CAN EXPONENTIAL CREEP OF OLIVINE EXPLAIN THE FORMATION OF THE RING AROUND CHICXULUB? E. P. Turtle[1] and H. J. Melosh[2], Lunar and Planetary Laboratory, University of Arizona, Tucson AZ 85721-0092 ([1]turtle@lpl.arizona.edu, [2]jmelosh@lpl.arizona.edu).

Seismic data [1] have revealed the structure of a portion of the Chicxulub crater and the surrounding crust. These data provide strong evidence supporting the interpretation of Chicxulub as a terrestrial multi-ring basin. The seismic profiles show a flat-floored basin ~1 km deep and ~65 km in radius within which lies a peak ring 40 km in radius. Exterior to the basin at a radius of almost 100 km is a scarp 400–500 m high which appears to be the surface expression of a shallow-dipping, circumferential, normal fault that penetrates the entire crust and offsets the Moho by ~1 km [1]. These data provide the first peek at the deep structure associated with a multiring crater. Although faults are predicted by the ring tectonic theory [2] that was proposed to explain the formation of rings around large craters, neither the shallow dip (30°–40°) nor the depth observed for the fault around Chicxulub were expected. Therefore, the seismic data provide fundamental information concerning the three-dimensional nature of a multiring basin, information which is essential to performing accurate numerical simulations of crater collapse and ring formation.

We have used finite-element modeling to simulate crater collapse and to demonstrate the formation of rings according to the ring-tectonic theory [2]. This theory predicts that rings form around craters in targets consisting of two rigid layers between which lies a layer with a significantly lower effective viscosity. Our simulations of crater collapse have demonstrated that inward motion in a low-viscosity layer with either a Newtonian rheology or a low-cohesion, low-angle of internal friction plastic rheology, can generate extensional stresses sufficient to fracture the overlying rigid layer [5,6]. When we introduce faults in the upper rigid layer, substantial offset (as much as several hundred meters depending on the depth to and the thickness of the low-viscosity layer) can occur on at least one of the faults. These results are promising, but the number of unknown parameters makes it difficult to discriminate which models are the most accurate. Furthermore, aside from the fact that it is consistent with ring formation, there is little reason to expect crustal or mantle material to depart from their more rigid power-law rheologies.

The Chicxulub seismic survey provides information that can be used to assess the accuracy of simulations of crater collapse under various conditions. It may also elucidate the mechanism that accounts for the development of a low-viscosity layer. The depth of the fault observed around Chicxulub indicates that in the context of the ring-tectonic theory inward flow must have occurred within the mantle suggesting a possible explanation for this behavior: olivine has been observed to exhibit an exponential rheology when subjected to high stresses [7,8]. For stresses below 200 MPa, the strain rate of olivine follows a power-law dependence on the applied stress, but above this threshold the strain rate increases exponentially with increasing stress. In our simulations stresses of this magnitude are regularly achieved in the mantle around the collapsing transient crater. Therefore, we have incorporated the transition to an exponential rheology into our finite-element model to investigate whether it can explain the formation of the ring fault observed around Chicxulub. Current results are inconclusive, but we are undertaking a suite of simulations encompassing a broader array of parameters and we will present our conclusions at the conference.

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