

SPECTRAL RATIO METHODS FOR TELESCOPIC LUNAR TiO₂ MAPPING;

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Charette et al. [1] first established a means of estimating TiO₂ content in the lunar maria by constructing an empirical relation between the 400/560 nm spectral ratio and TiO₂ content in mature (agglutinate-rich) mare soils. This relation was subsequently refined [2,3] and used in constructing several TiO₂ abundance maps for various mare regions in the 1970s using images obtained from vidicon imaging systems [4,5,6]. However, the photometric limitations of the vidicon detectors produced significant uncertainties in the images and hence in the TiO₂ maps. The advent of solid state charge-coupled device (CCD) imaging systems capable of better photometric response has permitted acquisition of more accurate images. Image filters sets were obtained for 400 nm and 560 nm bandpasses in October 1989 at the Tumamoc Hill 0.5 m telescope using a RCA 320 x 512-pixel CCD chip. From these images an entire near-side TiO₂ abundance map for the lunar maria was constructed with 5.3 km pixel size [7,8,9]. Based on this TiO₂ map, further imaging of selected regions on the moon has been performed using an experimental 2048 x 2048-pixel CCD chip (built by Advanced Technologies Division of Photometrics Ltd. of Tucson) at the Catalina Observatory 1.5 m telescope [10] to obtain images that can be used to construct TiO₂ maps with 0.24 km pixel size. Such maps will help in locating regions that contain significant amounts of ilmenite (FeTiO₃), a potential lunar resource capable of providing oxygen for the first lunar bases [7,8,9,10,11].

In addition to the 400 nm and 560 nm image filter sets of the moon that were obtained to construct the above TiO₂ abundance maps, 730 nm image sets were also acquired using each CCD in order to investigate the potential of using a 400/730 nm ratio as a more sensitive indicator of TiO₂ content. The "1- μ m" pyroxene absorption band begins near 730 nm for many types of pyroxenes and results in an inflection point in the 700-800 nm region for many lunar spectral response curves. Figure 1 shows a typical reflectance spectrum (relative to the MS-2 standard area and scaled to a value of 1 at 560 nm) for a region in Mare Tranquillitatis [7,9]. The difference in reflectance relative to MS-2 between the 400 nm and 730 nm bandpasses is greater than that between the 400 nm and 560 nm bandpasses by about 40 %. This suggests that the 400/730 nm ratio should provide greater spectral contrast than the 400/560 nm ratio. Such improved sensitivity could be used to more precisely measure TiO₂ variations in the lunar maria, as has been suggested [12].

Careful normalization of the 400/560 nm and 400/730 nm ratio image sets to similar intensities and the use of identical contrast stretch parameters is necessary to properly compare color differences between areas. Comparisons between the full moon ratio mosaics [7,9] and ratio images of selected areas [10] do show a greater degree of contrast in the 400/730 nm ratio. Color differences in Mare Humorum and Mare Tranquillitatis, for example, are much more visible in the 400/730 nm ratio images than in the 400/560 nm ratio images and may further delineate titanium distribution within these areas.

The greater sensitivity of the 400/730 nm ratio provides an incentive to redefine the Charette relation in order to improve its accuracy in predicting TiO₂ content in the lunar maria. The 400/560 nm wavelength pair used to construct the original relation was chosen somewhat arbitrarily: the 400 nm bandpass was a practical lower limit for the near-UV portion of the laboratory lunar sample spectra and the 560 nm bandpass was a convenient wavelength to use as a reference [12]. A reevaluation of the relation would involve duplicating the analysis of the lunar sample spectral data set performed by [1] such that the

730 nm reflectance values would be used in place of the 560 nm values. However, the present laboratory spectra suffer from wavelength calibration uncertainties as well as certain insufficiently documented chemical analyses [7,9,13]. It would be most valuable to reanalyze the Charette relation using new laboratory measurements of lunar samples derived from modern spectrometers that could provide more reliable spectroscopic information as well as extend measurements further into the near-UV. The near-UV may also contain wavelengths that provide even greater spectral contrast when ratioed to the 730 nm band. For example, Figure 1 shows that the spectral contrast of the 350/730 nm ratio surpasses that of the 400/560 nm ratio by 68 %.

A reconstruction of the relationship between TiO_2 content in mare soils to a more sensitive (near-UV)/(red) ratio could be of great use to more precisely pinpoint areas of highest TiO_2 concentrations. If ilmenite will be used substantially as a lunar resource, future Earth-based and/or orbital remote sensing measurements of the moon could improve existing TiO_2 maps and provide valuable information in preparation for selecting potential lunar base sites.

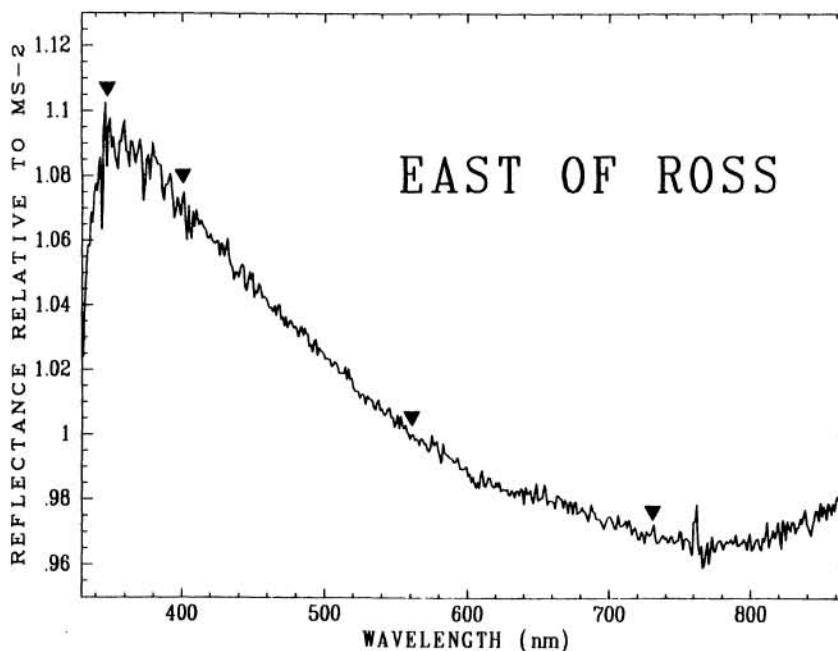


Figure 1. Reflectance spectrum (relative to MS-2 and scaled to unity at 560 nm) for region east of Ross in Mare Tranquillitatis from 330-870 nm. Reflectance difference between 400 nm and 560 nm is less than difference between 400 nm and 730 nm.

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