THE ROLE OF DAMAGE AND POROSITY ON CRATER SIZE: INSIGHTS FROM MODELING LUNAR IMPACTS. E. A. Silber[1] and G. R. Osinski[1,2], [1]Centre for Planetary Science & Exploration / Department of Physics and Astronomy, University of Western Ontario, London, ON, N6A 3K7, Canada, [2]Department of Earth Science, University of Western Ontario, London, ON, N6A 5B7, Canada (esilber@uwo.ca)

Introduction: Impact cratering is one of the most predominant geological processes in the Solar System. Since most of the craters on Earth have been erased or heavily modified due to tectonic activity, erosion and other surface processes, it is profoundly challenging to perform morphological studies of impact craters on Earth. Conversely, the lunar surface offers an abundance of well-preserved impact craters, ranging from simple, bowl-shaped craters, to complex crater structures, such as central peak, central-peak basins and peak-ring basins [1]. A sub-group of impact craters, termed “transitional”, falls between simple and complex craters in diameter, but morphologically cannot be defined as either. The crater diameter at which the transition from a simple to a complex crater takes place is approximately 19 km on the Moon. However, this value depends on the target [2]. Recently, it has been shown that transitional craters in mare targets range from 15 km to 42 km in diameter, and from 21 km to 38 km in diameter in highlands [3].

In addition to affecting the amount of melt [4], porosity plays a role in limiting crater growth [5]. For example, compared to a non-porous crystalline target, it has been shown that in a porous crystalline target, the transient crater radius is smaller and the depth greater [5]. A recently improved lunar crust porosity model derived from GRAIL data [6], along with lunar crust composition and thicknesses, allows for better parameter constraints in numerical models. In this study, we investigate the role of target porosity and pre-damaged target on temporal evolution and morphology of transitional lunar craters and the simple-to-complex transition.

Methodology: Cratering simulations are performed using iSALE-2D, a multi-material, multi-rheology shock physics hydrocode [5, 7]. The impactor and the crust are represented with the equation of state tables derived using ANEOS for dunite [8] (impactor) and basalt [9] (target), and the strength and failure model [7, 10]. We also included the effect of acoustic fluidization [11] and, in a number of cases, porosity [12]. Vertical impact velocities were set to 10 km/s and 15 km/s to account for a range of typical asteroidal impacts. Pre-existing target damage was set at 0, 0.5 and 1, where 0 is no damage, and 1 is total damage. Although the latter may be representative only for a limited portion of the lunar surface [6, 12], we wanted to investigate the maximum possible effect imposed by a damaged target. Porosity was set at either 0% or 25% (Table 1). Post-processing was done using iSALE Plot to extract the crater profile parameters (e.g., radius and depth), as well as visualize the simulation (e.g., Fig. 1). High resolution simulations are ongoing, and thus the preliminary results presented here are derived from low resolution simulations (10 cells per projectile radius). The latter choice of the resolution is the lower limit to obtain good results [5].

Table 1: Summary of simulation parameters

Impactor Radius	200 m - 2000 m
Impactor Velocity	10 km/s - 15 km/s
Target Porosity	0% - 25%
Target Damage	0 - 1

Results: The preliminary results suggest that target damage, even when set at maximum, plays a relatively minor role in transient (Fig. 1) and final crater radius and depth. These results are consistent with previous studies which examined the effect of target damage on lunar basin forming impacts [12].

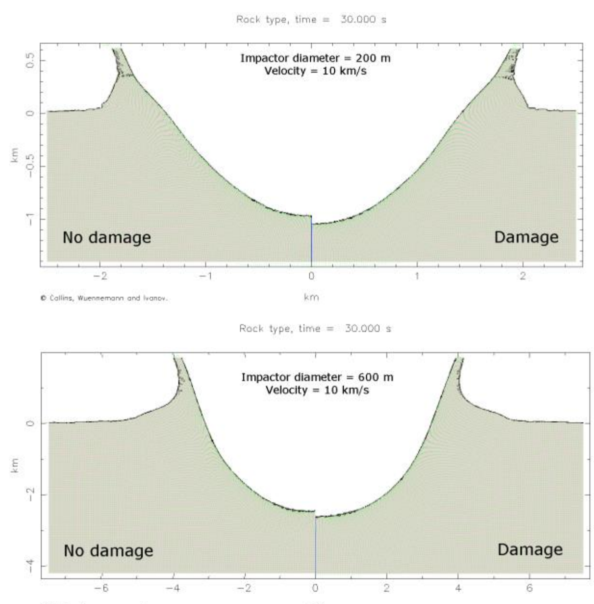

Figure 1: The cross-section of a crater showing the simulated impact into intact (left panel) and damaged target (right panel) 30 seconds after the contact. Top panel: Impactor diameter = 200 m. Bottom panel: Impactor diameter = 600 m.

