THE FORMATION OF PEAK RINGS IN LARGE IMPACT CRATERS

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Introduction: Peak-ring craters are an important class of impact crater, among the largest found on rocky planetary surfaces [1]. The ring of mountains in the crater centre, which gives the class its name, provides a window into the deep structure and composition of planetary crusts [2]. However, with few terrestrial examples and a lack of direct sampling, debate has surrounded the mechanics of peak-ring formation and their depth of origin [3].

The 66 Ma Chicxulub impact crater, Mexico, is one of very few peak-ring impact craters on Earth. It is uniquely well-preserved, but is buried and only accessible through drilling. IODP-ICDP Expedition 364 sampled the Chicxulub peak ring, recovering rocks formed from uplifted, fractured, shocked, felsic basement rocks [4]. The peak-ring rocks are cross-cut by dikes and shear zones and have an unusually low density and seismic velocity. Ongoing analysis of this unique and rich new dataset permits a more thorough assessment of peak-ring formation models and their predictions.

Here we show that simulations of Chicxulub crater formation are in good agreement with both large-scale geophysical observations and fine-scale geological and petrophysical observations from the IODP-ICDP Expedition 364 drill core.

Results: Simulation predictions that peak-ring rocks derived from mid-crustal depths and experienced shock pressures of 10-35 GPa are consistent with observations. Moreover, high-fidelity analysis of the stress-strain-time path of peak-ring rocks reveals a complex, multi-stage deformation history in close correspondence with that inferred from the cross-cutting dikes and shear zones. The match between simulations and observations provides strong support for the dynamic collapse model of peak-ring formation [5] and its application to large craters on other planets. New 3D simulations of Chicxulub crater formation also provide new insight into the direction and trajectory angle of the impact.

Implications: The Chicxulub asteroid impact released ~2.7 x 10^{23} J energy (equivalent to 64 million Mt TNT), forming a ~90-km wide, 30-km deep hole in the crust that collapsed within 10 minutes to produce the ~180-km diameter crater observed today. Separate numerical calculations of the volume of climatically active gases ejected to high altitudes, using impactor size and trajectory constraints from this work, suggest 325 ± 130 Gt of sulfur and 425 ± 160 Gt CO_2 were released by the impact to produce severe changes to the global climate [6].

References: [1] Melosh, H.J., (1989) Oxford University Press, New York. [2] Kring, D. A. et al. (2016) Nature Communications 7, 13161. [3] Baker, D. M. H. et al. (2016) Icarus 273, 146–163. [4] Morgan, J.V. et al. (2016) Science 354, 878–882. [5] Collins, G.S., et al. (2002) Icarus 157, 24–33. [6] Artemieva, N. et al. (2017) Geophys. Res. Lett. 2017GL074879.