ANALYSIS OF ABSORPTION TROUGH FEATURES USING CLEMENTINE UVVIS+NIR IMAGERY

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Introduction: This contribution explores the mapping of spectral parameters of lunar features using the Clementine UVVIS+NIR data set covering the wavelength range between 415 and 2000 nm [1]. The extracted spectral features are the minimum and depth of the principal absorption trough near 1000 nm and the corresponding values of secondary absorption features present at higher wavelengths, as well as the full width at half maximum (FWHM) of the principal absorption trough. Based on the derived spectral feature maps we provide a brief discussion of the mineralogical components present in the soils around the craters Aristarchus and Dionysius.

Spectral features: The Clementine UVVIS+NIR multispectral data set contains pixel-synchronous lunar global mosaics at 415, 750, 900, 950, 1000, 1100, 1250, 1500, 2000, 2600, and 2780 nm. The five UVVIS bands between 415 and 1000 nm were made publicly available some years ago [2]. Recently, however, the first four calibrated NIR bands covering the range from 1100 to 2000 nm have been released so that both datasets can be used seamlessly [1]. Calibration for the last two NIR bands is generally thought to be less reliable.

Relation to mineral composition. Information about the identity of iron bearing (mafic) minerals (orthopyroxenes and clinopyroxenes) is contained in the band minimum, depth, and width parameters of the absorption trough near 1000 nm [3]. In some cases, secondary absorption features due to the presence of an olivine or impact melt glass component are present at higher wavelengths. Pyroxene has an absorption band near 1000 nm and a shallow secondary trough at about 1250 nm, the latter not being analysed here. Some types of basalt have a high olivine content of up to 10–20% that causes a broadening of the pyroxene band and a slight shift of the minimum towards higher wavelengths. All rocks containing pyroxenes have absorption wavelengths between approximately 900 and 1000 nm. Norite, which is comprised of plagioclase feldspar and low-Ca pyroxene, has an absorption band between 900 and 930 nm. As the low-Ca pyroxene content increases, the strength of the absorption band also increases. If an area of lunar rock has an absorption band between 930 and 950 nm, it is probably noritic, but higher-Ca pyroxenes may be intermixed. Gabbroic rocks are very similar to basalts in mineral content, but they were formed by intrusive processes while basalts were formed extrusively. They can be almost pure high-Ca pyroxene, with an absorption band range of 970–1000 nm, or they can be both high-Ca and low-Ca pyroxene, with an absorption band range of 950 to 970 nm. The mineral olivine displays an absorption band due to a crystal field absorption of Fe^{2+} at wavelengths varying from about 1050 to 1080 nm, corresponding to a FeO content below 9% or higher than 50%, respectively [4,5]. Dunite and troctolite, two rocks composed of olivine, have absorption bands centred beyond 1000 nm and often around 1100 nm when present in a purer form unmixed with other minerals.

Extraction of spectral features. For lunar impact craters, the continuum of the spectrum usually corresponds to the line connecting the reflectance values at 750 nm and 1500 nm [6]. However, we believe that the best choice of continuum line depends upon the spectra of the particular region studied. The continuum is removed by dividing the spectrum by the continuum line. The continuum-removed spectrum is then interpolated with the Akima algorithm [7]. This interpolation algorithm is favourable in that it preserves the shape of the original spectrum and does not produce artifacts. The wavelength of an absorption trough corresponds to a local minimum of the interpolated spectrum. The band depth is given by $(1–I_{min})$ with I_{min} as the continuum-removed reflectance at the minimum. The FWHM of the absorption trough is computed directly based on the interpolated continuum-removed spectrum. Shallow secondary absorptions often do not appear as local minima but as inflection points of the interpolated spectrum which at the same time have a small absolute slope value (in our analysis smaller than 0.02 continuum-removed reflectance units per 100 nm wavelength). When having a positive slope and appearing in the wavelength range between 1000 and about 1100 nm, these inflection features are usually due to a minor admixed olivine component. Sometimes a subtle inflection feature can be converted into a trough by a slight adjustment of continuum line placement.

Analysis of lunar impact craters: In the absorption wavelength maps shown in Figs. 2 and 3, the minimum of the trough around 1000 nm is represented by the pixel values in all three colour channels. If an inflection feature exists between 1000 and 1100 nm, its wavelength is encoded by the green channel. If a second absorption minimum is present at a wavelength below 1150 nm, its wavelength is encoded by the blue channel. Each channel covers the wavelength range from 900 to 1155 nm. The band depths are encoded in an similar manner in the corresponding band depth maps over a range from 0 to 0.2, where the red and the blue channel represent the depth of the primary and secondary absorption minimum, respectively, and the green channel the depth of the olivine-related inflection feature. The FWHM maps are represented by greyscale images covering the range between 100 and 500 nm.

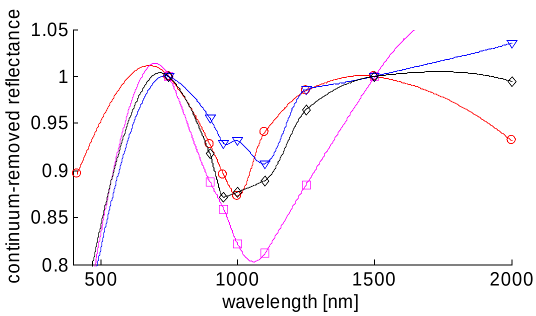

Fig. 1: Example spectra of the Aristarchus region. Circles: pyroxene trough; triangles: double trough (pyroxene and olivine); diamonds: single trough with inflection feature (minor admixed olivine component); squares: olivine trough.

