

HIGH-RESOLUTION OBLIQUE IMPACT SIMULATIONS OF THE FORMATION OF THE SOUTH POLE-AITKEN BASIN. T. M. Davison, N. Baijal, and G. S. Collins. Impacts & Astromaterials Research Centre, Department of Earth Science and Engineering, Imperial College London, London, UK (E-mail: thomas.davison@imperial.ac.uk).

Introduction: The 2500-km diameter South Pole-Aitken (SPA) basin is the largest known impact structure in the Solar System, which dominates the topography, crustal structure, surface composition and subsurface density of the lunar farside and South Pole [1–3]. Numerical modeling of the formation of SPA could help constrain the thermal state of the Moon at the time of impact [4] and thereby illuminate the Moon’s earliest bombardment history [5]. Numerical modeling can also predict the spatial distribution of ejecta, the depth from which mantle was exposed, and the fate of the impactor, which have implications for interpreting lunar compositional and geophysical anomalies [3, 6, 7].

Vertical-incidence simulations have previously investigated the influence of the near-surface thermal gradient on crater size [4]. SPA’s elliptical planform and asymmetric surrounding topography, however, imply that the impact was oblique [1]. 3D models of SPA have included an oblique incidence angle [6, 7] but did not simulate until the final crater was formed, did not distinguish between different target layers, and did not consider different thermal profiles.

Here we present results from new high-resolution 3D simulations of the formation of the SPA basin as an oblique impact. We investigate the effect of different thermal profiles, and of including compositionally distinct layers in the Moon and the impactor, on final crater structure, ejecta production and impactor fate.

Modeling: The SPA impact was simulated using the iSALE3D shock physics code [8]. Two lunar thermal profiles were considered (a hot 50 K/km profile, and a colder 10 K/km profile). To produce similar sized transient craters, we used a velocity of 10 km/s with the hot profile and 15 km/s with the cold profile. For both scenarios, impacts were simulated with angles of 30° and 45°. The 200-km diameter differentiated impactor consisted of an iron core (33% by mass) and a dunite mantle. The Moon consisted of a 350 km radius iron core, a dunite mantle and a 50 km granitic crust. All materials used ANEOS-derived equation of state tables [9–12] and strength models used by [4]. The mesh resolution was 5 km per cell (20 cells per impactor radius), equivalent to the resolution used in previous 2D SPA simulations [4] and 2–4 times higher than previous 3D SPA simulations [6, 7]. Lagrangian tracer particles tracked cratering motions. The landing positions of ejected tracers were determined using ballistic projection.

Results: For the cold profile, transient crater diameters of 1050 and 920 km were formed for the 45° and 30°, respectively, within the range considered by previous works [4, 6, 7]. For the hot profile, the transient diameters were 960 km and 860 km. The ellipticity (ratio of semimajor axis to semiminor axis) of the transient craters was ≈ 1.15 for both 45° simulations, similar to the ellipticity of the outer topography of the SPA basin (1.17), but not as elliptical as the inner ellipse (1.35) [1]. The transient craters from the 30° simulations have ellipticities in the range 1.2–1.3.

The radius of the zone of excavated crust in the basin center was 470–540 km in the two cold-profile simulations, and 460 km in the 30°, hot-profile simulation. These are consistent with the observed paucity of upper crustal material inside a radius of 630 km from the crater centre [13] and the size of the hole in lower crustal material predicted by [4] (500 km). However, the 45°, hot profile simulation produced a region of excavated crust of 690 km, which was too large to match these observations. Ejected material was widely distributed across the lunar farside in all simulations, with some material reaching the nearside. In the 45° simulations mantle material was ejected from depths of 130–150 km. In the 30° simulations, much less mantle was excavated; the deepest material came from 80–90 km depth.

Conclusions: High resolution, multi-material simulations of the SPA basin formation have shown that the spatial distribution and thickness of ejecta, the depth of excavated mantle and the amount of ejected projectile are all strongly dependent on the impact angle, impact velocity and target thermal profile. Comparisons with observational constraints on the spatial distribution and thickness of SPA ejecta [e.g. 14] will allow discrimination between impact scenarios.

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