CLEMENTINE MULTISPECTRAL ANALYSIS OF TSIOLKOVSKY CRATER, LUNAR FARSIDE. D. J. Heather[1] and S. K. Dunkin[1], [1]Department of Physics and Astronomy, University College London, Gower Street, London, WC1E 6BT, England. (contacts: djh@star.ucl.ac.uk and skd@star.ucl.ac.uk).

Introduction: Tsiolkovsky (128° E, 22° S) is a Late-Imbrian crater on the lunar farside, within the 700 km pre-Nectarian basin Tsiolkovsky-Stark. It has a diameter of 180 km, and exhibits many features typical of a complex crater, including a central peak, terraced walls and pools of impact melt. The floor of the crater is flooded by mare basalts, standing out from the otherwise heavily cratered highlands. Craters in the area range in age and condition from near complete structures through to almost totally obliterated. Of particular interest to this study are the remains of Fermi, a very large crater whose eastern rim has been destroyed by the formation of Tsiolkovsky.

Previous photogeological studies of Tsiolkovsky have identified several areas that warrant extended multispectral analysis. Of particular interest are:

1) The presence of a heavily cratered platform on the central peak. This could be the result of volcanic activity and it has been suggested that the peak itself may be a volcanic edifice [1].
2) The mare basalt on the crater floor, the sheer volume of which suggests it to have probably resulted from several generations of flow.
3) Two 'edge of floor' units on Tsiolkovsky's floor, younger than the terracing but older than the mare flooding. Although these units show contrasting morphology, both have been interpreted as being of impact melt origin [2].
4) A lobate 'ejecta slide' unit on the north-western rim, suggested by [3] to be the result of a major landslide.

In 1994, the NASA/BMDO Clementine mission mapped the entire lunar surface in 11 different wavebands from 0.4 to 2.8μm [4]. This provided us with the first global high resolution multispectral dataset of the Moon from which details of the composition and relative maturity (i.e. the degree of space weathering) of an area can be derived. For this study, we have constructed a multispectral image of Tsiolkovsky and used it in combination with precursory photogeological mapping with the aim of extending our understanding of the geology of Tsiolkovsky and its environs.

Analysis: Using frames from three Clementine UVVIS camera wavebands, initial 250 m/pixel resolution mosaics of the area were made at 415 nm, 750 nm, and 950 nm*. These were then ratioed and combined to form a false colour image in which red is controlled by the 750/415 nm ratio, green by 750/950 nm and blue by 415/750 nm. The red and blue channels are a measure of the steepness of the continuum (albedo) and indicate maturity relations (or titanium content in maria), while the green channel represents the strength of the absorption at one micron which increases with mafic content. So mature highlands appear reddish, fresh highlands appear blue and fresh exposures of mare basalt appear green or yellow. Due to its glassy nature and high Fe^{2+} content, impact melt will appear a bright orange-red [5]. Using methods developed by [6] and the recently calibrated algorithms of [7] and [8], maps were also produced to show the relative abundance of FeO and TiO_2 in the soil. Plots of five point spectra from the Clementine data were used as an analytical tool throughout.

Results: *Central Peak* **-** Tsiolkovsky's central peak structure lies to the north-east of the crater's centre and slopes down to the north, dropping approximately 2 km from its southern to its northern edge. The southern end of the peak embodies two ridges forming a south pointing 'V' that houses a raised platform approximately 16 km across. This platform has the highest crater density in Tsiolkovsky, leading to the suggestion of volcanism having occurred in the region, and the possibility of the peak itself being a volcanic edifice [1]. If this were the case, one would expect volcanic flows to show up as green in the multispectral image, having a relatively high pyroxene content (and a strong 1 μm absorption). However, the peak appears blue in our image, and five point spectra plots suggest it to be composed of generally feldspathic material. The cratered platform is difficult to resolve as a separate unit in the frame and there is no evidence in the multispectral image for the presence of any volcanic material on the edifice.

