ESTIMATES OF LUNAR MARE TITANIUM AND ILMENITE ABUNDANCES FROM CCD IMAGING AND SPECTROSCOPY; J.R. Johnson, S.M. Larson, and R.B. Singer, Planetary Image Research Laboratory, LPL, University of Arizona, Tucson, AZ, 85721.

An important criterion during lunar base site selection will be the availability of ilmenite ($FeTiO_3$) for use as a local resource. Significant quantities of oxygen can be liberated from ilmenite during chemical reactions [1] and used both for propellant and life support. It is therefore important to know the distribution of lunar ilmenite.

Since ilmenite is the dominant Ti-bearing lunar mineral ($\approx$ 50 wt % TiO_2), those areas of greatest TiO_2 concentration are expected to contain the highest ilmenite abundances. Toward this end, Earth-based telescopic images of the moon obtained through bandpass filters centered near 0.40μm and 0.56μm have traditionally been ratioed to provide estimates of TiO_2 abundances in the lunar maria [2,3]. The University of Arizona Tumamoc Hill 0.5 m telescope has been used to obtain a set of multispectral images of the moon (including near-UV images down to 0.31μm) using a 320 x 512 element CCD system. This system permits spatial resolutions of about 5 km/pixel while imaging nearly one quarter of the full moon per image (five frames with substantial overlap are required to image the full disc). The ratio images have been calibrated to percent TiO_2 abundance using the revised relation of Pieters [3]. Preliminary analyses of these abundance maps for the near side maria show them to be consistent to about $\pm$ 2 wt % TiO_2 between frames.

Previous attempts to establish TiO_2 abundances using the 0.40μm/0.56μm ratio involved obtaining images via silicon vidicon tubes. Johnson et al. [4] mosaicked individual vidicon multispectral frames, ratioed them, and constructed TiO_2 maps for the northern maria using the calibration of Charette et al. [2]. Although the effective spatial resolution of these images is about 3 km/pixel, each frame covers a relatively small region of the lunar surface; comparison of color differences in the ratio images between distant areas are therefore prone to error. With larger areal coverage per frame, our CCD images permit greater photometric reliability between lunar regions than do mosiacs. The photometric processing required to produce the vidicon maps resulted in errors in the ratio value of up to 5% [4]. The processed CCD images do not suffer from as large an error, particularly since low frequency noise "shading" (induced by the mosaicking of Johnson et al. [4]) is not as significant a problem here. In addition, while vidicon intraframe photometric precision was about 1%, the present CCD system allows photometric precision within a frame of about 0.5%.

Observations of the high-TiO_2 areas using relatively high resolution slit spectroscopy are also being analyzed for discrete signatures attributable to ilmenite in order to estimate its relative abundance in a particular region. Slit spectra have been obtained for several areas on the moon (mainly within the high-TiO_2 regions) using the same CCD with a spectrograph/camera designed by one of us (SML). It permits 11 Å/pixel resolution in the spectral range from 0.30μm to about 0.85μm and uses a long slit to give spatial dimensions of about 5 x 500 km on the moon. Each spectral observation was followed immediately by acquisition of spectra for the standard area MS-2 in order to obtain relative reflectance spectra free from instrumental effects. The time delay between each pair of observations was $\leq$ 30 sec so that changes in atmospheric conditions between the spectral pairs are greatly minimized. In order to obtain absolute reflectance spectra, the University of Arizona Catalina Observatory 1.54 m telescope has been used with the CCD system to permit calibration of MS-2 (as well as the Apollo 16 standard area and an area in Mare Tranquillitatis) with a solar analog star (HD 28099) over the appropriate air masses. Analysis of absolute spectra can be more readily compared to laboratory reflectance measurements of Apollo sample soils. It should also be noted that the image of the spectrograph slit on the moon was simultaneously videotaped for all lunar spectra so that the precise region being analyzed could be recorded accurately.

Preliminary calibrations and initial analyses of the image ratios allow areas of high-TiO_2 to be located. Table 1 shows the highest observed values of TiO_2 (for regions at least 200 km^2 in size) for several of the lunar maria along with the approximate location in the mare for each.

