REMOTE SENSING STUDIES OF THE DIONYSIUS REGION OF THE MOON.

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Introduction: The Dionysius region is located near the western edge of Mare Tranquillitatis and is centered on Dionysius crater (2.8° N, 17.3° E). This 18 km-diameter crater exhibits a well-developed dark ray system. The nature and origin of these dark rays have been the subject of much controversy. Proposed origins include impact melt deposits and dark primary ejecta from Dionysius [e. g., 1, 2, 3]. It has been proposed that the dark primary ejecta was derived from surface basalt flows [4, 5], cryptomare deposits [3, 6], or a mafic plutonic complex [3]. We have been investigating the origin of lunar crater rays in support of the new Lunar Geologic Mapping Program. Clementine multispectral images and a variety of spacecraft photography were utilized to investigate the composition and origin of geologic units in the Dionysius region. The goals of this study include the following: 1) To determine the composition and origin of the dark rays associated with Dionysius, 2) To investigate the origin of mafic material exposed by Dionysius crater, and 3) To identify possible cryptomare deposits in the region.

Methods: The U. S. Geological Survey's Astrogeology Program has published on CD-ROM a Clementine five-color UV-VIS digital image model (DIM) for the Moon [e. g., 7, 8]. Data from this DIM were mosaicked to produce an image cube in simple cylindrical projection centered on Dionysius crater. This calibrated image cube served as a basis for the production of a number of other data products, including optical maturity (OMAT) images and FeO and TiO_2 maps [9, 10]. In addition, five-point spectra were extracted from the calibrated and registered Clementine UV-VIS image cube.

Results and Discussion:

Dionysius Crater Rays. Well-developed dark rays were mapped in the highlands west of Dionysius crater by Morris and Wilhelms [1]. FeO and TiO_2 maps produced from Clementine UV-VIS images were used to determine the compositions of the darkest portions of these rays. The FeO and TiO_2 values range between 13.2% and 15.6% FeO and from 3.7% to 5.8% TiO_2. In contrast, the bright ejecta immediately west of Dionysius exhibits FeO values of ~9% and TiO_2 values of ~1.9%. The background highlands terrain west of Dionysius exhibits FeO abundances < 10% and TiO_2 abundances < 2%. The FeO and TiO_2 data suggest that the dark rays west of Dionysius are dominated by mare basalts.

Five-point spectra were acquired for the dark rays and bright proximal ejecta north and west of Dionysius as well as impact craters in Mare Tranquillitatis (MT). Three representative spectra extracted for the high-albedo proximal ejecta have absorption bands centered near 0.90 µm, which suggests a mafic assemblage dominated by low-Ca pyroxene. These ejecta deposits appear to be composed largely of anorthositic norite. The spectra obtained for relatively young impact craters in MT exhibit "1 µm" absorption features, and the band shapes indicate mafic assemblages dominated by high-Ca clinopyroxene. Spectra were extracted for six dark ray segments west of Dionysius. These spectra have "1 µm" absorption bands that are centered near 0.95 µm, which indicate the dominance of high-Ca pyroxene. The dark ray spectra are very similar to the spectra collected for mare craters in MT. However, the dark ray spectra exhibit slightly higher reflectance values than those of the mare craters. The portions of the dark rays for which the spectra were obtained are composed of mare debris contaminated with minor amounts of highland material.

Fully mature surfaces in the Dionysius region exhibit OMAT values that range between 0.116 and 0.123. In contrast, the darkest portions of the rays west of Dionysius have OMAT values that range from 0.144 to 0.149. Clearly, the dark rays are not fully mature. Both the five-point spectra and OMAT values indicate that the dark rays are not composed of impact melt.

Although Morris and Wilhelms [1] mapped only light rays east of Dionysius, dark rays are also present [2,3]. The four spectra obtained for these dark rays are even more similar to the spectra collected for the mare craters than are those acquired for the dark rays west of Dionysius. This suggests that even smaller amounts of highland material are present in the dark rays east of the crater. The chemical values exhibited by the east rays also indicate that less highland debris is present. The FeO and TiO_2 values range between 15.8% and 16.5% FeO and 7.0% and 8.0% TiO_2.

The Clementine FeO and TiO_2 maps were utilized to determine the compositions of the brightest segments of the light rays east of Dionysius crater. The FeO and TiO_2 values of these high-albedo ray segments range between 10.3% and 12.8% FeO and 3.4% and 5.5% TiO_2. While these bright rays are dominated by highland debris, they also contain a large, though variable, component of mare material.