In contrast, porosity plays a significant role, affecting both the crater radius and depth (Fig. 2). The temporal evolution and crater morphology exhibit different features in porous vs. non-porous target. When porosity is taken into consideration, the transient crater is narrower and deeper, mainly due to the lower bulk density of the target and lower shock pressures, which result from less frictional resistance [5]. While not significantly different in early stages, the effect of porosity on crater radius as a function of time beyond the excavation stage is non-negligible, and it appears to be conducive to lateral crater growth, contrary to the behavior seen in a transient crater. For an 1800 m impactor, the crater radius starts diverging upward from the non-porous slope ~150 s into the simulation. The transient crater depth reaches maxima less than 20 s after the impact in a porous target and 35 s in a non-porous target, with depths of ~8 km and ~6.5 km, respectively.

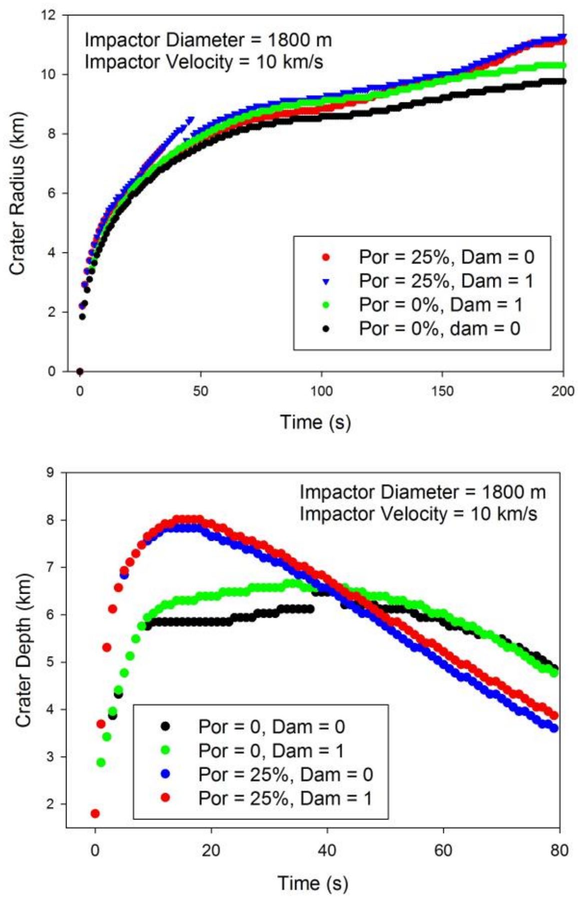

Figure 2: Crater (a) radius and (b) depth as a function of time for an 1800 m diameter impactor during the first (a) 200 s and (b) 80 s after the impact.

Summary and Future Work: The results and findings derived through numerical modeling offer an important step in further understanding the mechanisms by which transitional craters [3] form. This work provides new insights into the role of target damage and porosity on temporal evolution and morphology of impact craters on the Moon. Our study suggests that the level of lunar surface damage plays a negligible role on the final crater diameter even for transitional and simple-to-complex lunar craters. When compared to a non-porous target, the crater radius in a porous target increases substantially as a function of time. This behavior indicates that, in addition to target lithology, the amount of target porosity may be more significant in simple-to-complex and transitional lunar crater temporal evolution and morphology than previously thought.

The next step is to compare the preliminary findings presented here with high resolution numerical simulations implementing damage gradient and GRAIL derived porosity, which are currently in progress. Further investigation of the role of porosity on the crater morphology offers a new conduit to at least partially account for mechanisms by which specific crater features (e.g., wall slumping and terracing) occur in different targets [3]. We also wish to investigate the production and role of melt on crater morphology. While currently under development, transverse isotropy will be applied in due time to investigate the role of target layering and the effect of material anisotropy [13]. Furthermore, we wish to implement iSALE 3D to determine if similar trends are observed for oblique impacts.

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