TARGET INFLUENCE IN GRAVITY DOMINATED CRATERING: THE CASE FOR CONCENTRIC CRATERS. J. Ormö[1], K. R. Housen[2], I. Melero-Asensio[1] and A. P. Rossi[3], [1]Centro de Astrobiologia (INTA-CSIC), 28850 Torrejon de Ardoz, Spain (ormoj@cab.inta-csic.es), [2]Applied Physics, MS 2T-50, The Boeing Co, P.O. Box 3999, Seattle WA 98124, [3]Department of Earth and Space Sciences, Jacobs University Bremen, College Ring 1, 28759 Bremen, Germany.

Introduction: A cosmic impact is a violent interaction between a projectile and a target. How much the target influences the cratering depends on the ratio of target strength to the lithostatic stress, which in turn depends on the gravity, the target density, and the crater diameter. When this ratio is large, the crater size is determined by target strength and when it is small, gravitational forces determine crater size. Small, strength controlled concentric craters, i.e. craters with a wide outer crater developed in a weaker near-surface target layer, and with a deeper nested crater in the more rigid substrate, have proved useful to determine lunar regolith thickness [1, 2]. However, concentric morphologies occur also at much larger gravity controlled craters of reasons that are still not known [3]. As an example of such a target influence on the final crater shape at gravity controlled cratering, we are here presenting laboratory impact experiments in unconsolidated layered targets.

The terminology regarding concentric craters (i.e. outer crater, inner crater) was coined by Quaide and Oberbeck in their studies of small, strength controlled, lunar and laboratory craters [1]. The concentricity is in their examples due to a crater configuration made up of a shallow outer crater developed in the upper, low-strength layer surrounding a smaller, nested crater in the mechanically stronger substrate. When the surface layer is so thin that the energy transmitted to the substrate overcomes its dynamic yield strength a concentric crater develops. For larger, gravity dominated craters the relations have been successfully applied in numerical simulations when determining the thickness of a strengthless, upper layer, i.e the target water depth at marine-target craters [e.g. 4]. However, the mechanisms behind the concentricity of larger, gravity dominated craters in rock have not been analysed in detail. Figure 1 illustrates an example of such craters on Mars. Obviously, the cratering process in these cases must be different from that suggested for the small strength dominated craters in lunar regolith and previous experiments.

Even though strength can be considered of less importance for gravity dominated craters, there will still be differences in the density and the wave speed between the weaker upper layer and the rigid substrate. The product of these two factors is the mechanical impedance of a material. It determines how a shock wave reflects when it hits a boundary between two materials with different densities and wavespeeds. Possibly, for large gravity controlled craters, the differing impedances of the two layers could result in reflection of the shock, with a reduction of the energy transferred into the basement. It may be that it is the wavespeed, the density, or the combination of both (i.e. impedance) that is the critical factor. We are here investigating these effects with the use of laboratory impact experiments.

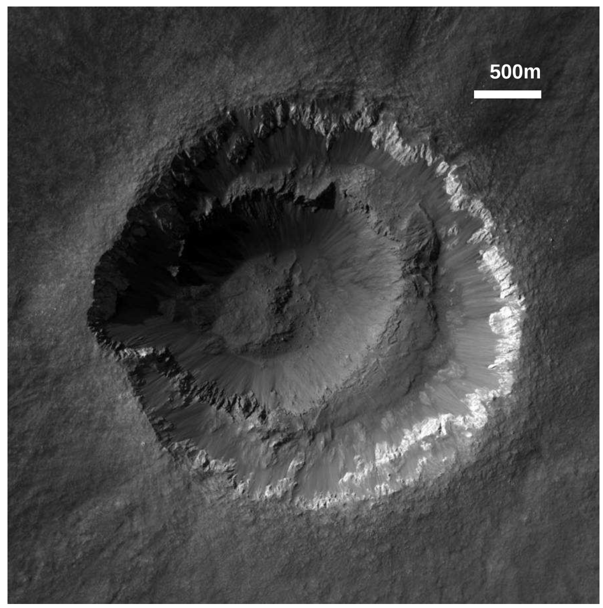

Fig. 1. Martian example of concentric crater formed in the gravity regime. HiRISE image PSP_001348_1770_RED.

Methods: In order to better understand gravity-dominated concentric crater formation, we are in the process of conducting impact experiments in a 1G setting at the Laboratory for Experimental Impact Cratering at Centro de Astrobiologia (CAB), Spain, and at the Boeing geotechnic centrifuge, Seattle, USA.

At this point we have conducted a single, half-space experiment on the Boeing centrifuge (Fig. 2A). A polyethylene cylinder (1.2 cm length and diameter, 1.8 km/s) impacted the target at nearly normal incidence under an acceleration of 150G. The target consisted of a 0.5 cm layer of dry quartz sand (1.5 g/cm^3) on top of dense chromite sand (3.8 g/cm^3).

