PROXIMAL EJECTA EMPLACEMENT OF A VERY SMALL IMPACT CRATER BASED ON 100 M IN DIAMETER MORASKO CRATERS IN POLAND.

A. Losiak[1], M. Szokaluk[2], P. Rozwalak[2], A. Sierzputowska[2], M. Baranowska[2], W. Szczuciński[2], M. S. Huber[3]. [1]Institute of Geological Sciences, Polish Academy of Sciences (ul. Podwale 75 50-449, Wroclaw, Poland, anna.losiak@twarda.pan.pl), [2]Faculty of Geographical and Geological Sciences Adam Mickiewicz University, Poznań, Department of Earth Science, University of the Western Cape, RSA.

Résumé: L'épaisseur de l'éjecta proximal de Morasko est hétérogène et varie de plus de 50 %, à équidistance du bord du cratère, selon les directions. Le paleosol est conservé sous 6% de la couverture d'éjectas. Les traces d'une d'éjectas avec à la base une coulée de débris, sont observes jusqu'à à 0,1R du bord du cratère.

Introduction: Most numerical modelling and laboratory experiments generally assume that target material is homogenous in its properties within each horizontal layer. Although there are some examples of impact craters that, to some extent, fulfil this constraint (e.g., Barringer [1] or Kaali [2], most asteroids impact into more complex, heterogenous targets. This issue is especially important for smaller craters (<200 m in diameter) in which strength and physical properties of the target material play a more significant role in shaping the final form of the structure.

The aim of this study is to analyse the proximal ejecta blanket of a very small impact crater developed in heterogenous, irregularly distributed and unconsolidated materials to better understand the ejecta deposition process (e.g., ballistic deposition vs radial flow, ejecta-target surface mixing).

The Morasko Craters are a strewn field consisting of ~7 craters formed ~5 ka [3]. The largest crater is ~100 m in diameter and 30 m deep. They are located on a slope of a glacio-tectonically modified moraine of the last glaciation ~20 ka. The target consists of up to a couple of meters of glacial/fluvioglacial sand, up to a couple of meters of glacial till (called “diamicton without clasts” in [3]), underlaid by glacio-tectonically affected Neogene clays at depths up to a couple of meters. The distribution of all those materials is patchy.

Methods: Within the proximal ejecta blanket of Morasko, we made 42 drillings with full sediment core recovery, 194 hand drillings, and a 16 m long up to 2 m deep trench (as part of the PhD of Monika Szokaluk [3]) A location of trench excavated in 2021 (52.48972303 N, 16.8968134 E; Fig. 1) was selected to target a preserved paleosol so that the boundary between ejecta and target rocks is certain. The trench was L-shaped to analyse the proximal ejecta profile along the radial and tangential directions in relation to the largest Morasko crater. The longer walls of the trench were 3.5 m in diameter and approximately 2.3 m deep.

Results and Discussion: Clear signs of the ***paleosol*** have been detected in 6% of the drill cores (6 out of 42 full-recovery cores, 8 out of 194 hand-drillings). A ~30 cm long section of the paleosol was also present in the northern part of the 16 m long trench, and along most of the new L-shaped trench. In all cases, the paleosol was developed on sands, however this may be an observation bias, as it is easier to observe a small addition of organic material in light-coloured sand than in glacial tills; modern soils developed on Neogene clays in this area are thin.

As expected, the most likely place to preserve a paleosol is at/near the rim (8 out of ~80 drill sites = 10%), but in most places at the rim there are no signs of the paleosol. This may be related to initially patchy soil formation, but at least in some places, it is caused by target surface destruction during ejecta deposition. Interestingly, preserved paleosols seem to co-locate with the clay/till patches at the surface [3], potentially suggesting that clay/till blocks might have shielded the surface from interaction with more energetic sections of the ejecta.

Ejecta maximal thickness (material above the paleosol) decreases from 2 m at the crater rim, to 60 cm at the 1.5 radii from the crater centre (further away it becomes harder to recognise the ejecta because of the overwriting by modern soil processes). However, the thickness at the same distance from the crater can vary by >50%; e.g., within the L-trench ejecta is 175 cm thick while less than 50 m to the East, at the same geomorphological setting it is only 70 cm. This shows a high level of heterogeneity in impact craters developed in heterogenous target rocks.

Ejecta deposition process: Most of the ejecta is made of diamicton with clasts / ”sedimentary breccia” formed by mixing of all target materials, with more competent, angular clasts of Neogene present within till- and sand-rich matrix. Clasts display signs of brittle deformation (like cracks filled with matrix), but there is no sign of clasts or microstructures elongated/deformed in a way suggestive of any material flow. This is consistent with a simple ***ballistic deposition*** without much later movement.

