DEEP CRUST/MANTLE MINERALOGY EXPOSED IN THE UPLIFTED PEAK RING AND BASIN WALLS OF SCHRÖDINGER.

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Introduction: Schrödinger basin is 315 km in diameter, has an average depth of ~4-5 km, and is located at 75°S, 132.5°E, which places it on the western rim of the oldest and largest lunar basin, South Pole-Aitken (SPA). More precisely, Schrödinger is nestled between SPA's two prominent rings [1, 2], in what is probably equivalent to the modification zone. Schrödinger is one of the youngest lunar basins, only marginally older than Orientale [3, 4]. These unique conditions mean Schrödinger basin provides a window into the stratigraphy of the lunar crust in the vicinity of SPA near the end of the basin-forming epoch. We have probed Schrödinger with the Lunar Reconnaissance Orbiter, Moon Mineralogy Mapper (M^3), and crater-scaling relationships. Here we focus on the material exposed in Schrödinger's peak ring, which represents material derived from the greatest stratigraphic depth, and the basin wall, which reveals the composition of the target crust.

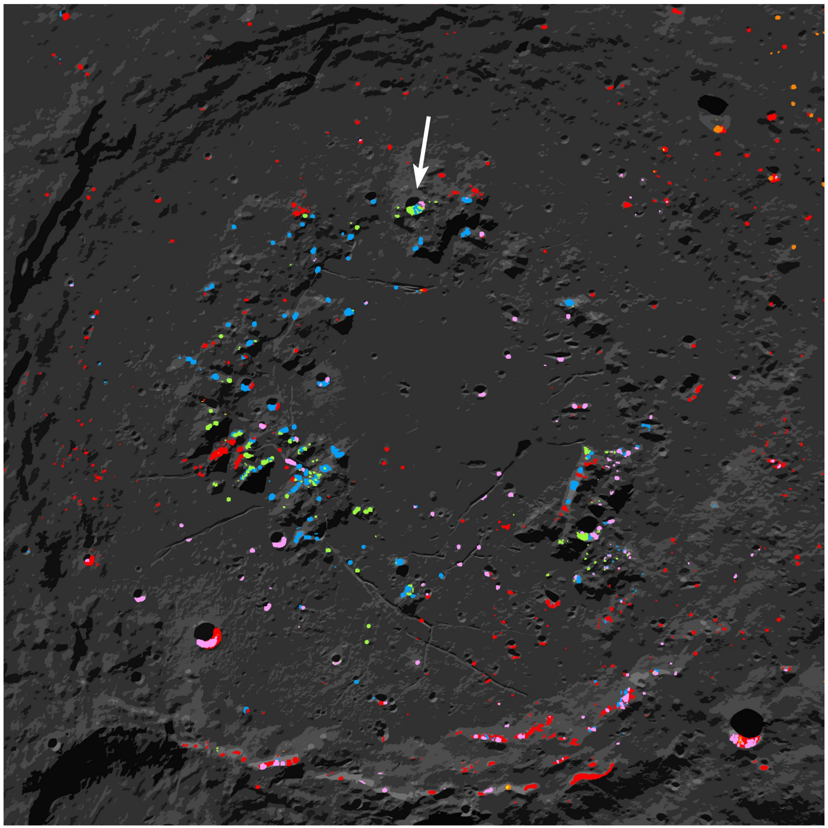

Figure 1: Locations of different lithologies identified from M^3 spectra in Schrodinger Basin. Green = olivine (dunite and/or troctolite), blue = anorthosite (>97% anorthite), magenta = pyroxene-bearing anorthosite (3-10% pyroxene + 90-97% plagioclase), red = norite (>10% orthopyroxene + <90% plagioclase), orange =gabbro (>10% clinopyroxene + <90% plagioclase). Arrow points to crater featured in Fig. 2.

Data & Methodology: We used M^3 level 2 reflectance data for this analysis. Schrödinger is located at high latitudes, which means there are low signal levels as a result of the low sun angle. The low illumination conditions dictate that the best locations from which data can be extracted and still exhibit identifiable spectral features are in the sun-facing sides of steep slopes, such as crater walls and mountain scarps. Sampling from these surfaces also provides a means to observe optically immature material representative of the pristine lithology beneath the mature surface regolith.

Results: M^3 spectral data distinguish five distinct lithologies made up of coarsely crystalline material in the peak ring and basin wall (see caption Fig. 1). These mineral associations are consistent with those recently identified and mapped in the peak ring by Yamamoto et al. [5] using Spectral Profiler (SP) and Multiband Imager (MI) data from Kaguya.

The spatial resolution of the M^3 data used to make the Schrödinger mosaic is 280 m/pixel. To be identifiable in the spectrum, the mineral must spatially dominate the area observed in the pixel. Therefore, the outcrops mapped in Figure 1 represents massive exposures (>280 m^2) of diverse lithologies.

Schrödinger's peak ring is a 125 km diameter mountain range composed of massive blocks of structurally competent material that rises 1 to 2.5 km above the basin floor. Deep faults have cut into the peak ring, creating steep cliffs and chasms between vertically offset massifs. Schrödinger's peak ring is the most mineralogically intriguing and complex of the region. Massive monomineralic outcrops occur in isolated peaks and are juxtaposed next to other massive monomineralic exposures (Fig. 1). Such massive accumulations of dense, coarsely crystalline material suggests a deep, high-pressure origin, such as the lower crust or upper mantle.