Our preliminary experiments at CAB utilize a modified paintball marker (Fig. 2B) [for details see 5] in anticipation of a continuation with the more powerful

EPIC gun [see 3]. The experiment is in quater-space setting with the gun shooting a 16.1 mm diameter glass projectile at about 45 m/s along a polycarbonate window into a target made up of a layer of dry beach sand (1.56 g/cm^3) covering a substrate made up of iron grit sand (4.53 g/cm^3) of similar grain size. We conducted two shots at 5 mm dry sand layer thickness, as it best corresponds to the relative layer thickness configuration of the centrifuge experiment, one shot at 8 mm thickness, and one shot at 11 mm layer thickness.

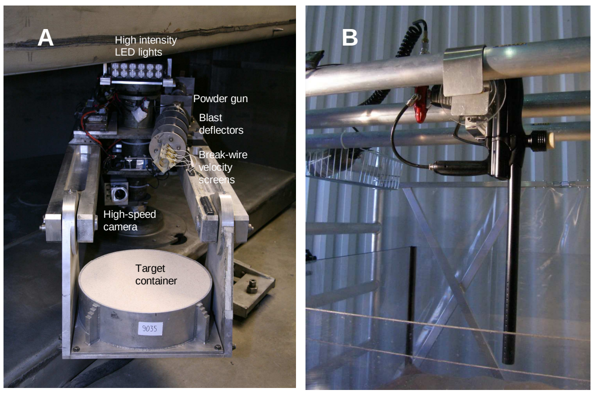

Fig. 2. The equipment used in the experiments. A) the centrifuge gun at Boeing, and B) the paintball marker at CAB.

Results: The shot with the centrifuge setup generated a concentric crater structure with an inner apparent crater diameter in the chromite sand of ~3.6 cm and an outer apparent crater diameter in the quartz sand of ~8 cm (Fig. 3). Ejecta from the chromite sand can be seen around the periphery of the inner crater. The same concentric morphology and ejecta distribution (i.e. inner crater ejecta partially covering the outer crater) are observed in the 1G experiments (Fig. 4).

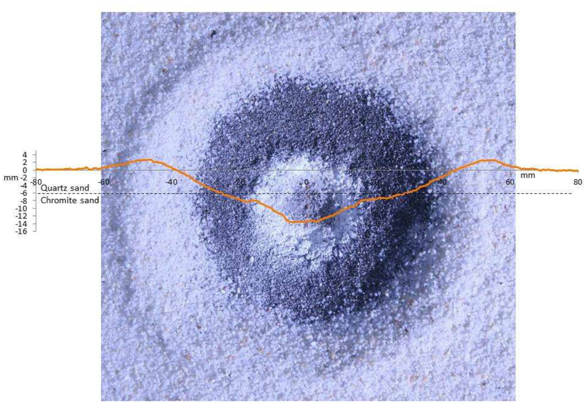

Fig. 3. Concentric crater generated at 150G with the Boeing centrifuge gun.

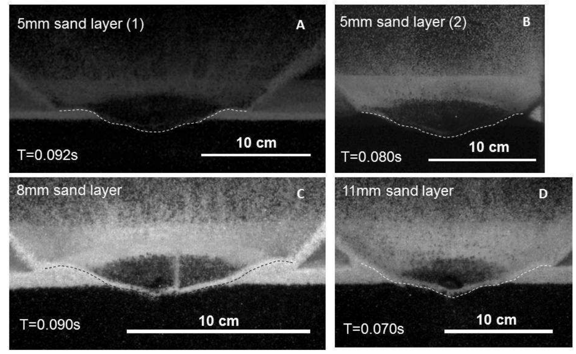

Fig. 4. Craters from four shots (A-C) with the paintball marker (glass projectile) at CAB.

Discussion: It is obvious from the experiments that the concentric crater growth may be related to differences in layer densities and/or wavespeed, which is of importance for large-scale, gravity dominated cratering, and not only strength differences as hitherto assumed. However, it is yet too early to tell how our experiments scale to natural craters, it depends on whether a point source applies or not. The centrifuge method allows crater formation to be studied at size scales much larger than can be accommodated in the lab. A small-scale cratering experiment conducted at, say 150G as used in this study, simulates the lithostatic stress and corresponding shear strength of a 1G crater that is 150 times larger in size. At present, we have only a few data points and we are working on the scaling relations to help relate the 1G experiments with those done in the centrifuge, and to larger scale events.

References: [1] Quaide W. L. and Oberbeck V. R. (1968) *JGR, 73*, 5247-5270. [2] Bart G. D. et al. (2011) *Icarus, 215*, 485–490. [3] Ormö et al. (2012) *Meteoritics & Planet. Sci.*, (in press). [4] Lindström M. et al. (2005) *Planet. Space Sci., 53*, 803-815. [5] Ormö et al. (2010) *Geol. Soc. Am. Spec. Pap., 465*, 81-101.

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