A FRESH LOOK AT THE COPERNICUS CRATER CENTRAL PEAK REGION USING HIGH-RESOLUTION NIR DATA FROM THE SIR-2 MISSION.

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Introduction: Around 800 Ma [1] a meteorite impact excavated the lunar surface to a depth of around 10 km, thereby creating a circular depression of 95 km in diameter: the Copernicus Crater. The impact dynamics also caused materials at depth (bedrock) to be excavated and brought to the surface [2]. These otherwise inaccessible geological samples now represent three distinct mountainous systems located at the centre of the crater floor, reaching a maximum height of around 800 meters.

Remote sensing studies [3,4] have found evidence in these features of distinct mineralogical compositions. In particular they detected the presence of the mafic mineral olivine in place of the otherwise ubiquitous pyroxene silicates.

The instrument and data set. The MPS designed SIR-2 instrument, which formed part of the scientific payload of the Chandrayaan-1 Indian lunar polar orbiter mission [5], collected high spatial resolution (~200 m) near infrared data of the area (47 sample points in total) during two separate flyovers (orbits 1095 and 1929) using a Grating NIR Point Spectrometer, at wavelengths between 0.9 and 2.4 microns with spectral resolution 6 nanometres (256 bands). Fig. 1 shows the geographical locations of these reflectance data.

Sample analysis and results: Spectral properties of lunar surface materials (e.g. Fig. 2) are dictated by their compositional (mineralogy) and physical properties (e.g. grain sizes, space weathering processes) [6,7]. Remote sensing lunar science is built on the foundations laid by laboratory analysis of returned lunar samples supported by theoretical studies and direct measurements of the spectral properties of key minerals [8]. We conducted a thorough survey of the whole Copernicus edifice analyzing more than 400 spectra along the two intersecting orbits. Thirteen distinct absorption types were identified based on broadly comparable spectral signatures. Here we present a relatively simplified classification comprising four broad spectral types (Figs. 3 and 4) focused around the central peaks area: Group (1): weak-to-very weak absorption features, typical of mature basalt-like materials. This type of soil is present over much of the crater floor surface, in particular across its northern half. Group (2): a weak-to-average absorption feature with band centre around 1.06 μm accompanied by a much stronger '~2.1 micron' dip which is a diagnostic of Ca-rich pyroxene phases. Group (3): very pronounced '1 micron' absorption feature together with a (much) weaker depression ~1.30 μm deep. Either none, or extremely subdued, '2 micron' absorption. These absorption characteristics strongly suggest that Fe-rich olivine is the dominant mafic fraction (troctolite) in the surface materials. Group (4): strong absorption feature estimated to be at around 0.90 μm (see Fig. 2) as suggested by the shape and trend of the absorption curve. This, along with the strong 2 μm absorption feature, points to the presence of fresh crystalline materials rich in (Ca-poor) pyroxene minerals.

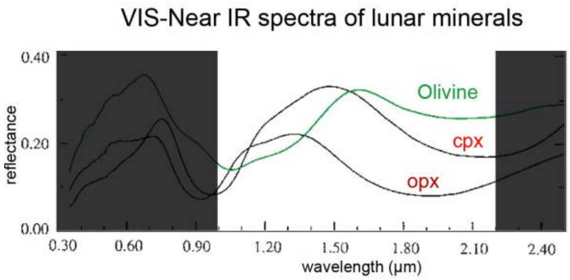

Figure 2. Lunar materials spectra from RELAB database [11]. Comparable range highlighted.

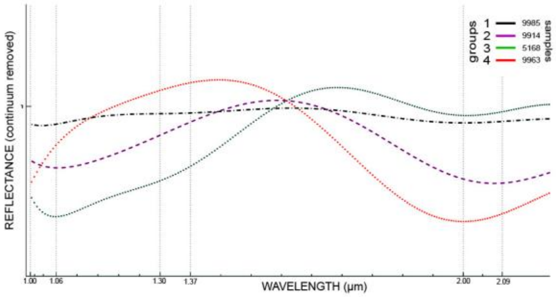

Figure 3. Residual absorption spectra (after continuum removal) of the four Groups of representative samples.

