THE EFFECT OF TARGET PROPERTIES ON SMALL-DIAMETER CRATER SIZE-FREQUENCY DISTRIBUTION - NUMERICAL EXPERIMENTS.
N. C. Prieur[1], R. Luther[2], K. Wünnemann[2] and S. C. Werner[1]. [1]Centre for Earth Evolution and Dynamics, University of Oslo, Norway. [2]Museum für Naturkunde, Leibniz-Institute for Evolution and Biodiversity Science, Berlin, Germany. (contact: nilscp@geo.uio.no).

Introduction: One of the most fundamental geological processes that shapes the surface of terrestrial bodies is crater formation caused by impacts. For a given impact cratering rate, the crater size-frequency distribution (CSFD, i.e. the number of craters of given diameter per unit area) can be used to derive the age of a geological unit on a planetary surface [1]. This requires a chronological function to link the relative age (from CSFD) to the absolute model age (AMA).

The Moon is an ideal natural laboratory to study impact cratering due to the lack of post-modification processes, and the radiometrically dated rock samples brought back from the Apollo and Luna missions [2]. The calibrated lunar chronology function serves as reference and can therefore be used to determine chronological functions for other planetary bodies, provided that the flux of impacting body is known [3]. Another precondition has been highlighted in [4]: "empirical lunar chronologies [e.g. 5] have been derived based on the assumption that the effects of target properties on the cratering on different terrains are negligible".

Recent studies on small craters (<100 m) have demonstrated that the shape of CSFDs show considerable variation due to various factors such as target properties [4, 6-11], secondaries [6,8,9,12], crater-saturation [13] and atmospherical interactions [6]. A clear understanding of these factors and their influence on the CSFDs is still missing, but crucial for the determination of ages of geologically young features by crater counting. [6].

In most previous studies [6,7,11], common crater scaling laws [14] were used in order to quantify the effect of target properties on AMAs. Unfortunately, existing scaling laws only predict the size of the transient crater on a homogeneous target [4], heterogeneities in the target are neglected despite their obvious existence on planetary surfaces.

We have used numerical experiments of impact crater formation to assess the effect of target properties in a more systematic way (e.g in [4,15]). In particular, in this study we focus on small craters (< 500 meters) on the lunar regolith and basalt. Target parameters such as porosity, friction, cohesive strength and different material types were investigated with our numerical models and to study the effects on the crater-size frequency distribution slope, and/ or systematic diameter shifts.

Methods: In this work we use the iSALE shock physics code [16-18]. We conducted numerial experiments for small craters on the Moon (<500 meters in diameter). We modeled vertical (90^o) impacts with a projectile diameter range between 2 to 40 meters and an impact velocity of 12.7 km/s (which corresponds to the vertical component of the most likely impact velocity 18 km/s at a 45^o angle on the Moon). Simulations were carried out for two types of targets, a dust-like and a rock-like layer to represent the respective behavior of the regolith and basalt. We account for differences in porosity and material strength in the two targets by using a porosity compaction model [18] and two different strength models: Drucker-Prager (regolith) and a more complex strength model for hard rocks (basalt) described in [15,17]. Target properties such as porosity, friction and cohesive strength were varied over a range of plausible values (Table 1). In all models, the projectile consists of non-porous dunite, and a resolution of 20 cells per projectile radius was selected, to keep the relative error on crater diameter below 5%.

Table 1 iSALE parameters. Further details on defined parameters: f_{dam} *(basalt)*=0.6, Y_{dam} *(basalt)*=10kPa, and abbreviations: dam= damaged, int=intact, f= friction, Y= maximum yield stress, Str. model= strength model, EoS=equation of state, Coh Str.= cohesive strength.

