HYDROCODE MODELING OF IMPACT STRUCTURES ON ASTEROID 16 PSYCHE.

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Introduction: Asteroid 16 Psyche is the largest M-type (metallic) asteroid in the Main Asteroid Belt (MBA) [1]. The upcoming NASA mission Psyche: Journey to a Metal World, set to launch in 2022, will reach Psyche in 2026 and orbit the asteroid for 21 months [2, 3]. Psyche is the largest exposed metallic body in the MBA, and the mission will be the first of its kind to visit a metallic body rather than one composed of rock or ice [4]. Psyche is likely the remnant of a differentiated planet core from a time when planetary accretion was disrupted by frequent solid-body collisions [4]. However, because of its distant location and the limits of available measuring techniques, basic information about Psyche is under debate. Estimates of Psyche's diameter vary considerably and typically fall in the range from 213 km to 264 km [1]. Estimates of Psyche's bulk density typically range from 1.4 ± 0.3 g/cm^3 to 4.5 ± 1.4 g/cm^3 [1].

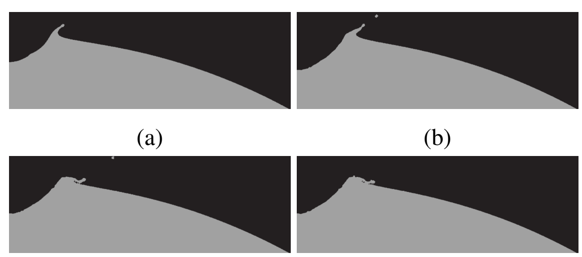
Psyche has two large impact structures in its Southern hemisphere [7]. The largest of these structures is estimated to be about 70 km in diameter and up to 6.4 km deep [7]. The goal of this work is to study the composition of Psyche by modeling its largest impact crater. We study various possible material compositions and porosity levels, and we compare the crater profiles in 2D and 3D to estimate Psyche's material composition.

Materials and Models: The FLAG hydrocode, previously shown to be effective in modeling impact craters [8], is an ideal choice to model this crater. FLAG uses a finite-volume method to model physical processes in 1–3 spatial dimensions [8, 9]. FLAG offers a number of mesh optimization techniques, including adaptive mesh refinement (AMR) and arbitrary Lagrangian-Eulerian (ALE) remapping [8, 10].

The probable impact velocities involving Psyche are between 4.434 km/s and 4.639 km/s [11]. Caldwell et al. [8] showed that FLAG converges at relatively low resolutions for velocities of 5 km/s. Velocities in this range indicate that material strength is a factor in crater formation, which FLAG is able to model well [8, 12].

We used a variety of materials and models for both impactor and Psyche. For Psyche, we used iron, nickel, and Monel, a nickel-copper alloy that contains titanium, aluminum, silicon, and iron [13]. For the impactor, we used iron, Monel, and silicon dioxide (SiO_2). The constitutive models we used for these materials were Preston-Tonks-Wallace (PTW) [14], Steinberg-Guinan (SG) [15], and perfect plasticity (pp) [16]. For equations of state (EOS), we used the tabular SESAME EOS [17] and the analytic Mie-Grüneisen EOS [18].

2D Results: We began with a series of 2D axisymmetric simulations in order to investigate a variety of materials with reduced computational resources. We modeled Psyche as a circle of radius 125 km and the impactor as a circle of radius 5 km, consistent with estimates in the literature [7, 19], and we modeled the surrounding material as a void. We chose an impact velocity of 4.5 km/s, consistent with the probable impact velocities of collisions involving Psyche, and an impact angle normal to Psyche's surface [11]. Figure 1 shows the crater formation and resulting overturned flap from our simulation using SiO_2 as the impactor material and Monel for Psyche.



(a) (b) (c) (d)

Figure 1: Images from the SiO_2-Monel simulation showing the eventual overturned flap: (a) ejected material follows expected trajectory out of crater; (b) hinge forms during crater excavation; (c) material collapses at hinge; (d) flap of hinged ejected material has overturned.

2D Porosity Study In addition to running solid material simulations using a variety of materials for impactor and Psyche, we also conducted a porosity study using the alloy Monel for both Psyche and impactor. For the porosity study, we initialized Psyche with 30%, 50%, 60%, 70%, and 80% porosity, and we used a solid impactor. Figure 2 shows the crater profiles from the porosity simulations.

3D Results: Our 3D simulations used a shape model for Psyche [7] and a sphere of radius 5 km for the impactor. To cover the existing craters on the shape model, we used a spherical cap of radius 110 km using the same material as Psyche. Our 3D simulations tested impact angles of 45° and 60° from vertical. We will present results

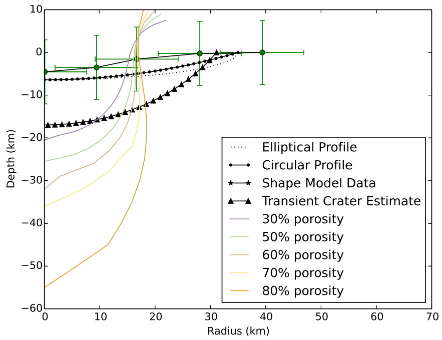


Figure 2: Crater profiles from Monel-Monel porosity study. Higher target porosity resulted in greater crater depths, while crater diameters were less affected by target porosity than crater depths.

and videos from our 3D simulations at the meeting.

Conclusions: From these simulations, we predict that Psyche is indeed likely mostly metallic with a porosity of about 50%. These predictions are consistent with the idea that M-type asteroids are differentiated planet cores.

Ongoing Work: We are currently using FLAG to simulate the smaller of the two main craters in Psyche's southern hemisphere. Our 2D results are nearing completion, with 3D simulations planned in the coming weeks. We anticipate presenting results from these simulations at the meeting.

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