REMOTE SENSING STUDIES OF LUNAR ANORTHOSITE DEPOSITS;

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INTRODUCTION

In recent years, we have been conducting a variety of remote sensing studies of lunar basin and crater deposits in order to determine the composition of surface units and to investigate the stratigraphy of the lunar crust.[1,2,3,4] Special attention has been given to determining the distribution and modes of occurrence of pure anorthosite (plagioclase >90%) in order to answer the critical question of whether or not the lunar crust is enriched in plagioclase. If the Moon once had a magma ocean, an anorthositic crust should have been produced by plagioclase flotation. In previous studies, we combined telescopic visible and near-infrared spectral observations with Earth-based multispectral imagery in order to determine the lithology of relatively small areas (2-10 km) of the lunar surface. Now, high resolution multispectral images are available from the Galileo and Clementine missions. Numerous deposits of pure anorthosite have been identified, and interesting patterns have emerged. The purposes of this study were 1) to investigate the utility of a variety of image analysis techniques for the rapid identification of anorthosite deposits, 2) to summarize our current understanding of the distribution and modes of occurrence of lunar anorthosites, and 3) to assess the implications for composition, stratigraphy, and origin of the lunar crust as well as for the magma ocean hypothesis.

ANORTHOSITE DEPOSITS ON THE LUNAR NEARSIDE

Orientale Basin Region: Our previous spectral studies[1,2] demonstrated that two of the Inner Rook massifs are composed of pure anorthosite. Multispectral imaging data confirm this view; the entire eastern Inner Rook Mts. contain only very small amounts of pyroxene.[2] With the exception of the Inner Rook massifs, all of the highlands units associated with the Orientale basin are dominated by either noritic anorthosite or anorthositic norite.[1,2] We are currently utilizing Galileo and Clementine multispectral image cubes to investigate the spectral characteristics of previously identified anorthosites on the Inner Rook ring and to search for additional anorthosite deposits within the Orientale basin.

Grimaldi Basin Region: Spectra obtained for the inner ring of Grimaldi indicate that this feature is composed, at least in part, of pure anorthosite. Another anorthosite deposit has been identified between the inner and outer rings.[2,5] This material was excavated from beneath the basin floor material by subsequent impacts. Other highlands units in the Grimaldi region are composed of noritic anorthosite or anorthositic norite.[2,5]

Humorum Basin Region: Our previous near-IR spectral studies have demonstrated that at least a portion of the mare-bounding ring of Humorum is composed of anorthosite.[2,6] However, the entire ring is not composed of anorthosite, and no anorthosites have yet been identified on the outer Humorum rings.[6] We have recently conducted a study of the highlands NW of Humorum using a twelve-color multispectral data set obtained at the Mauna Kea Observatory. No new anorthosite deposits were located in this area. We are currently utilizing Galileo and Clementine images to further investigate the distribution of anorthosite in the Humorum region.

the central peaks of Theophilus and Piccolomini craters. Anorthosites have now been located on, or very near, the four innermost rings of Nectaris.

Northern Highlands: Recent studies utilizing both Earth-based spectra and Galileo SSI data suggest that pure anorthosite is exposed within Goldschmidt and west of Thales.[8] Both areas are plains units that have been affected by nearby large Copernican craters (Thales and Anaxagoras).

Other Occurrences: Anorthosites have been identified in the central peaks of Alphonsus and Petavius craters.[7,9] Both of these craters are very near major rings of ancient impact basins.[10,11] Very recently, Clementine near-IR images were used to show that anorthosite was present in the central peak of Aristarchus crater.[12]

DISCUSSION

The distribution of anorthosite on the lunar nearside exhibits a very interesting pattern. With the exception of the Aristarchus central peak, pure anorthosites have only been identified in a relatively narrow belt in the southern highlands, extending from Petavius in the east to the Inner Rook Mts. on the western limb, and at two locations in the far north. Extensive spectral studies of many nearside regions (e.g., Imbrium, north-central highlands) have failed to reveal additional deposits of pure anorthosite.[1,2,3,4,7] However, few spectra are available for some nearside regions (e.g., southern and southeastern portions of the central highlands, east limb) and future studies of the Galileo and Clementine data sets may reveal additional anorthosites. A preliminary analysis of the Clementine multispectral data by Lucey and Taylor[13] suggests that anorthositic rocks may be more common on the lunar surface than has previously been thought.

The results of our studies indicate that nearside anorthosite deposits very commonly are found on or very near basin rings.[1-5] This association is significant only for the inner rings of basins such as Humorum, Grimaldi, and Orientale. Major portions of these rings are composed of pure anorthosite, and they were derived from beneath more mafic-rich layers in the pre-impact target sites. In contrast, the anorthosites associated with the outer rings of Nectaris and other basins are found in the central peaks and walls of large impact craters. It appears that these anorthosites were derived from layers many kilometers beneath the crater target sites and that the surfaces of these outer rings are not composed of anorthosite.

The results of our spectral studies have important implications for the stratigraphy of those portions of the nearside crust that exhibit anorthosite deposits. In every instance, the anorthosites on the nearside were exposed from beneath a shallower near-surface layer of more pyroxene-rich material. This is usually noritic anorthosite or, less commonly, anorthositic norite. It should be pointed out that while this unit is more mafic than the pure anorthosite layer, it still contains abundant feldspar. On the nearside, the thickness of this more pyroxene-rich layer ranges from a few kilometers to tens of kilometers. Recent results from the Clementine mission suggest that pure anorthosite may be quite abundant on certain farside surfaces.[13] Future work will focus on understanding the processes responsible for the formation of these stratigraphic sequences.

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