REMOTE SENSING STUDIES OF THE SCHILLER-SCHICKARD REGION OF THE MOON: FINAL RESULTS.

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Introduction: The Schiller-Schickard region is located in the southwestern nearside highlands, south-southeast of the Humorum basin and southeast of Orientale basin. A number of interesting features which have long provoked controversy are found in the region. Schickard (~44°S, 55°W) is a large (227 km diameter) pre-Nectarian crater whose floor contains mare basalt ponds and a light plains unit. Schiller crater (~52°S, 39°W) is elongated and is superimposed on the outer ring of the Schiller-Zucchius basin. Wargentin crater exhibits a floor that is topographically higher than the surrounding terrain. The association of dark-haloed impact craters (DHCs) with light plains deposits has been cited as evidence of ancient (pre-Orientale) mare volcanism in the region [1,2,3,4,5,6,7,8].

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., 9]. Data from this DIM were mosaicked to produce an image cube centered on the Schiller-Schickard area. This calibrated image cube served as the basis for the production of a number of other data products, including optical maturity (OMAT) images and FeO and TiO_2 maps [10,11]. Five-point spectra were extracted from the calibrated and registered Clementine UV-VIS image cube. In addition, Earth-based near-IR reflectance spectra obtained for DHCs were utilized in this investigation. [3,4,7].

Three Lunar Prospector (LP) gamma ray spectrometer (GRS) and neutron spectrometer (NS) elemental abundance data sets were used. The half-degree iron abundance data product contains data from the LP-GRS acquired during the low-altitude portion of the mission. A description of the reduction of this data set is given by Lawrence *et al.* [12,13]. The half-degree titanium abundance values were derived from LP-NS measurements acquired during the low-altitude portion of the mission. The reduction of the data is described by Elphic *et al.* [14]. The half-degree thorium data were described by Lawrence *et al.* [15].

Finally, the depolarized 70-cm radar images recently obtained by Campbell *et al.* [20] were used to investigate the surface textures, block populations, and compositions of units in the SS region.

Results and Discussion:

Dark-Haloed Impact Craters. Several workers have identified a limited number of DHCs in the SS region and suggested that the region was the site of ancient mare volcanism [e.g., 1,4,6,7,8,16]. We have used Clementine 750 nm images to identify numerous DHCs in the region, and 28 well-developed DHCs were selected for detailed analysis. Five-point spectra were extracted from the Clementine UV-VIS image cube for DHCs in the SS region. These spectra have moderately strong "1µm" bands centered near 0.95 µm. The portions of the dark haloes for which these spectra were obtained are dominated by mare basalts. FeO and TiO_2 maps produced from UV-VIS images were used to determine the compositions of DHCs in the SS region. The FeO and TiO_2 values range between 11.4 wt% and 15.3 wt% FeO and from 0.4 wt% to 3.0 wt% TiO_2. Clearly, a major expanse of cryptomare exists in the Schiller-Schickard region.

Cryptomare in the Schiller-Schickard Region. Several workers have devised criteria for the identification of cryptomare [e.g., 1,6,17,18]. A classification of evidence for cryptomare identification was presented by Antonenko *et al.* [6]. The major criteria are 1) the presence of dark-haloed impact craters, 2) association with mafic geochemical anomalies, and 3) the presence of a significant component of mare basalt in the high-albedo surface unit as determined by spectral mixing analysis [5,7]. We have used the location of DHCs as well as FeO and TiO_2 maps produced from Clementine images to determine the distribution of cryptomare in the SS region.

Cryptomare occurs in most portions of the Schiller-Schickard region. The mapped cryptomare deposits extend from north of Lacus Excellentiae to Zucchius crater and from just east of Schiller to Inghirami crater in the west. Much of the interior of the Schiller-Zucchius basin contains cryptomare deposits. The largest expanses of cryptomare are correlated with Imbrian-aged light plains deposits and other highlands units thought to have been emplaced as a result of the Orientale impact event.

It is important to determine the ages of the buried mare basalts in the SS region. Since most of the cryptomare are associated with deposits emplaced by the Orientale basin, these buried basalts are Imbrian or older in age. At least one DHC appears to have excavated mare material from beneath the rim deposits of a pre-Nectarian crater, so at least some of the mare basalts could have been emplaced during pre-Nectarian time. Some of the cryptomaria in the SS region are related to the mare basalts that were emplaced after the Orientale event. These post-Orientale basalts have been obscured by highlands-rich ejecta from Zucchius and other craters.