Dionysius Crater Interior. Since mafic debris was ejected by the Dionysius impact event, we have attempted to determine the origin of this material. Did Dionysius excavate surface basalt flows, buried mare basalts (cryptomare), or an intrusive igneous complex of basaltic composition? The proximal ejecta of Dionysius should have been derived from great depth within the pre-impact target site. As discussed above, the proximal ejecta is relatively low in FeO and TiO_2 and dominated by anorthositic norite. Hence, it appears unlikely that the basaltic material in the dark rays was excavated from a deep mafic intrusion. The material present in distal ejecta deposits such as the dark rays should have been derived from a much shallower surface or near-surface layer.

Support for a shallow origin is provided by remote sensing data obtained for the interior of Dionysius crater. Dark material with relatively high FeO and TiO_2 values occurs on the eastern and southern portions of the crater wall. An analysis of five-point spectra extracted for this dark material indicates that it is dominated by relatively fresh mare basalt. This dark material was derived from an iron-rich layer very high on the crater wall. This layer probably represents a mare deposit that was present at or near the surface of the pre-impact target site. The spectral characteristics of this mare unit suggest that it may be a westward extension of the basalt flows in MT [e.g., 4,6].

Cryptomare Deposits in the Dionysius Region. Cryptomare deposits are associated with Cayley-type light plains in some portions of the lunar surface [e.g., 11,12]. It has been suggested that cryptomare are associated with Cayley plains in the Dionysius region [13]. We used five-point spectra as well as FeO and TiO_2 maps to search for crytomare deposits in the region. No well-developed dark-haloed impact craters were identified on the Cayley plains. Spectral and chemical data were obtained for Cayley, De Morgan, and Ariadaeus B craters. These moderate-sized craters (8-14 km in diameter) should have penetrated the Cayley plains and excavated any subjacent mare deposits. No evidence for buried mare basalts was found. Similar results were presented by Staid and Pieters [6]. Five-point spectra and FeO and TiO_2 data were also collected for relatively small (diameter < 5 km) craters on Cayley plains in the region. With one exception, no evidence for cryptomare was found. The exception is a small (diameter = 650 m) crater located on light plains northwest of Cayley crater. The spectrum obtained for this crater indicates the presence of major amounts of high-Ca clinopyroxene. The crater exhibits enhanced FeO values (13.4%). While the crater is on the trace of a Dionysius dark ray, the mafic ray material is not responsible for the relatively high FeO values associated with this small crater. The crater, which exhibits an OMAT value of 0.329, is extremely fresh. It would have penetrated the thin Dionysius dark ray deposit and exposed subjacent material. This small crater may have exposed a clinopyroxene-rich facies of the Cayley Formation, or it may have penetrated the light plains deposit and excavated buried mare material.

Conclusions: 1) The dark rays of Dionysius crater are dominated by mare debris and contain minor amounts of highland material. These rays are not fully mature and are not composed of glassy impact melts. 2) The light rays east of Dionysius are dominated by highland debris and contain a large, though variable, component of mare basalt. These rays are bright because of compositional contrasts with adjacent mare-rich rays. 3) The mafic debris ejected by the Dionysius impact event was derived from a dark, iron-rich unit exposed high on the inner wall of the crater. This layer probably represents a mare deposit that was present at or near the surface of the pre-impact target site. 4) With one possible exception, there is no evidence for buried mare basalts associated with Cayley plains in the Dionysius region.

References: [1] Morris E. and Wilhelms D. (1967) U.S.G.S. Map I-510. [2] Schultz P. (1976) *Moon Morphology*, U. Texas Press. [3] Schultz P. and Spudis P. (1979) *PLPSC 10*, 2899. [4] Thomson B. *et al.* (1998) *LPS XXIX*, Abstract #1820. [5] Li L. and Mustard J. (2000) *LPS XXXI*, Abstract #2007. [6] Staid M. and Pieters C. (1998) *LPS XXIX*, Abstract #1853. [7] Robinson M. *et al.* (1999) *LPS XXX*, Abstract #1931. [8] Eliason E. *et al.* (1999) *LPS XXX*, Abstract #1933. [9] Lucey *et al.* (2000) *JGR*, *105* (E8), 20,297. [10] Lucey *et al.* (2000) *JGR*, *105* (E8), 20,377. [11] Hawke B. and Bell J. (1981) *PLPSC 12*, 665. [12] Hawke B. *et al.* (1985) *E.M.P. 32*, 257. [13] Staid M. *et al.* (1996) *JGR*, *101*, 23,213.