USING THE SCHRÖDINGER BASIN ON THE MOON TO INFER PROPERTIES OF THE BURIED CHICXULUB CRATER PEAK RING.

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Introduction: The Chicxulub impact crater is the best preserved peak-ring basin on Earth, but it is difficult to study because it is buried by Tertiary sediments. An effort to probe the peak ring will soon be underway with the International Ocean Discovery Program Expedition 364, a joint IODP-ICDP Mission Specific Platform Expedition, so we have attempted to use observations of the exceptionally well-exposed Schrödinger basin on the Moon to provide information that may help during the drilling phase of the IODP expedition and with subsequent interpretations of recovered borehole samples.

Schrödinger Basin: Following the production of a general geologic map of the entire impact basin [1], we began a series of detailed analyses of specific locations within the basin (e.g., [2-4]), including a representative portion of the peak ring (Fig. 1). If we integrate those results, we have the following findings: (a) A complicated pattern of faults transected the peak ring when it was emplaced, creating steep cliffs and chasms between vertically offset massifs; (b) These faults juxtapose noritic blocks in the two upper left divisions in Fig. 1 and troctolitic hills in the middle and lower right divisions; (c) Some of these faults also divide and offset lithologies. Four long faults that are radially aligned with the center of the basin divide the peak ring into three parallel ridges in this location. (d) The striking pattern of faults that offset lithologies of the peak ring is reminiscent of the severely faulted central peaks of Earth's Sierra Madera [4] and Upheaval Dome [5], albeit on a much larger scale.

We interpret the peak ring as the remnant of a displaced structural uplift (DSU) [6], rather than from an uplifted ring of rock bounding the region of the impact melted material [7], more recently described as the nested melt-cavity model [8]. In our DSU model, central peaks and peak rings are produced by a similar central uplift process, but in which the central uplift in a larger structure collapses outward and either collides with or overthrusts the inwardly collapsing transient crater rim, to form the peak ring. This model is supported by hydrocode simulations that are consistent with available observations of the Chicxulub impact structure [9,10] and can be tested with the upcoming IODP Expedition 364 drilling project.

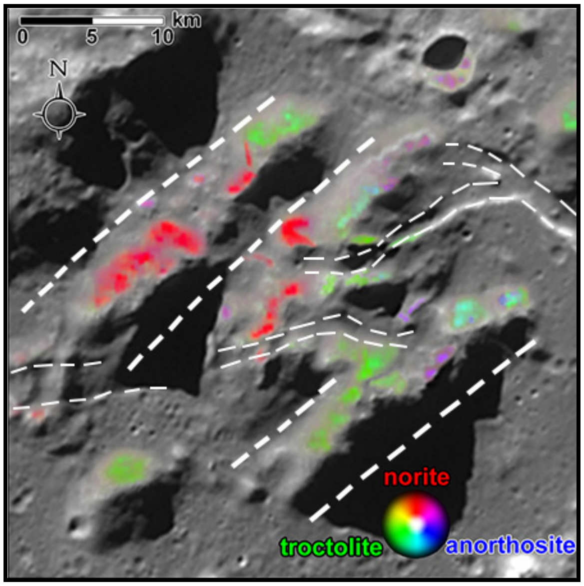

Fig. 1. A series of faults (heavy dashed lines) with km-scale offsets were produced during the emplacement of the Schrödinger peak ring, as seen here in the southwest quadrant of the basin. Later, a graben (light dashed lines) further dissected the peak ring.

To further assess the model, iSALE hydrocode simulations of the Schrödinger were conducted for 20 and 40 km thick lunar crust (Fig. 2; see also [11]). The simulation results have two important implications. The peak ring material is not composed of material that rose from a depth equivalent to the depth of the transient crater (e.g., 62.5 km in the case of the model with a 40 km thick crust). Nor is the peak ring composed of material that was uplifted vertically from the side wall of the transient crater as in [7]. Rather, it was produced from material in the central uplift that was displaced laterally in nappe-like structures (Fig. 2). The source depth of the crystalline rocks is 25 to 30 km, although they may have originally intruded the middle crust rather than the lower crust, because the Schrödinger target area was covered by several kilometers of older basin ejecta.

