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Composition of the Lower Crust Identified at Basin Rings

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Summary Abstract

In contrast to the extensively mixed lunar mega-regolith [e.g., 6], materials exposed along the inner ring of several impact basins exhibit compositionally distinct mineral lithologies. We interpret these rock-types to be deep-seated materials brought to the surface and exposed by the basin forming event. An initial survey of such materials using data from the Moon Mineralogy Mapper (M^3) reveals compositions expected from the lunar samples (anorthosite, norites, troctolites), as well as new and unusual lithologies (pink spinel anorthosite, pyroxenite, and perhaps dunite). A simple magma ocean model is consistent with remote observations and samples from the upper crust, but is inadequate to describe our observations of the lower crust. We are beginning to glimpse the actual complexity of lunar lower crust evolution.

1. The Orientale Basin Example

The diversity of compositions in and around the Orientale Basin was noted with the first return of high-spectral and high-spatial resolution data from M^3 [7]. Overall, the region is highly feldspathic, but massive crystalline anorthosite was detected for the first time along the Inner Rook Mountains (IRM) based on a diagnostic 1300 nm absorption feature due to small amounts of Fe^{+2} in the plagioclase structure. This lithology is found in direct association with the featureless form of shocked plagioclase detected earlier and well known to lunar astronomers [2]. With the high spatial resolution available to modern sensors such as M^3 and those on Kaguya, the crystalline form of anorthosite was found to be widespread [5]. Example spectra are seen in Figure 1.

A remarkable observation at Orientale, however, is that the *entire* IRM is shown to be composed of crystalline and shocked anorthosite. This extensive unit was uplifted and exposed from depth by the impact event [e.g., 3, 4]. The scale of Orientale and its location on the western limb leave little doubt that the IRM anorthosite represents massive exposures of magma ocean products of the primary upper crust.

2. Moscoviense and Nectaris Basins

The Moscoviense and Nectaris Basins both also occur in regions of highly feldspathic crustal material. The inner ring of Moscoviense on the farside contains widely dispersed km-scale regions of three distinct lithologies embedded in the feldspathic matrix [8]. The mafic mineral content is exceptionally high in all, and two could approach pyroxenite and harzburgite in composition. The third is a new rock-type identified on the Moon that is dominated by Mg-rich spinel with no other mafic minerals detectable (<5 % pyroxene, olivine). All these exposures along the inner ring are old and appear undisturbed since basin formation. They are effectively undetectable in panchromatic image data and are only recognized by their distinctive composition identified spectroscopically. A possible schematic cross section of the pre-basin region is shown in Figure 2.

A second exposure of the new Mg-spinel rock type was discovered in association with the Nectaris Basin on the nearside [1]. In this case Nectaris ring material was excavated and exposed in the central peaks of the large crater Theophilius (D=100 km). A spectrum of the Mg-spinel-rich lithology is included in Figure 1. Coordination with high spatial resolution imagery demonstrates that the Mg-spinel lithology is in direct contact with outcrops of shocked plagioclase.

3. Other Basins

Analyses are under way for the South Pole-Aitken Basin (SPA) and superimposed basins Schrödinger and Apollo. Due to their location and size, each has a story to tell. Although SPA contains excellent exposures of highly noritic materials, it is also one of the few non-mare areas that contain regions with high-Ca pyroxene as the dominant mafic mineral. Example spectra that identify these components are shown in Figure 1. The Schrödinger Basin provides an important window into these deep-seated lithologies. Preliminary analyses show prominent exposures of plagioclase as well as olivine [e.g. 9].

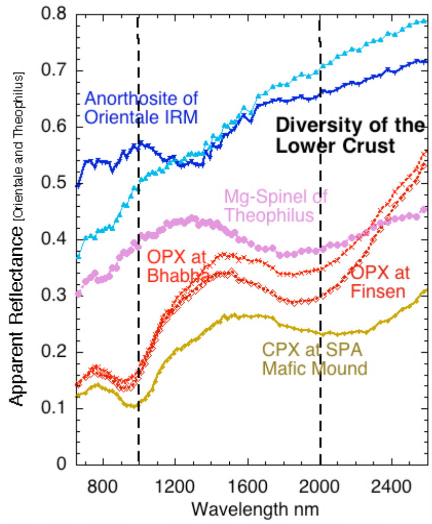

Figure 1. Apparent Reflectance of basin materials. Deep-seated lithologies exposed include both crystalline and shocked Anorthosite across Orientale IRM, Mg-spinel at Theophilus (Nectaris), Low-Ca pyroxene at the central peaks of SPA craters Bhabha and Finsen, and Fe-and Ca-rich pyroxene at SPA Mafic Mound. The reflectance scale for Orientale and Theophilus spectra is twice that of the SPA spectra. Vertical lines are provided at 1000 and 2000 nm for ease of comparison.

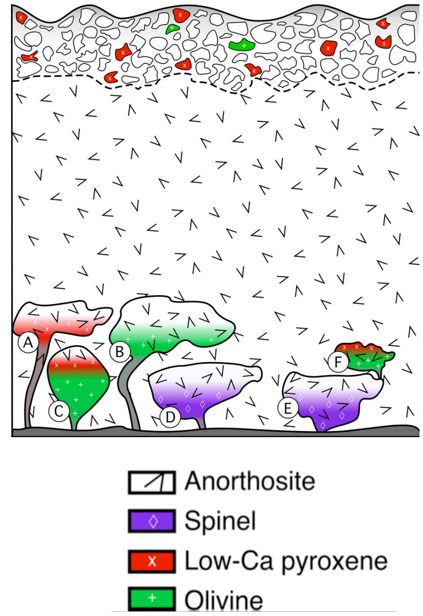

Figure 2. Possible schematic cross section for the crust exposed at Moscoviense Basin (after [8]). The mixed megaregolith [6] is at the top. In this example the diverse lithologies of the lower crust are portrayed as plutonic intrusions that may have interacted with an anorthositic upper crust.

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