Dark Floor Material **-** Analysis of the multispectral image confirms results from spectral studies carried out by Pieters *et al.* (1995) [9], showing this extensive floor unit to have a low titanium content in comparison to nearside maria and a strong 1 μm absorption (high clinopyroxene abundance) in comparison to the surrounding highlands.

The size of the unit, given by [3] to be approximately 11, 500 km^2, suggests the presence of more than one flow unit although no flow fronts are visible even on the high resolution Orbiter images. Using the multispectral image and five point spectral plots, it should be possible to identify different generations of flow with similar composition, since significantly

* For details of the photometric coefficients used and the data processing procedures employed, please contact the authors.

younger, fresher units would appear spectrally brighter than their older counterparts. Although brighter areas are seen in our image, these correlate well with crater chains seen on the Orbiter frames. This relationship is also seen in the TiO_2 map, with the more heavily cratered floor displaying freshly excavated basalts with lower TiO_2. This does not preclude the possibility of there being several generations of flow in the unit since they may not have a significant enough difference in either age (space weathering) or composition for the Clementine data to resolve [10].

Edge of Floor Material - This material is older than the dark mare floor and younger than the inner wall, forming a discontinuous bench between the two. Two outcrops displaying contrasting morphologies are present, one to the south-west the other to the north. It has been suggested that the material is probably of impact melt origin [2]. However, in five point spectra, these units appear to display a combination of the spectral signatures of impact melt and crater wall units. Since all of the impact melt in the crater would have been formed at the same time, the spectral differences cannot be the result of space weathering. It is therefore suggested that mixing of the impact melt and highland units on the crater wall occurred during the emplacement of this material to give the spectral characteristics seen.

The different morphologies of the two edge of floor units probably results from differences in elevation and structure of the crater wall, perhaps also partially governed by underlying (pre-existing) structures. This theory is supported by the location of both units, which appear to have occurred in regions close to the point where Tsiolkovsky cuts through the rim of Fermi.

Inner Wall and Rim Material: The rounded nature of the terraces and rim of Tsiolkovsky, and distinct lack of craters, suggest creep or mass movement of some sort to have occurred, and the presence of scree at the foot of some of the gullies underlines this possibility.

Analysis of the multispectral image shows the crater wall and rim to be composed of fairly weathered feldspathic material, with fresher exposures along the terraces. Several small areas within the terraces and large areas on the rim contain ponds and sheets of glassy impact melt. In the south-western and northern regions of the wall, the melt has mixed with the wall material to form the 'edge of floor' units below. The melt appears to be distributed in patches around the whole of the rim except for the region of the ejecta flow unit (see below), implying the flow to have occurred after the emplacement of the impact melt.

Continuous Ejecta **-** Previous studies show Tsiolkovsky's ejecta blanket to extend radially some 200 km from the crater lip [2]. The multispectral image shows little spectral contrast in the blanket. Although several blue (fresher) rays appear to radiate from the main impact, they are very subdued and the blanket is fairly dark in the single filter mosaics. In general, the ejecta is composed of fairly mature and weathered highland soil (~3 to 4 % FeO). Several pools of impact melt and mare material within the ejecta blanket can be clearly differentiated in the multispectral cube.

Ejecta Slide - This unit forms a wedge shaped body on the north-western rim of Tsiolkovsky reaching onto the flat floor of Fermi, thinning as it extends from the rim. The morphology of the unit clearly suggests a flow origin and [2] notes that the ridge curvature can be explained by mass slumping of the crater rim. This is consistent with analysis of the Clementine data in which the unit appears to be compositionally very similar to the rest of the crater rim, implying the flow to have occurred very soon after or during the crater formation.

This work will form an integral part of a larger project that aims to derive a detailed stratigraphic history of Tsiolkovsky and a timeline for the formation, emplacement, and evolution of units present [10].

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