Figure 1 shows initial plots of relative reflectance spectra (scaled to unity at 0.56μm and to MS-2) for high and intermediate TiO_2 regions in western Mare Tranquillitatis. The spectra are taken from two different locations along the same slit, which crossed high and intermediate TiO_2 regions that are visible on the TiO_2 abundance maps.

ACKNOWLEDGEMENTS: This work is funded through the NASA/University of Arizona Space Engineering Research Center for Utilization of Local Planetary Resources.

REFERENCES: [1] Gibson, M.A. and Knudsen, C.W. (1985), Lunar Bases and Space Activities of the 21st Century, 543. [2] Charette et al., (1974), JGR, 79, 1605. [3] Pieters, C.M., (1978), Proc. LPSC 9th, 2825. [4] Johnson, T.V. et al. (1977), Proc. LPSC 8th, 1029.

TABLE 1. Preliminary estimates of highest % TiO_2 in several lunar maria (based on 0.40μm/0.56μm image ratios calibrated using [3]).

Mare	TiO_2 (wt %)	Approximate location (Lat., Long)
Crisium	3.2	12°N, 59°E
Serenitatis	4.9	19°N, 14°E
Tranquillitatis	11.0	11°N, 26°E
Fecunditatis	6.5	02°S, 53°E
Vaporum	5.6	12°N, 06°E
Nubium	5.8	20°S, 12°W
Humorum	5.7	20°S, 36°W
N. Ocean. Procell.	5.7	18°N, 60°W
S. Ocean. Procell.	7.5	03°S, 43°W
East Imbrium	4.9	33°N, 08°W
West Imbrium	6.1	39°N, 21°W

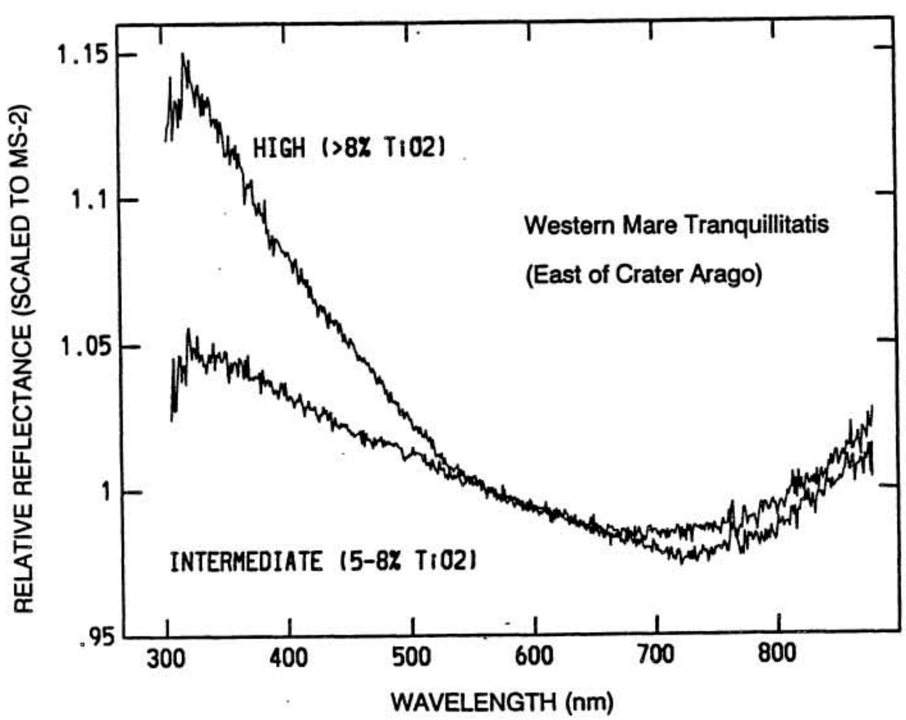

Figure 1. Preliminary relative reflectance spectra (scaled to MS-2) for high and intermediate TiO_2 regions in western Mare Tranquillitatis. Both curves scaled to unity at 0.56μm.