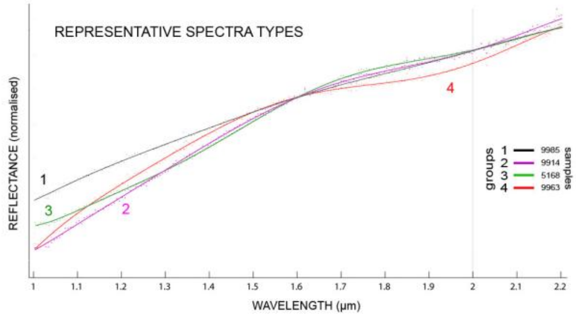

Figure 4. Representative chosen spectra 1-4, here presented normalized to pixel 102 (1.616 µm).

Discussion: Figure 1 shows the spatial distribution of the remotely sampled terrain. It can be seen that the two parallel orbits (at this scale) offer a unique opportunity to follow the compositional variations of exposed materials in a highly heterogeneous environment. Mare-like materials of presumably basaltic compositions (Group 1, or G1) are detected across the entire basin: this suggests that, despite the relatively young age of the impact structure and later emplacement of melt products, space weathering contributed significantly to subduing most of the reflectance characteristics of the base minerals [7]. G4 soil is located in the area around the northern foot of the main peak. Its strong absorption features are diagnostic of exposed crystalline materials (i.e. fresh, less weathered) and its origin can be understood by observing the ejecta pattern of the small crater highlighted in figure 1 (FC). Indeed, G4 spectra may be taken to present the 'true' reflectance characteristics of most of the crater's floor with hundreds of millions of years of progressive space weathering stripped away. G3 reflectance data represents the unambiguous detection of olivine, a silicate commonly present at mantle depths. The near textbook absorption fingerprint derived from SIR-2 measurements testifies to the accuracy of detection and calibration of this instrument. Finally, G2 materials, detected in areas along the flanks of the central peaks suggest the presence of 'mixed' materials, probably due to a combination of both olivine and pyroxene phases (olivine gabbro or olivine norite)..

Conclusions: Copernicus central peaks have been the subject of several in-depth remote sensing analyses both using telescopes [e.g. 1] and orbiting instruments [e.g. 9,10]. Our results confirm the published data and geo-mineralogical conclusions provided by several previous studies [e.g. 10] but at much higher spatial and spectral resolution. Given that this first scientific application of the SIR-2 data employed just 47 spectra out of ~12 million spectra recorded during orbits (1026) that crossed the whole of the lunar surface, we are confident that the excellent quality of the acquired data hold the potential to support future highly accurate mapping of lunar surface materials.

References:

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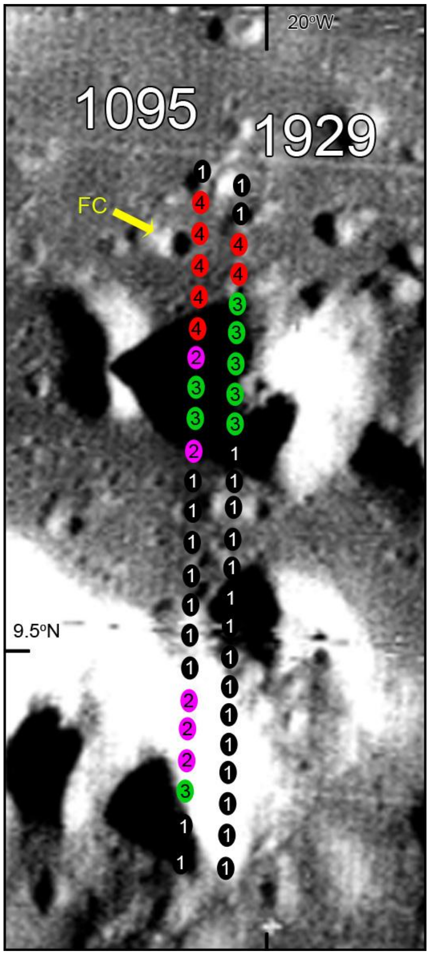

Figure 1. Copernicus Crater central peaks region. Dots are not drawn to scale to represent ~200 m true ground diameter (they are here enlarged to twice their real surface in aid of clarity). Base map: Lunar Orbiter IV (©NASA).