EXPERIMENTAL CRATERING INTO LAYERED TARGETS: MEMIN EXPERIMENTS WITH MAGGIA GNEISS.

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Introduction: The surfaces of earth as well as several other planetary bodies consist to a large degree of either sedimentary rocks or others lithologies that have a distinct layering and stratification. A few studies have dealt with the effects of layering on the impact process. Lithological interfaces can lead to shock pressure excursions, additional accumulated strain, and localized shear displacements as observed both on the micro-scale [1] as well as in the field [2,3]. Within the MEMIN Research Unit, exploratory impact experiments were performed on targets with varied layering to gauge how this affects experimentally measurable cratering features.

Methods: Two impact experiments were carried out at the two-stage light-gas gun facilities of the Ernst-Mach Institute on Maggia gneiss. Spherical aluminum projectiles with diameters of 5 mm were accelerated to ~7 km/s. Targets were 25 cm edge length cubes. The impacts were recorded with high-speed cameras and ejecta particle catchers were set up opposite of the target surface. The target in the first experiment (A37) was set up with the gneiss layering perpendicular to the direction of impact; the second experiment (A38) had the parallel layering.

Maggia gneiss, a metamorphic gneiss from the Maggia valley in southern Switzerland, was chosen as a target material due to its fine interlayering of feldspar- and quartz-rich bands with biotite-rich mafic bands. The gneiss layers are 1-2 mm thick and thus both smaller than the diameter of the projectile as well as an order of magnitude smaller than the expected crater depths and diameters. The banding is very homogeneous and planar throughout the target blocks. Brazilian disc tensile experiments were carried out parallel and perpendicular to the gneiss layering and show surprisingly little difference at 7.0±2.2 and 7.1±1.2 MPa, respectively. Compressive strength measurements will be carried out in the near future. The density is estimated at 2.7 g/cm³.

Results: Crater profiles generated from 3D scans show that the crater from the experiment with perpendicular layering (A37) is wider and deeper than the crater with parallel layering (A38; Fig. 1). Depths are 1.8 and 1.4 cm, average diameters are 8.5 and 7.1 cm, respectively. Surprisingly, depth-diameter ratios (d/D) are nearly the same at 0.21 and 0.20. On the other hand, A37 has a larger volume than A38, with 24.2 cm³ compared to 18.3 cm³. A closer look at the morphology does show that A37 has a flat outer region with a sharp transition to a steeper pit, while A38 shows a smoother inwards slope. From the imprint of the ejecta cone into the ejecta catchers, ejecta angles can be derived. A37 has a slightly broader cone, with angles measuring 59° to the target surface than A38 with 61°.

Discussion: The larger size as well as the wider ejecta cone angle in the target with perpendicular layering (A37) is interpreted as an expression of structural weakness parallel to the target surface. Crater width is determined by the size of spall plates which here show step-wise tensile fracturing along weak, biotite-rich layers. The deeper central region of A37 reflects exploitation of the biotite layers upon shock relaxation [c.f., 4]. The wider cone angle is presumably due to reduced resistance of these weaker layers during excavation. These results also compare well to previous MEMIN experiments on sandstone, where larger craters were formed by impacts into targets with perpendicular layering orientation than into an exploratory experiment with parallel layering orientation.

Outlook: We plan to examine microscale subsurface deformation and compare compressive deformation styles versus tensile relaxation phenomena for further insights on the effects of layering.

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References: [1] Heider N. & Kenkmann, T. 2003. MAPS 38:1451-1460. [2] Kriens et al. 1999. JGR 104:18867-18887. [3] Kenkmann & Ivanov 2006. EPSL 252:15-29. [4] Winkler et al. 2016 MAPS, accepted.

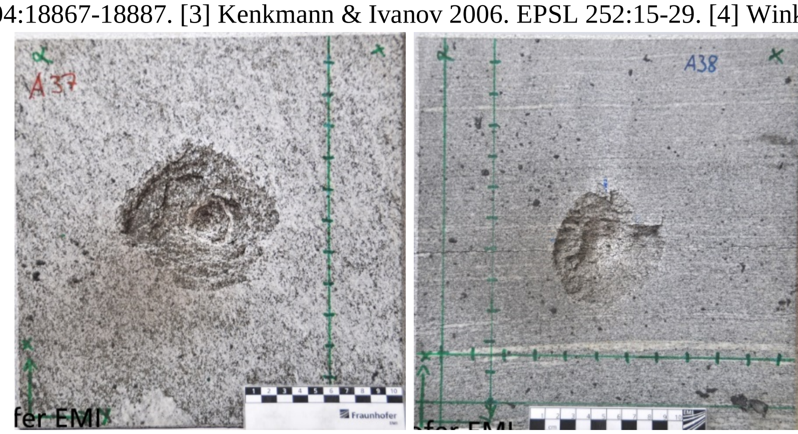

Fig. 1: Impact craters in Maggia gneiss. Layering is perpendicular to the direction of impact in A37 (left) and parallel in A38 (right). The resulting crater is larger for perpendicular layering.