	Regolith	**Basalt**
Porosity	0, 7, 15, 25, 38 %	0, 12 %
f_{dam}/f_{int}	0.4, 0.6, 0.8, 1.0	1.0, 1.2, 1.5, 2.0
Coh. Str.	Cohesionless	0.1 ,1 ,10, 50 MPa
Y_{dam}/Y_{int}	100 MPa[1]	2,5 GPa
Str. model	Drucker-Prager[2]	Rock[3]
EoS	ANEOS Quarzite	ANEOS Basalt

1: from [21] , 2: described in [15] , 3: described in [17]

In order to investigate the effect of target properties on the age derived from crater counting, the final crater diameter needs to be determined. Due to small diameters of the crater forming projectiles and relatively high impact velocities (several km/s), the models cause high demands on computational resources. Therefore, first evaluations will be made from model runs for the transient crater. The transient crater is measured at the time when the crater volume reaches its first local maximum [19]. In our case, for simple craters, we can estimate the final crater diameter (D_f) from the transient crater diameter (D_t) according to [20]: $D_f = 1.18D_t$ (1)

For examples, the final crater will be computed in the numerical experiments to develop more transient to final crater scaling.

Results and Discussion: In total, we will perform more than 500 models over a wide range of plausible values for porosity, friction and cohesive strength to simulate the lunar regolith and maria. Results for slightly larger projectile diameters (larger than 40 to 100 meters) show that the influence of target properties can be quite variable depending on target properties. We confirm previous observations [15], of an increases porosity causeing a reduction in crater size due to less energy available in the system for crater excavation (energy lost due to compaction of pores). On the other hand, a decrease in friction and cohesive strength leads to bigger crater diameter.

We will demonstrate our results for smaller craters (evaluation of the results are still in progress) with respect to the influence on variability of the slope of the crater size frequency distribution and possible systematic diameter shifts and their implication on age determination.

References: [1] G. E. McGill (1977) *Geol. Soc. of America, 8, 1102-1110* [2] Stöffler, D. et al. (2006) *Rev. in Mineral and Geochem., 60, 519-596* [3] G. Neukum and Wise D. U. (1976) *Science, 194, 1381-1387.* [4] K. Wünnemann et al. (2012) *LPSC 43rd, Abstract #1805.* [5] Schmidt, R. M. and Housen, K. R. (1987) *IJIE, 5, 543-560.* [6] J. P. Williams and Pathare A. V. (2015) *Workshop on Issues in Craters Studies, Abstract #9051.* [7] M. R. Kirchoff et al. (2015) *LPSC 46th, Abstract #2121.* [8] Zanetti et al. (2015) *Workshop on Issues in Craters Studies, Abstract #9041.* [9] C. H. van der Bogert et al. (2010) *LPSC 41st, Abstract #2165* [10] H. Hiesinger et al. (2010) *LPSC 41st, Abstract #2287* C. H. van der Bogert et al. (2015) *Workshop on Issues in Craters Studies, Abstract #9021* [12] A. S. McEwen and Bierhaus E. B. (2006) *Annu. Rev. Earth Planet. Sci.* [13] Z. Xiao and Werner S. (2015) *Workshop on Issues in Craters Studies, Abstract #9009.* [14] Holsapple K. A. (1993) *Annu. Rev. Planet. Sci. 12, 333-373.* [15] K. Wünnemann et al. (2010) *Proc. 11th HVIS, 120.* [16] Amsden et al. (1980) *Los Alamos National Report, LA-8095, 0-101.* [17] Collins et al. (2004) *MAPS, 39, 2, 217-231.* [18] K. Wünnemann, G. S. Collins and Melosh, H. J. (2006) *Icarus, 180, 514-527.* [19] D. Elbeshausen et al. (2009) *Icarus. 716-731.* [20] Chapman, C. R., and McKinnon, W. B. (1986) *Satellites, Univ. of Arizona Press, 492-580.* [21] Miljkovic et al. (2012) *AIP Conf. Proc. 1426, 871-874.*

Acknowledgements: NCP and SCW appreciated the support by the Research Council of Norway (235058/F20 CRATER CLOCK) and IS-DAAD mobility grant (NFR 244761/F11). KW, RL, and MS are supported by the IS DAAD mobility grant 57159947. We would like to acknowledge the developers of iSALE, including Gareth Collins, Dirk Elbeshausen, Boris Ivanov and Jay Melosh. We would also like to thank Tom Davison for the pySALEPlot tool which was used in this work.