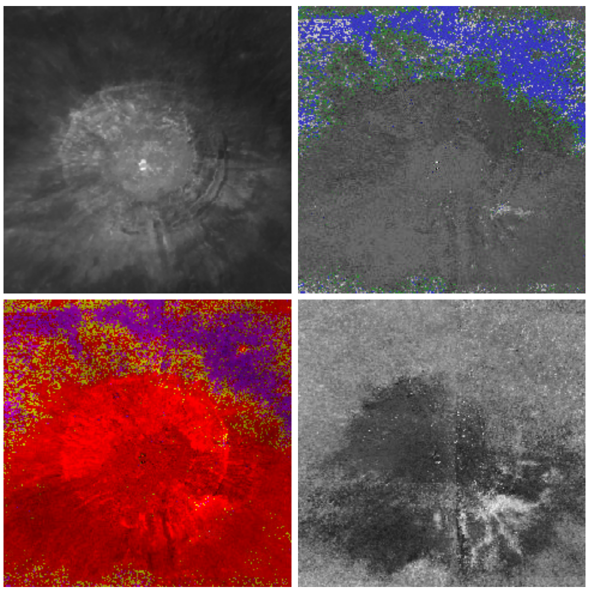

Fig. 2: Spectral maps of Aristarchus. Upper left: 750 nm image; upper right: absorption wavelength; lower left: band depth; lower right: FWHM.

Aristarchus. The crater floor and terraces of Aristarchus mainly display pyroxene spectra with a single absorption minimum (Fig. 2). Deep absorption minima around 970 nm appear in the northern and northwestern part of the crater, an area mapped as rich in clinopyroxene in [8,9] (circles in Fig. 1). Shallower absorptions at wavelengths around 1000 nm occur in the crater centre and its southwestern part, mapped as plagioclase-rich soils in [8]. Broad absorptions in the northeastern crater wall and additional absorption minima and inflection features between 1020 and 1080 nm in the ejecta immediately northeast of the crater indicate an admixed olivine component [8,9] (triangles and diamonds in Fig. 1). A pattern of pixels indicating deep and very broad single absorption troughs at wavelengths around 1070 nm appears at the southeastern crater rim, indicating soils rich in olivine [8,9] (squares in Fig. 1).

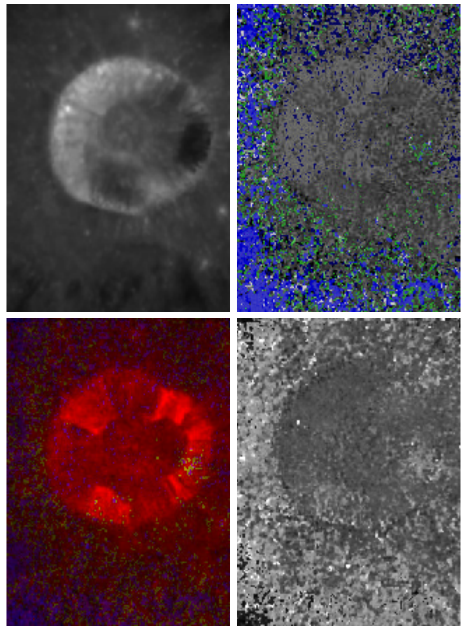

Fig. 3: Spectral maps of Dionysius. Upper left: 750 nm image; upper right: absorption wavelength; lower left: band depth; lower right: FWHM.

Dionysius. The inner crater wall of Dionysius contains dark basaltic deposits in its eastern and southern part, showing deep absorptions at wavelengths around 970 nm (Fig. 3) [10]. The other parts of the crater wall display shallower absorptions at about 1000 nm. In the western and northern parts of the inner wall and in the areas immediately north, west, and south of the crater, some pixels (dark blue in the absorption wavelength map) indicate an additional absorption at 910 nm, attributable to a noritic component [10]. The eastern basaltic deposit shows a cluster of pixels displaying inflection features at 1040–1050 nm and large FWHM values, indicating an olivine component.

Conclusion: Direct extraction of absorption trough features from Clementine UVVIS+NIR imagery is an easily applicable approach to the qualitative distinction between compositional units on the lunar surface.

References: [1] http://www.mapaplanet.org; [2] Eliason et al. (1999), *PDS Volumes USA NASA PDS CL 4001 4078*; [3] Smrekar and Pieters (1985), *Icarus 63*; [4] King and Ridley (1987), *J. Geophys. Res. 11*; [5] http://speclab.cr.usgs.gov/spectral.lib06/ds231/datatable.html; [6] Le Mouélic et al. (2000), *J. Geophys. Res. 105(E4)*; [7] Akima (1970), *J. ACM 17(4)*; [8] Lucey et al. (2008), *NLSI Lunar Sci. Conf.*; [9] Le Mouélic et al. (1999), *LPSC XXX*; [10] Giguere et al. (2005), *LPSC XXXVI*.