EXPLORING THE CRISIUM REGION WITH MULTISPECTRAL IMAGERY;

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INTRODUCTION: Centered near 17.5° N, 58.5° E, the Crisium basin is a major feature of the eastern portion of the lunar nearside. A massif ring of 540 km diameter bounds Mare Crisium. The topographic rim of the basin may be represented by a ring of scarps about 740 km across [1]. Geologic and remote sensing studies of Mare Crisium were published a number of years ago [2], but the highlands units associated with the basin have not received as much attention. The Crisium highlands harbor a number of interesting features including geochemical and radar anomalies, light plains units, and probable disguised mare deposits (cryptomaria). The present work seeks to answer a number of questions regarding the nature and origin of these features.

DATA & ANALYSIS: We have recently completed a near-infrared (0.6-2.5 μm) spectral study of the Crisium region [3]. That work used analysis of the mafic mineral absorption band near 1 μm to provide information on the composition of the lunar areas observed (typically 2-25 km in diameter). In addition to band analysis, spectral mixing models based on the results of principal components analysis of a group of Crisium spectra were conducted.

The results of the spectral work invited further study at higher spatial resolution. Such data sets for the Moon have been provided by CCD cameras operating in the extended visible range (~0.4-1.0 μm). Instruments of this type have been installed on a Univ. of Hawaii telescope at Mauna Kea Observatory (MKO) [4], and are carried aboard the *Galileo* [5] and *Clementine* [6] spacecraft. The MKO and *Galileo* SSI cameras provide regional views, with resolution of ~2 km/pixel. *Clementine* UVVIS and NIR imagery has a spatial resolution about ten times greater, permitting detailed examination of features. Our initial focus is on the MKO and *Galileo* data.

The MKO image set consists of one scene of the western Crisium region. The camera obtained images through 12 filters. Standard dark and flat field corrections were applied [4]. The images were registered using a routine in the PICS image processing system, and assembled into an image cube for analysis. The *Galileo* data considered here are portions of a mosaic from the spacecraft's second Earth-Moon encounter (LUNMOS 7, six filters), provided by the U. S. Geological Survey, Flagstaff, AZ [7].

The Mauna Kea data were studied using image spectral mixing analysis [8]. This involves selection of small endmember areas within the scene. An unmixing routine then finds the best-fit contribution of the endmembers to each pixel. The result is an abundance image for each of the chosen endmembers and an image depicting the error in the model fit. For the present case, four endmembers were used: fresh highlands, mature highlands, fresh mare and mature mare.

Several analysis techniques have been applied to the *Galileo* data. In addition to the image mixing models described above, a color-composite image was constructed from 0.41/0.76, 0.76/0.99 and 0.76/0.41 μm ratios [7]. This image product shows variations attributed to soil maturity, relative strength of the "1 μm" band, and Ti-content of mare basalt. We also plan to utilize an Fe-abundance algorithm [9] to produce an Fe-abundance image for the Crisium region.

RESULTS and DISCUSSION:

Crisium Highlands Observations of fresh and mature surfaces in the massifs surrounding the basin reveal spectral properties consistent with the presence of noritic anorthosite or anorthositic norite (i.e., rocks containing >60% plagioclase, with low-Ca pyroxene as the major mafic mineral) [3]. Pure anorthosite (>90% plagioclase), which has been found at some other basins [10], was not identified at Crisium [3]. However, observations of only a limited number of areas on the inner rings were made.

In an attempt to examine possible changes in lithology with depth, a near-IR spectrum was obtained for the central peak of the crater Taruntius. This 56 km-diameter crater located southwest of Crisium may expose uplifted pre-Crisium material in its central peak. The spectrum has characteristics indicative of anorthositic norite, because the strength of the "1 μm" absorption band is greater than that found in spectra of the circum-Crisium massifs. Hence the crust in this area may become more mafic with depth [3].

Light Plains and Cryptomaria The highlands west and southwest of Crisium contain several exposures of material mapped as "light plains" or "smooth terra" of Imbrian age [11]. These units often contrast with the surrounding highlands in remote sensing data sets such as the color-difference image of Whitaker [12], radar images at various wavelengths [13], and *Apollo* orbital geochemistry measurements [14].

