THE COMPOSITION AND ORIGIN OF SELECTED LUNAR CRATER RAYS. B. R. Hawke[1], D. T. Blewett[1], P. G. Lucey[1], C. A. Peterson[1], J. F. Bell III[2], B. A. Campbell[3], and M.S. Robinson[4], [1]Planetary Geosciences/HIGP, University of Hawai'i, Honolulu HI 96822, USA, [2]CRSR, Cornell University, Ithaca NY 14853, USA [3]CEPS, National Air & Space Museum, Washington, DC 20560, USA, [4]Department of Geological Sciences, Northwestern University, Evanston IL 60208, USA

Introduction: The nature and origin of lunar crater rays has long been the source of major controversy. Some lunar scientists have proposed that rays are dominated by primary crater ejecta, while others have emphasized the role of secondary craters in producing rays [e.g., 1,2,3]. Pieters *et al.* [2] presented the results of a remote sensing study of a portion of the ray system north of Copernicus. They provided evidence that the present brightness of the Copernicus rays in this sector is due largely to the presence of a component of highland ejecta intimately mixed with local mare basalt and that an increasing component of local material is observed in the rays at progressively greater radial distances from the parent crater. These results have been questioned, and the origin of lunar rays is still uncertain [e.g., 4]. In an effort to better understand the processes responsible for the formation of lunar rays, we have utilized a variety of remote sensing data to study selected rays associated with Olbers A, Lichtenberg, the Messier crater complex, and Tycho [6,9]. The data include near-IR reflectance spectra (0.6-2.5 µm) and 3.8- and 70-cm radar maps. In addition, Clementine UV-VIS images were utilized to produce high-resolution FeO, TiO_2, and maturity maps for the various rays using the methods presented by Lucey and co-workers [10,11].

Results and Discussion:

Messier Crater Complex. Messier (14 km in long dimension) and Messier A (diameter = 11 km) are located near 2° S, 47° E in Mare Fecunditatis. Major rays from these craters occur to the south and west of the parent craters. Spectra were obtained for portions of the rays west and south of the crater complex, as well as for Messier A and nearby mature mare regions.

The spectrum of Messier A exhibits an extremely deep (29%) ferrous iron absorption band centered at 0.98µm, and a fresh mare composition is indicated. Both the near-IR spectrum and the FeO image clearly demonstrate that Messier A did not penetrate the Fecunditatis mare fill. In addition, Messier A crater exhibits strong returns on both the 3.8- and 70-cm depolarized radar images [6,7,8]. The spectrum collected for the ray west of Messier A has a 15% absorption feature centered at 0.99 µm. The ray has slightly enhanced values in the depolarized 3.8-cm radar image, but no enhancement is apparent in the70-cm data set. The mature mare unit adjacent to this ray has a spectrum with a shallower band depth (12%) and a similar band center. The FeO image indicates that the west ray exhibits FeO values similar to adjacent mare deposits. The brightness of the ray west of Messier A is due to the presence of large amounts of fresh mare basalt. Near-IR spectra as well as the FeO and maturity maps indicate that the ray south of the Messier complex is also dominated by fresh mare material.

Tycho Ray in Mare Nectaris. A major ray from Tycho crater crosses much of Mare Nectaris. The 80-km long ray segment northeast of Rosse crater (17.9° N, 35° E) has a somewhat conical shape, ranging in width from 8 km near Rosse to 16 km northwest of Bohnenberger crater. Spectra were obtained for Rosse crater (diameter = 12 km), mature mare units, and two small areas on the Tycho ray northeast of Rosse. Both of the spots on the ray are located near a Tycho secondary crater cluster which is ~1400 km from the center of the parent crater. The spectrum collected for a mature mare area east of Rosse exhibits an 8.5% absorption feature centered at 0.98 µm. Both ray spectra have 11.6% bands centered at ~0.99 µm. It appears that the ray in the areas for which spectra were collected are dominated by fresh mare debris. These results are in agreement with those presented by Campbell *et al.* [6]. These workers noted that the Tycho secondary craters in the cluster are easily seen in high-resolution 3.0-cm radar images, and a radar-bright area extends 10-15 km downrange of Tycho from the approximate center of the cluster. In addition, they noted that the radar-bright region exhibited a deeper “1-µm” feature in multispectral ratio images and suggested that fragmental material was emplaced well downrange of the visible secondaries, perhaps by a secondary debris surge. The FeO and maturity images support this interpretation.

In summary, analyses of near-IR reflectance spectra, multispectral imagery, and a variety of radar data suggest that Tycho ray in Mare Nectaris is dominated by fresh local material excavated and emplaced by secondary craters. While some highlands material from Tycho is undoubtedly present in the ray, the major factor that produces the brightness of the ray is the immature mare basalt.

Olbers A Ray. This Copernican-aged impact crater (diameter = 43 km) is located in the highlands on the Moon's western limb (8.1° N, 77.6° W) and exhibits an extensive ray system. Eight near-IR reflectance spectra were obtained for a prominent ray that extends northeast of Olbers A across Oceanus Procellarum. Three of these spectra are for small (3-6 km in diameter) areas near the intersection of two major ray elements approximately 385 km northeast of Olbers A. Three spectra were collected for a portion of the ray immediately northeast of Seleucus crater. This ray segment is approximately 550 km from the rim of the parent crater. Two spectra were obtained for diffuse ray elements in the same general area. Spectra were also obtained for Olbers A crater as well as both mature mare and fresh craters near the ray.

All spectra were analyzed and spectral mixing model studies were conducted using the techniques described by Blewett *et al.* [5]. Three component mixing studies were performed using mature mare, fresh mare, and either fresh or mature highland material as endmembers. The spectra obtained for areas near the ray intersection are dominated by mare material. However, highland debris is quite abundant (contributing 30-50% of the flux to the spectra). Perhaps these high values are due to the fact that two rays cross in the area for which the spectra were collected. Surprisingly, even larger amounts (35-55%) of highland material were found to be present in portions of the ray northeast of Seleucus. Lesser amounts (26-38%) of highland debris were determined to be present in the more diffuse segments of the ray. Maturity and FeO maps produced from Clementine UV-VIS images suggest that the ray is less mature than the adjacent terrain and that it contains a significant amount of highlands debris.

Lichtenberg Crater Rays. Lichtenberg crater (diameter = 20 km) is located in Oceanus Procellarum on the western portion of the lunar nearside (31.8° N, 67.7° W). This Copoernican-aged impact structure displays a relatively high-albedo ejecta blanket and ray system to the north and northwest. However, Lichtenbertg ejecta is embayed by mare basalt south and southeast of the crater. The FeO map produced for the Lichtenberg region indicates that the ejecta and rays north and northwest of the crater exhibit relatively low FeO abundances. These deposits appear to be dominated by low-FeO highlands debris. The maturity image demonstrates that these highlands-rich ejecta deposits and rays are fully mature. Hence, the Lichtenberg rays exhibit a relatively high albedo because of their composition. These mature highlands-rich rays appear bright in comparison to the adjacent mature mare surfaces. These "compositional" rays stand in stark contrast to the immaturity rays associated with the Messier crater complex.

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