Because the most ancient mare basalts were formed by magmas generated by the earliest melting of the lunar mantle, chemical data for cryptomaria provide information concerning the composition of the early partial melts. Hence, we used the composition of DHCs in the SS region to investigate the compositions of the buried basalts. After correction for highlands contamination, it was found that the pre-Orientale cryptomare deposits have TiO_2 abundances that range from 0.4 wt% to 2.6 wt%. Both VLT and low-TiO_2 mare basalts were emplaced in the SS region prior to the Orientale impact. The VLT basalts are concentrated in the southwestern portion of the study area. Post-Orientale cryptomare deposits have TiO_2 values that range from 1.5 wt% to 4.8 wt%. Since all of the DHCs exhibit FeO values <15.3 wt%, at least some high-alumina mare basalts may occur in the region.

A major mafic geochemical anomaly is associated with the Schiller-Schickard region. The LP-GRS FeO values for the SS cryptomare surfaces range between 7 wt% and 11 wt%. These values are in general agreement with those measured from Clementine FeO images (7-13 wt%). In contrast to the LP-GRS FeO data, no major enhancements were identified in the LP-NS TiO_2 and LP-GRS Th data sets. TiO_2 abundances in the SS region are generally <1.5 wt%. Slightly higher TiO_2 values are exhibited by Lacus Excellentiae. The low TiO_2 concentrations associated with the cryptomare surfaces are consistent with low TiO_2 abundances determined for the buried mare basalts. Th values for the SS region are <2 ppm.

Spectral mixing analyses have suggested that major amounts of mare material were incorporated into the light plains units by local mixing during the emplacement of Orientale basin ejecta in the Schiller-Schickard region [5,7]. The LP-GRS FeO values (7-11 wt%) exhibited by the cryptomare surfaces in the SS region are consistent with a highlands-mare mixture.

The depolarized 70-cm radar images recently obtained by Campbell and co-workers [20] were used to investigate the block populations and compositions of units in the Schiller-Schickard region. The SS region contains several areas that exhibit low returns on the depolarized 70-cm radar images. Post-Orientale mare ponds, such as those in the floor of Schickard, correlate with some of the areas with low backscatter. The post-Orientale cryptomare deposit southwest of Schiller is characterized by low 70-cm radar echoes. In addition, low 70-cm backscatter values are associated with pre-Orientale mare deposits that contain Orientale secondary crater chains and clusters.

Processes Responsible for the Formation of Cryptomare Deposits. Cryptomaria that were formed by the burial of mare units by the thick, continuous ejecta of a single impact crater are termed Copernicus-type cryptomare because the relationship was first conclusively demonstrated at Copernicus crater. In the SS region, a Copernicus-type cryptomare deposit is associated with the ejecta blanket of Hainzel A crater.

Far away from the continuous ejecta deposits of major impact craters, mare basalt flows can still be obscured by the compound effects of discontinuous, distal ejecta deposits of several nearby impact structures. Such a situation was identified by Hawke and Spudis [17] and Hawke *et al.* [18] near Balmer crater on the east limb of the Moon. A Balmer-type cryptomare deposit has been identified immediately southwest of Schiller crater in the SS region. Here, a post-Orientale mare deposit has been contaminated by highland-rich distal ejecta from Zucchius and other nearby craters.

When a cryptomare is located near a large impact basin, the ancient mare unit will be covered by a primary ejecta deposit that is thick and continuous. In proximal basin ejecta-type cryptomare, local mixing by secondary impacts will not be an important process, and the spectral signature of the buried mare unit will be swamped by primary basin ejecta. At greater distances from major impact basins, ejecta deposits will be thinner, and a larger percentage of local material will be incorporated into the resulting basin deposits by secondary cratering processes [19]. The combined effects of thin ejecta deposits and high percentages of incorporated local material allow the chemical and spectral signatures of cryptomare to be preserved [6,18]. Most of the cryptomare deposits in the Schiller-Schickard region are of the distal basin ejecta type.

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