Interpretations: Yamamoto et al. [5] surmised that SPA impact melt flooded the area where Schrödinger formed and differentiated to produce an olivine-rich unit below a pyroxene-rich unit, both of which were emplaced on top of the original Lunar Magma Ocean (LMO) plagioclase-rich crust. In this scenario, the olivine in Schrödinger's peak ring is derived from a relatively shallow impact melt unit deposited by SPA.

In contrast, peak rings are usually interpreted as being collapsed central peaks that were uplifted from great depths. In a structure the size of Schrödinger, a peak ring should be derived from depths up to 50 km (based on equations from [6]), which is far deeper than the ~5 km-thick sequence of SPA ejecta expected at the Schrödinger target site (based on equations from [7]). Thus, we interpret the coarsely crystalline lithologies exposed in Schrödinger's peak ring to be evidence of a deep, stratified lower crust and possibly upper mantle origin. The peak ring material likely represents cumulates of the LMO and subsequent intrusions into the crust.

Some regions of the peak ring (e.g., in the south and southwest) could be interpreted as layered intrusive bodies rather than mantle cumulates. However, higher resolution studies, if not field work, will be needed to test that possibility or whether the juxtaposition of those lithologies is a consequence of the movement of blocks from depth. The crystalline lithologies in the peak ring were derived from regions of the LMO that survived the excavation of SPA. The origin of the peak ring material was also not affected by the adjacent basin, Sikorsky-Rittenhouse, but may have been marginally affected by the Amundsen-Ganswindt Basin.

An intriguing example of this mineral complexity is found in an 8 km-wide impact crater that was produced in the middle of the northern rise of the peak ring (Fig. 2). On the sunlit side of this crater, four distinct lithologies can be seen: olivine-rich (dunite or troctolie), anorthosite, >90% plagioclase + pyroxene, and orthopyroxene. Of the five different types of mineralogies exposed in the Schrödinger region, only clino pyroxene is not found in the peak ring, although there is one exposure in the southern wall. Olivine was found only in the peak ring.

The spectra of fresh material exposed in scarps and fresh craters in Schrödinger's rim and wall are dominated by orthopyroxene, although a few scarps in the south basin wall contain isolated patches of anorthosite and pyroxene-bearing anorthosite, and in one location a pigeonite-bearing material was identified (Fig. 1). Virtually all of the strong spectral exposures in Schrödinger's southern wall occur at the summit of a terrace, and can be distinguished up to half-way downslope. Since these strongly crystalline spectral signatures in the southern wall are mostly confined to within the upper 1 km of a basin terrace wall, it can be argued that these are blocks of Schrödinger ejecta, and therefore derive from the maximum depth of excavation, ~20 km.

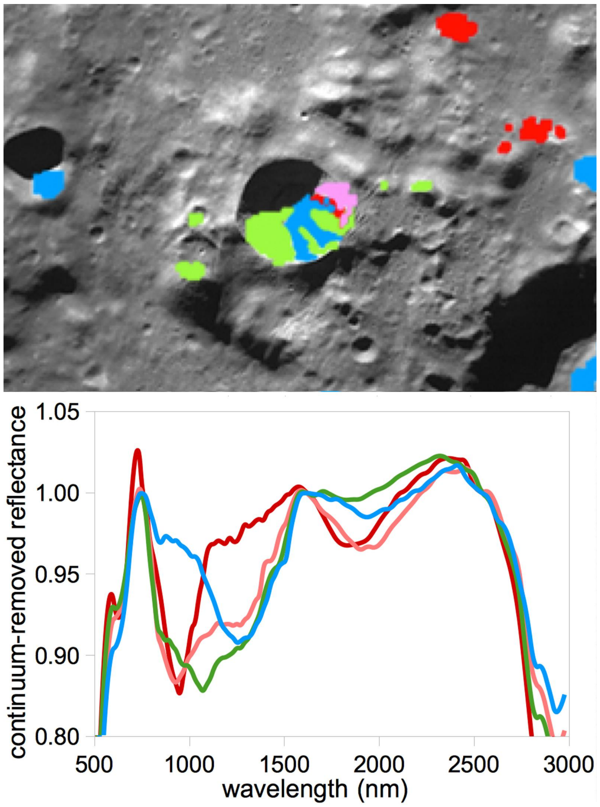

Figure 2: (a) Close-up of 8 km diameter crater in northern part of the peak ring of Schrodinger. (b) M^3 spectra showing four distinct lithologies in the wall of the crater.

Conclusions: The associated exposures of olivine are key to determining whether the uplifed peak ring entrained only crustal lithologies or whether it also entrained mantle material. If the olivine outcrops are true dunites, a mantle origin interpretation is reasonable, although not conclusive. The Ca abundance and Mg# of the olivine would be a more precise indicator. However, the tools necessary to quantify this chemistry are not currently available from orbit at the latitudes of Schrödinger. To conclusively determine the origin of the peak ring might require a sample return mission. Until such time as we can sample and quantitatively determine its origin, the relative contributions of mantle and crustal components that make up Schrodinger's peak ring exists in a state of uncertainty.

References: [1] Garrick-Bethell and Zuber (2009) *Icarus*, **204**; [2] Uemoto et al. (2011) *LPSC 42*; [3] Wilhelms (1987) *USGS Prof. Paper 1348*; [4] Shoemaker et al. (1994) *Science*, **266**; [5] Yamamoto et al. (2012) *Icarus*, **218**; [6] Cintala & Grieve (1998) *Met. Planet. Sci.*, **33**; [7] McGetchin et al. (1973) *EPSL*, **20.**