unit	415 nm/ 750 nm	750 nm/ 950 nm	albedo
1	very high	very low	high
2	high	high	moderate
3	low	moderate	low
4	moderate	low	very low

Figure 1: Geologic Map of Central Peaks within Eratosthenes



Note: Width of map is ~25 km.

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