CLEMENTINE CASE STUDY: NEW VIEWS OF THE MOON'S FELDSPATHIC TERRANE.

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Introduction: It has long been known that the feldspathic lunar highlands are dominated by anorthosite, confirmed on a global scale using the multispectral data returned by the Clementine mission in 1994. Because of this overwhelming feldspathic dominance in the highland terrane, it is of particular interest to understand the origins of any atypical lithologies (gabbroic, noritic, or troctolitic rocks) that appear within them. The Clementine UVVIS multispectral dataset is now allowing for analyses of such lithologies and observations of their situation within the highland stratigraphy, particularly through the study of large fresh impact craters. *Korotev* [2000] suggests that the atypical lithologies are unlikely to be related to the Mg-suite, and thus these craters may provide a clearer view of the variability within the crust formed during early lunar differentiation, or through subsequent magmatic activity.

The Ongoing Survey: UVVIS camera multispectral images for 12 complex, highland craters (Table 1) have been extracted from the USGS global Clementine mosaics. At these craters, the composition and spatial extent of spectrally distinct units across each scene is being mapped. Estimates of mineralogy and surface chemistry using approaches outlined by *Tompkins and Pieters* [1999] and *Lucey et al.* [1998] allow for the first order identification of spectrally distinct units. Where possible, these observations are supplemented by NIR telescopic spectra, Lunar Prospector elemental abundance maps, and Lunar Orbiter photography for further insight into morphological and textural constraints on composition. It is not assumed that these craters have common origins, and is important to consider each independently, rather than as variations on a single theme.

Analyses of Tycho: A detailed analysis of the crater Tycho and its surrounding region is nearing completion [e.g., *Tompkins and Hawke*, 2001]. This investigation has shown that Tycho is far less mafic than previously assumed, with Clementine values of FeO ranging from 0–12 wt.% (depending on the approach used for topographic correction), and Lunar Prospector values of <2 wt.%. Analyses of Clementine UVVIS images have also shown that Tycho, while remarkably uniform when seen through telescopic spectra [*Hawke et al.*, 1986], actually exhibits a broad range in composition across its walls and central peaks. Small outcrops of pure anorthosite appear in the crater's south wall, while the remainder of the crater ranges from anorthositic gabbro to gabbroic anorthosite (Figure 1). Some of the smaller craters surrounding Tycho exhibit a similar gabbroic composition, while others are clearly anorthositic. Together, these craters suggest a region whose average composition is that of a gabbroic anorthosite, but with distinct, spatially coherent zones of more mafic material.

Regional Investigations: Similar studies have been carried out in the region of King [*Heather and Dunkin*, 2001] and Tsiolkovsky craters [*Pieters and Tompkins*, 1999; *Heather*, 2000] on the lunar farside. These craters are separated by approximately 550km, so investigations of their lithologies also allowed for first order investigations of the lateral variation of the highland crust between the two sites.

By studying the walls and central peaks of these two impact craters, it was possible to determine that both craters had impacted parts of the lunar crust that become more anorthositic with depth. However, while the vertical composition in the region exhibits the same trend, King crater is in an area that has a much higher mafic content, highlighting the lateral diversity between the two regions.

The central peaks of King exhibit many lithologies, including mafic units that appear to be gabbroic in nature. As was seen at Tycho, several of the smaller craters around King also show similar mafic compositions, while others are anorthositic. The spatial distribution of the mafic exposures, and the nature of the distinct mafic zones in King's walls and ejecta suggest a cryptomare origin for the mafic units, and indicate that much igneous activity occurred in the region [*Heather*, 2000; *Heather and Dunkin*, 2001].

Conclusions: The Clementine multispectral data are a valuable tool in surveying the feldspathic highland terrane for atypical lithologies. Such a survey is required if we are to fully understand the origins of the crust and the manner in which the variability within the crust formed, either during early lunar differentiation or via subsequent magmatic activity. Detailed observations of Tycho and King have already demonstrated the use of these techniques to investigate the compositional geology of an impact site. The reduced Clementine UVVIS dataset provided by the USGS will help to streamline the ongoing analyses of a wide range of impact features across the lunar crust.

References:

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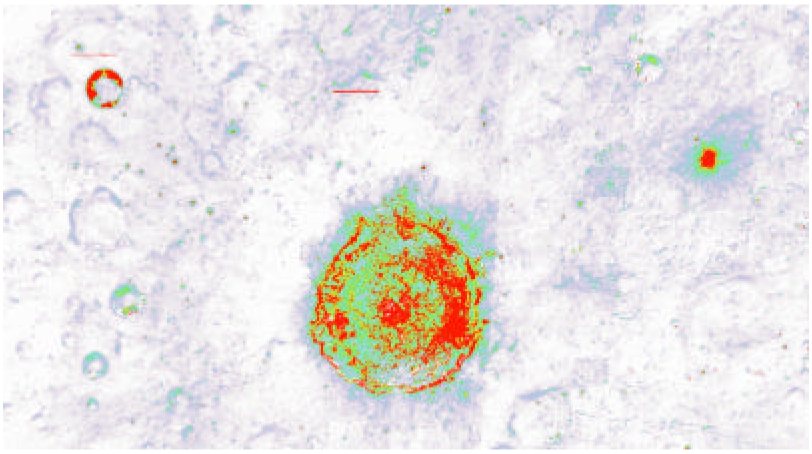

Figure 1: Distribution of fresh gabbroic (high-Ca pyroxene-rich) material within Tycho and surrounding regions. High concentrations are shown in red.

crater	*lat*	*lon*	*diam (km)*	*age*	*setting*	*peak lithologies*
Atlas	47°N	39°	87	UI	highland	GNTA1, AG
Jackson	22°N	197°	71	C	highland	GNTA1, GNTA2, AGN
King	06°N	120.5°	75	C	highland	GNTA2, AGN
Langmuir	36.5°S	231°	85	unk.	highland	A, GNTA1, GNTA2, AGN
Ohm	18°N	246°	64	C*	highland	GNTA1, GNTA2, AG
Orlov	26°S	185°	61	unk.	highland	A, GNTA1, GNTA2, AGN
Crookes	10.5°S	195°	50	C	highland	GNTA1,GNTA2, AT
Keeler	10°S	162°	132	LI	highland	A, AT
Scaliger	27°S	109°	78	UI	highland	A, GNTA1, GNTA2, AG
Stevinus	33°S	54.5°	75	C	highland	GNTA2, AG, AGN, AN
Vavilov	01.5°S	221°	99	C	highland	A, GNTA1, GNTA2, AGN
White	46°S	190°	45	unk.	highland	GNTA2, AG, AN, GN

TABLE 1: List of highland impact craters under study, for which mafic central peaks compositions have been identified.

Age: Approximate crater ages are presented where available; the abbreviations are: UI (Upper Imbrian), E (Eratosthenian), and C (Copernican). *Setting*: Craters are subdivided based on whether they occur in the highlands or within or near major impact basins. *Peak Lithologies*: Rock type abbreviations are: A (Anorthosite), GNTA1 (gabbroic-noritic-troctolitic anorthosite with 85 - 90% plagioclase), GNTA2 (gabbroic-noritic-troctolitic anorthosite with 80 - 85% plagioclase), AN (anorthositic norite), AGN (anorthositic gabbronorite), AG (anorthositic gabbro), N (norite), GN (gabbronorite), G (gabbro), and AT (anorthositic troctolite).