Two such anomalous units are found in the vicinity of Taruntius: one adjacent to the crater in the north and northeast, and another triangle-shaped area in the terra ~140 km north of the crater's center. Spectra of these features were obtained, and band analysis demonstrates that some mare basalt-like material must be present in these highland units. Mixing analysis conducted on spectra for these units indicate that the spectra can be modeled as mixtures of highlands and mare, with a >50% contribution from mare spectral types. It is likely that these units represent pre-existing mare basalt deposits that have been masked highlands debris introduced by impact processes. Other examples of this type of cryptomaria have been recognized in the Schiller-Schickard region [8, 15] and in the Balmer basin [16].

Image mixing analysis generally confirms the findings of the near-IR spectral mixing study, and allows the spatial extent and variation of the mare component to be seen. Both MKO and *Galileo* results reveal the high percentage (>75% in places) of mare material in the plains N and NE of Taruntius. A small crater on the rim of Taruntius, Taruntius C, appears to have excavated mare-rich material from beneath the Taruntius ejecta deposit. The image analysis indicates that the triangular plains unit has an average mare component less than that found by the near-IR spectral mixing model, however portions of the unit do possess mare basalt fractions exceeding 50%.

Pyroclastic Deposits Another anomalous area southwest of Crisium, a strip of dark highlands near the eastern shore of Mare Tranquillitatis, has near-IR spectral properties similar to the areas near Taruntius. Spectral mixing analysis indicates that mare basalt contributed approximately 50% of the measured flux. However, the local rugged topography and mantle-like appearance of dark material make it unlikely that the mare component originated as flowing lava. It is therefore possible that explosive activity emplaced pyroclastic material with spectral properties like those of some mare deposits.

The endmember abundance images demonstrate that the majority of the dark highlands unit contains 25-50% mare basalt, with small portions >50% - in agreement with the result from analysis of the near-IR spectrum. The model error image produced by the analysis shows that in much of the dark highlands the model does not fit the original data as well as in other parts of the image. One possible cause is the occurrence of a spectral type which is not represented as one of the chosen endmembers. If it is indeed the case that pyroclastic material is present at this location, as is suspected from the topographic evidence, then the lack of a pure pyroclastic endmember could explain the poor model fit.

Suspected pyroclastic deposits have been previously identified in a number of locations in the circum-Crisium massifs [17], using Earth-based and *Lunar Orbiter* photography. Criteria for detection include characteristic albedo, texture and morphology. Preliminary examination of a *Galileo* color-ratio composite image indicates that some of these suspected pyroclastics have a distinctive appearance. Additional work may provide further information on the spectral properties and composition of these deposits.

References: [1] W. Hartmann and G. Kuiper (1962) *Comm. LPL* **1**, 51; K. Howard et al. (1974) *Rev. Geophys. Space Phys.* **12**, 309; P. Spudis (1993) *Geology of Multi-Ring Impact Basins*, Cambridge U. P. [2] C. Pieters *et al.* (1979) *Proc. LPSC 10th*, 2967; J. Head *et al.* (1978) in *Mare Crisium*, Pergamon, pp. 43. [3] D. T. Blewett et al. (1994) *LPSC XXV*, 127; D. T. Blewett et al. (1995) *Geophys. Res. Lett.*, submitted. [4] G. Neukum et al. (1991) *LPSC XXII*, 971. [5] M. Belton et al. (1992) *Science* **255**, 570. [6] P. G. Lucey (1993) *LPSC XXIV*, 907. [7] M. Belton et al. (1994) *Science* **264**, 1112. [8] D. T. Blewett et al. (1994) *J. Geophys. Res.*, submitted. [9] P. G. Lucey, this volume. [10] B. R. Hawke et al. (1991) *Geophys. Res. Lett.* **18**, no. 11, 2141; B. R. Hawke et al. (1993) *Geophys. Res. Lett.* **20**, 419. [11] D. E. Wilhelms (1972) U.S.G.S. Map I-722. [12] D. E. Wilhelms (1987) U.S.G.S. Prof. Pap. 1348, Fig. 5.20. [13] S. Zisk et al. (1974) *Moon* **10**, 17; T. Thompson (1974) *Moon* **10**, 51; T. Thompson (1978) *Icarus* **36**, 174. [14] E. Schonfeld (1981) *Proc. LPSC 12th*, 809; M. J. Bielefield et al. (1978) in *Mare Crisium*, Pergamon, 33. [15] J. Head et al. (1993) *J. Geophys. Res.* 98, 17149. [16] B. R. Hawke *et al.* (1985) *Earth, Moon, Planets* **32**, 257; I. Antonenko et al. (1994) *Earth, Moon, Planets*, submitted. [17] B. R. Hawke, unpub. data; C. Coombs and B. R. Hawke, this volume.