Implications for Chicxulub: These results have implications for the upcoming IODP drilling project into the buried peak ring of the Chicxulub impact crater. The DSU model, as illustrated with hydrocode simulations of the Schrödinger peak ring formation, suggests peak rings are not simple anticlinal structures that preserve crustal sequences as a function of depth (implied by the nested melt-cavity model), but are instead recumbent fold structures with overturned crustal sequences (Fig. 2). The hydrocode simulations also indicate, however, that the structural and paleodepth sequence seen in a single borehole depends on its radial position on the peak ring. In the outer portion of the peak ring, a single borehole is more likely to penetrate an overturned sequence. In contrast, in the core of the peak ring, a borehole may penetrate an upturned, rather than overturned, sequence. In that case, the core would be composed of units with shallow pre-impact (paleo)depths and then continue into a vertically-oriented unit with a deeper, yet relatively constant paleodepth, without completely piercing that unit to re-penetrate the units with a shallower paleodepth.

Our observations of the spectacularly exposed peak ring of Schrödinger provide an additional level of lithologic detail not evident in the hydrocode simulations. The km-scale fault displacement exposed at the top of the peak ring of Schrödinger basin (Fig.1) indicates that material of different paleodepths can be juxtaposed. The observed faults and juxtaposition of lithologies implies one of two outcomes. That the faults are modest modification of the nappe-like structure and that an overturned sequence at Chicxulub may be evident if the IODP borehole is sufficiently deep. Alternatively, those faults are a near-vertical product of the collision of the outward flowing collapsing peak and the inward flowing modification zone. In this case, one set of faults will have a sense of motion away from the crater center and another set will have a sense of motion towards the crater center. Both are listric at depth (as in Fig. 16 of [12]). In this case, a borehole will encounter multiple truncating faults rather than an overturned sequence.

It is also important to note that the summits of the massifs in the peak ring of Schrödinger are still fairly sharp (Fig. 1), despite being ~3.8 billion years old. Regolith formation and mass wasting caused by later volcanic, tectonic, and impact events have softened the features, but far less efficiently than erosion on the Earth. Thus, if similar peak ring summits were produced at Chicxulub, they likely generated colluvial scree on lower slopes and pediments of debris in topographic lows before being buried. It took ~300 ka before the base of the peak ring was covered with marine sediments [13], so erosion of the peak ring summits probably occurred over 10^6-10^7 years before they were buried. That debris would have been deposited on either exposed target rocks in the peak ring or on top of impact breccias that were previously deposited among the massifs of the peak ring during the impact event like that seen in Schrödinger [1] and implied by breccia deposits that flowed over and beyond the peak ring at Chicxulub (e.g., [14]). Thus, depending on the location of the IODP borehole, lithologies not yet seen in other Chicxulub boreholes may be recovered. The IODP borehole will be an important in situ test of the DSU model versus that of the nested melt-cavity model, but interpretations of that borehole will be greatly enhanced by the three-dimensional view of a peak-ring provided by the exposures in the Moon's Schrödinger basin.

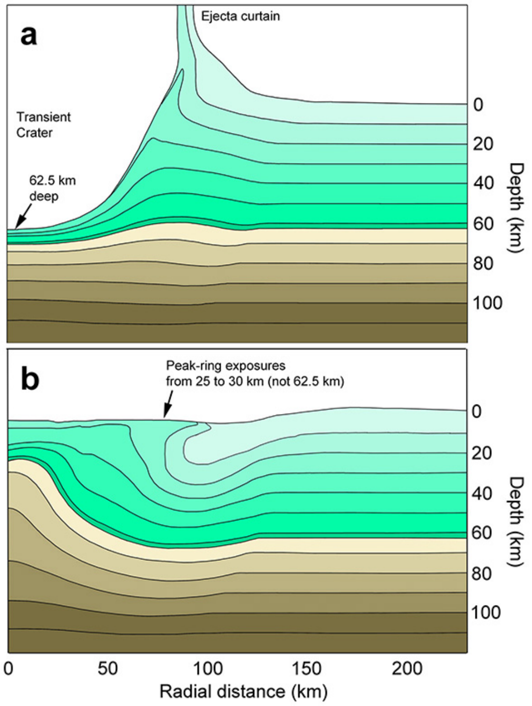

Fig. 2. A schematic diagram illustrating the outcome of iSALE hydrocode simiulations of the Schrödinger basin-forming event (a) 2.5 min and (b) 41.7 min after impact into a 40 km thick crust.

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