POST-IMPACT POROSITY AND GRAVITY ANOMALIES FOLLOWING THE HYPERVELOCITY DART IMPACT ON ASTEROID DIMORPHOS.

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Introduction: As one of the primary mechanisms driving the evolution of asteroids and comets, impact processes are commonplace in our Solar System [1]. From small meteorites to large Moon-forming impacts, impact cratering processes provide crucial insights into the dynamic history of the solar system dating back to ~4.5 billion years ago [2]. Over the past decade, asteroid missions have steeply advanced in characterizing the Near-Earth Objects (NEO). Very recently, on 26th of September 2022, NASA's Double Asteroid Redirection Test (DART) [3] space mission demonstrated the first kinetic deflection of a near-Earth asteroid, the moonlet of the 65803 Didymos binary asteroid system, Dimorphos. The DART spacecraft impacted the asteroid Dimorphos successfully and altered its orbital period (initially at 11h 55m [4]) by ~32 minutes [5]. A couple of years following the DART impact, the European Space Agency's (ESA) Hera mission [6] will investigate the aftermath of the collision in greater detail, from the cratering process to exploring the surface, gravity, interior structure and dynamics. Asteroids have long been prone to cratering episodes caused by destructive impacts. Analyzing the aftermath of those cratering processes from shock physics simulations is one elegant approach to explore surface and subsurface characteristics of the asteroids. As a result, the morphologies of impact craters and the dynamics of ejecta give a direct diagnostic of the surface and subsurface structures. So far, previous numerical efforts have reported several factors [7] that can affect the response of Dimorphos to DART-scale impactors, such as target layering, surface strength [8], projectile impact angle [9] or target heterogeneities [10].

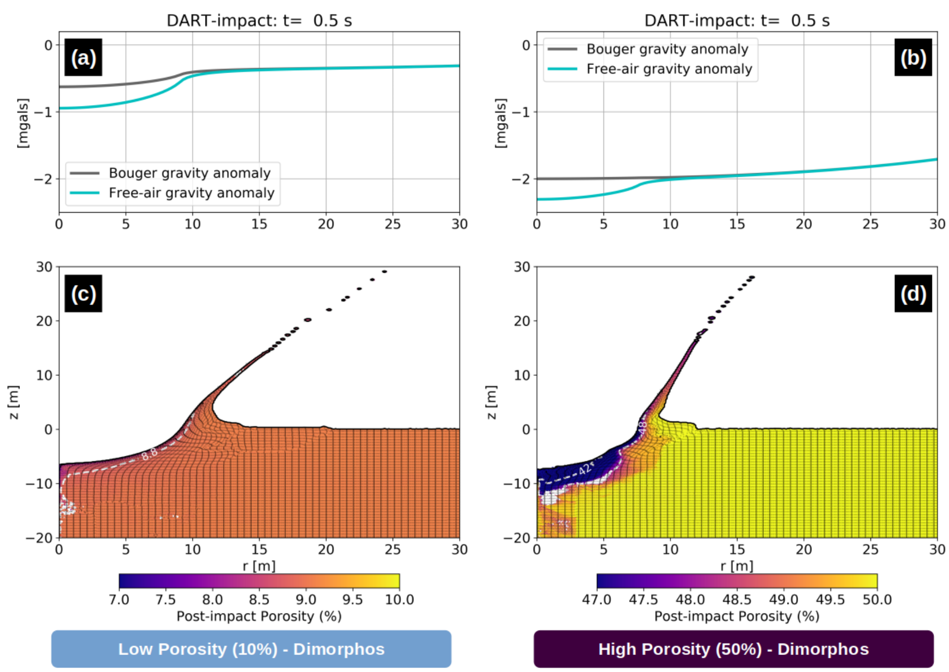

Figure 1: Bouger (gray solid lines) and free-air (cyan solid lines) gravity anomalies from DART-scale hypervelocity impact simulations at t=0.5 seconds after the impact event, on two different homogeneous targets. **(a)** low porosity (10%) & **(b)** high porosity (50%) target, Dimorphos. Generated porosity differs for the two targets, as well as the ejecta spread following the DART impact at t=0.5 s, on **(c)** low and **(d)** high porosity target scenarios.

