REMOTE SENSING STUDIES OF HIGHLAND UNITS ON THE LUNAR FARSIDE. C. A. Peterson[1], B. R. Hawke[1], P.G. Lucey[1], G. J. Taylor[1], D.T. Blewett[1], P.D. Spudis[2], [1]Hawaii Institute of Geophysics and Planetology, University of Hawaii, Honolulu, HI 96822 [2]Lunar and Planetary Institute, Houston, TX 77058.

Introduction: In order to understand the geologic history of the Moon [e.g., 1,2], it is essential to gain detailed knowledge of the composition and stratigraphy of the lunar highlands crust. There is much evidence to support the hypothesis that a giant impact on the early Earth created the Moon and that a magma ocean was present on the young Moon. As the magma cooled and crystallized, plagioclase flotation could have produced the upper part of the Moon's original crust. However, it is far from clear how much of this original crust may have survived to the present. Remote sensing studies of the lunar highlands, combined with analysis of lunar materials returned from known locations on the surface of the Moon, have allowed the determination of the lithologies present in many locations on the Moon. Our study of the distribution of the various lunar highland rock types has revealed large-scale patterns that suggest the broad outlines of the evolution of portions of the lunar crust.

Our previous efforts have used Earth-based spectra and Galileo SSI data to study the lunar nearside. Now we can use Clementine and Lunar Prospector data to investigate the composition of highlands units on the farside. The purposes of this study are: 1) to study the composition of farside highlands units; 2) to identify and determine the distribution of anorthosite on the lunar farside; and 3) to investigate the stratigraphy of the farside crust.

Method: The great majority of the Moon's highlands surface is composed of only a few minerals, and these are easily distinguishable using reflection spectroscopy at wavelengths from the UV through visible light and into the near infrared [e.g., 3]. The mafic minerals pyroxene and olivine contain iron which causes the minerals to absorb light with a wavelength near 1 µm. In contrast, plagioclase feldspar does not absorb light near 1 µm, although plagioclase can show absorption of light near 1.25 µm if it has not been highly shocked by impacts.

Through the use of Earth-based telescopic reflectance spectra, it is possible to determine the lithologies present in the area observed, typically from 2 to 6 kilometers in diameter. The Galileo and Clementine spacecraft returned multispectral images of the Moon that, while of lower spectral resolution than Earth-based spot spectra, covered large areas of the Moon and used filters at wavelengths useful for determining the lithologies present. These spacecraft data have also been used to determine the abundance of FeO and TiO_2 present in lunar surface materials. Other products, such as band ratio maps, have been produced, and spectra have been extracted from these image cubes as well.

The Lunar Prospector spacecraft is currently orbiting the Moon, and data from that mission are becoming available. In particular, the gamma ray spectrometer counting data for Th, K, and Fe [4] can be used to confirm and extend our knowledge of the composition of the lunar farside crust. A preliminary Th distribution map has been produced from the raw data by utilizing ground truth from the lunar landing sites [5].

Results and Discussion: The surface of the nearside lunar highlands is dominated by noritic anorthosite and anorthositic norite with lesser amounts of anorthosite, norite, troctolite, and gabbroic rocks [2]. Studies of Earth-based reflectance spectra initially revealed the presence of anorthosite in isolated outcrops extending in a narrow band from the Inner Rook mountains in the west to the crater Petavius in the east [e.g., 6]. More recently, additional outcrops of anorthosite have been identified in the central peaks of some craters, such as Aristarchus, and in the northern and northeastern nearside [7,8]. In most cases, these anorthosite deposits have been exposed by impacts that removed a more mafic overburden and raised them to the surface from deeper in the crust, for example in the peak rings of the Orientale, Humorum, and Grimaldi basins [9,10,11]. Much of the nearside lunar highlands likely shares this stratigraphic sequence: a layer of pure anorthosite overlies a more mafic lower crust and is in turn overlain by a somewhat more mafic layer. Much anorthosite likely remains hidden by this surface layer on the nearside today.

On the lunar farside, the giant South Pole-Aitken (SPA) basin shows a mafic anomaly that is the dominant compositional feature on the farside. At 2500 km in diameter, SPA (centered at 55° S, 180° E) is the largest unambiguously identified impact basin in the solar system. It is also the oldest identified lunar basin except, possibly, for Procellarum. There is a 12 km difference in elevation from the interior of the basin to the surrounding highlands [12]. The interior exhibits FeO values of 7-14 wt.%, and portions of the interior exhibit enhanced TiO_2 values [13]. Portions of the interior also display elevated Th and K abundances.

The high FeO values found inside SPA drop off with increasing distance to the north of the basin. The region between 100° E and 100° W and between 40° N and 70° N exhibits very low values of FeO and TiO_2. The new Lunar Prospector data show very low Th and K abundances there as well. FeO maps produced from high spatial resolution Clementine data reveal extremely low FeO values near the crater Fowler (43° N, 145° W) in the vicinity of the Coulomb-Sarton basin. We interpret these data as indicating a region in which pure anorthosite is dominant. Many areas in this region appear to contain nothing but anorthosite.

Between SPA and the far north, the data generally indicate intermediate FeO values and low Th values. However, some lower FeO values can be found in this intermediate region. In particular, very low FeO values are exhibited in the inner rings of the Hertzsprung and Korolev basins. This case parallels the situation at nearside basins where anorthosite was exposed from beneath more mafic material.

Summary: The striking difference between the distribution of lithologic types on the lunar nearside and that on the farside appears to be largely attributable to the enormous SPA impact event. Huge quantities of ejecta would have been deposited outside the basin, thickest near the basin rim and tapering off with increasing distance from the basin. This ejecta, especially that deposited nearest the basin rim, must have contained much material from the lower crust and possibly even some mantle material. If the original plagioclase flotation crust was largely intact at the time of the SPA impact event, the great thickness of more mafic ejecta deposited near the basin could have insulated that original upper crustal material (anorthosite) from all but the largest subsequent cratering events. Large impacts, such as those that produced the Orientale, Hertzsprung, and Korolev basins could have penetrated through the SPA ejecta deeply enough to expose anorthosite in their peak rings. Farther to the north, where the thickness of ejecta from SPA was much less, small basins such as Birkhoff and Coulomb-Sarton could have removed most of the overburden of SPA ejecta to reveal the underlying anorthosite crust.

If this scenario is accurate it has great implications for the geologic history of the Moon. It is conceivable that large numbers of very large impacts preceded the SPA event and are not seen today simply because evidence of them has been erased by subsequent impacts. However, that possibility is argued against if most of the original plagioclase flotation crust was still present on the lunar farside at the time of the SPA impact event. This has important bearing on the question of the flux of large impactors during the early history of the inner solar system.

The Lunar Prospector mission is continuing to collect data. As more data are collected and calibrated, the composition of the lunar highlands and the fate of the original flotation crust should become easier to understand.

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