Methods: Here, we performed hypervelocity DART-like kinetic impactor simulations using the iSALE-2D shock physics code [11-13]. We assumed the impact falling into the low-strength regime rather than the gravity regime, in which the asteroid cohesion, Y_0, is set to 100 Pa. The selection of this value has prominent effects on the DART impact cratering processes. Raducan and Jutzi (2022) [14] reported recently that the lower values of Y_0 (i.e., <10 Pa) may cause global resurfacing and deformation rather than creating a cratering. We modeled the porosity compaction of the target material using the ε-α model [13]. In order to model the pore-space alteration due to dilatancy, we make use of the model of Collins (2014) [15], which has been applied in different impact events on the Mesozoic Earth, Mars, and the Moon. In our simulations, the DART impactor (solid aluminum sphere with 650 kg mass) hits Dimormos in a vertical trajectory with a speed of 6.5 km/s, based on [9]. Here, we use Tillotson equation of state (EOS) for the aluminum projectile and basaltic target asteroid. ROCK and Johnson-Cook models were used for the strength models of the projectile and the target, respectively. We followed the material and mechanical parameters as listed in Ref. [9] (see their Table 3), in which the asteroid and material setup files were archived at DOI:10.5281/zenodo.5818242.

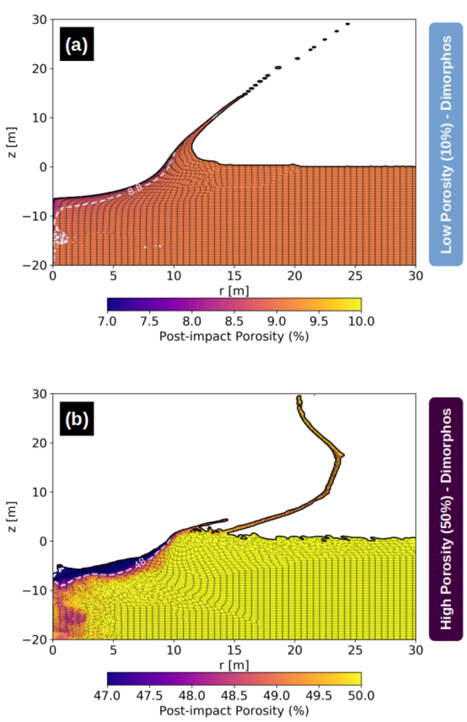

Figure 2: DART-scale hypervelocity impact simulations, to model porosity alterations at t=9 seconds after the impact event, on two different targets. **(a)** low porosity (10%) & **(b)** high porosity (50%).

Results & Discussion: In the present study, after verifying our results using recent impactor/target constraints [7-9], we further analyzed the likely consequences of a DART-scale impact. Here we showcase impact-induced porosity alterations as well as gravity signatures (i.e., in terms of free-air and Bouguer anomalies, see Collins, 2014 [15]) in two target scenarios: low (10%) and high (50%) porosity Dimorphos. Our impact simulations indicate that the pre-impact porosity can trigger the gravity signatures during the crater excavation stage. Such that it results in large anomalies up to ~0.5 mGal, corresponding to ~10% of the gravity of Dimorphos (Fig. 1). Moreover, contrary to the low porosity target, in which the crater porosity returns faster to pre-impact levels, irreversible changes occurred on the high porosity target, even 20 meters underneath the crater floor (Fig. 2). This would have significant implications for the subsurface characteristics and geophysical signatures on the DART impact crater. The Hera spacecraft will perform dedicated measurements to detect gravity field, using the radio science from the orbit as well as gravity from the surface. Juventas CubeSat, which will land on Dimorphos, has the GRASS gravimeter [16] designed to have surface accuracy better than 0.002 mGal [17].

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