Within the L-shaped trench, at the rim, ejecta is 175 cm thick (Fig. 2) and consists of overthrown, but not inter-mixed target material types with inverted stratigraphy: 10-20 cm of sand, 10-80 cm of glacial till, and 70-130 cm of Neogene clays. A presence of slightly tilted wave-shaped block of glacial till suggests that this zone experienced a type of ***debris flow***/movement like one suggested to explain double-layered ejecta craters on Mars [4], but in a much smaller scale. At Morasko, the extent of the debris flow region is very limited (from the rim up to ~10 m or 0.1 Radius). It is a transitional zone between the overturned flap where different target rocks move as a single block (e.g., in Barringer [1]), and location within proximal ejecta that is dominated by ballistic deposition. The tilting of a wave-shaped till block (Fig 2), shows that the top part of the ejecta (clays) was moving quicker/longer than the till. The till-clay boundary behind the wave-shaped till block is smooth and seems to be erosional, indicating that clay was sliding along the till, similarly to basal slip of ejecta at Ries [4]. The boundary in the crater-facing section of the wave-shaped till block is rough, with clay sections penetrating till up to 5 cm depth. We interpret it to mean that while glacial till and clay were first moving as separate packets within ejecta (erosional surface was formed), then the top part of the till was piled up and formed an obstacle for the quicker/longer moving top section of the clay-rich ejecta. This obstacle was pushed outwards by the clay-rich ejecta giving it this leaning appearance, the crater-facing side of the till obstacle started to be torn what resulted in a rough appearance of the contact. This single till block was experiencing both brittle and ductile behaviour during ejecta process within distance of <1 m.

This finding indicates that debris flow may be an important process during the ejecta deposition of very small impact craters, although its spatial extend is limited to the first 0.1 R outside the crater rim. Observations suggestive of a debris flow in a similar geomorphoplogical setting were made in Kaali Main crater proximal ejecta (100 m in diameter, 3.5 ka old, Estonia), what suggests this process is common, even if target rocks were not saturated with water like it was suggested in Ries [4], Stac Fada impact layer in Scotland [5,6] or in case of double-layered ejecta craters on Mars [7].

References: [1] Kring 2017. LPI Contribution No. 2040 [2] Losiak et al. 2016. MAPS 51:681–695. [3] Szokaluk et a. 2019. MAPS 54: 1478-1494. [4] Kenkmann and Ivanov 2006 EPSC 252: 15-29. [5] Amor et al. 2019. JGS 176: 830–846. [6] Osinski et al. 2021 JGS jgs2020-056. [7] Wulf and Kenkmann MAPS 50: 173-203. **Acknowledgements:** Research was funded by the National Science Centre, Poland grant no: 2020/39/D/ST10/02675. Travel grant to attend CIRIR-Congress-Festival 2021 was provided by Europlanet.

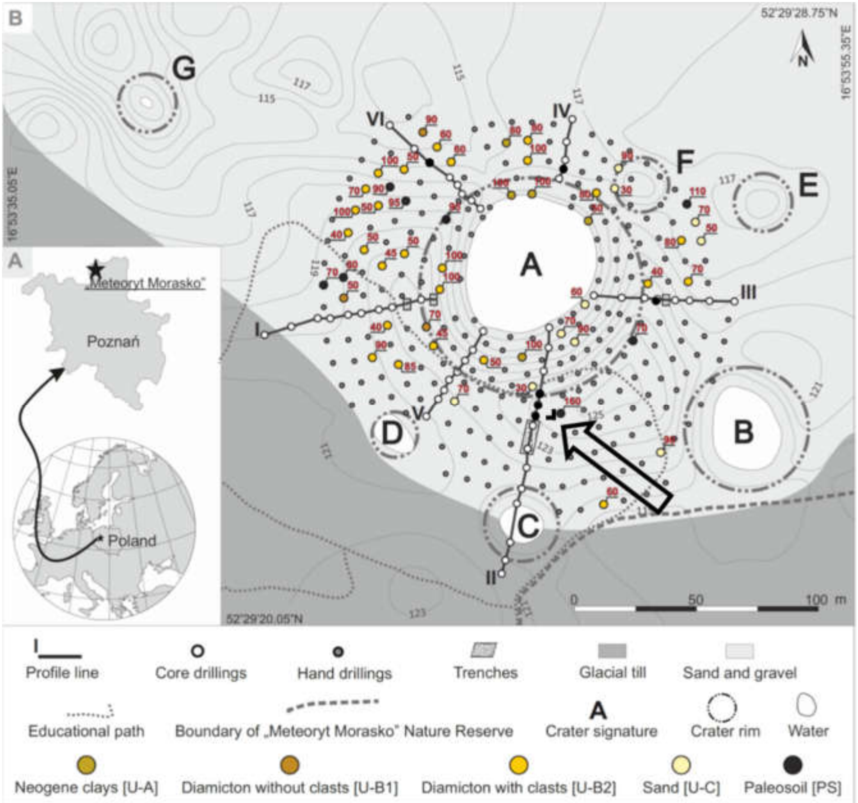

Fig. 1. A) Location of the study area ("Meteoryt Morasko" Nature Reserve) within Europe and the city of Poznan, Poland. B) Morasko impact craters (lettered from A to G) with marked locations of the investigated core and hand drillings and trenches (the 2021 trench is marked with a black L shape and an arrow). Drillings with numbers show locations with documented paleosol (black dot) or charcoal within ejecta (colorful dots – not discussed further in this abstract). Numbers describe the depth at which they were found.

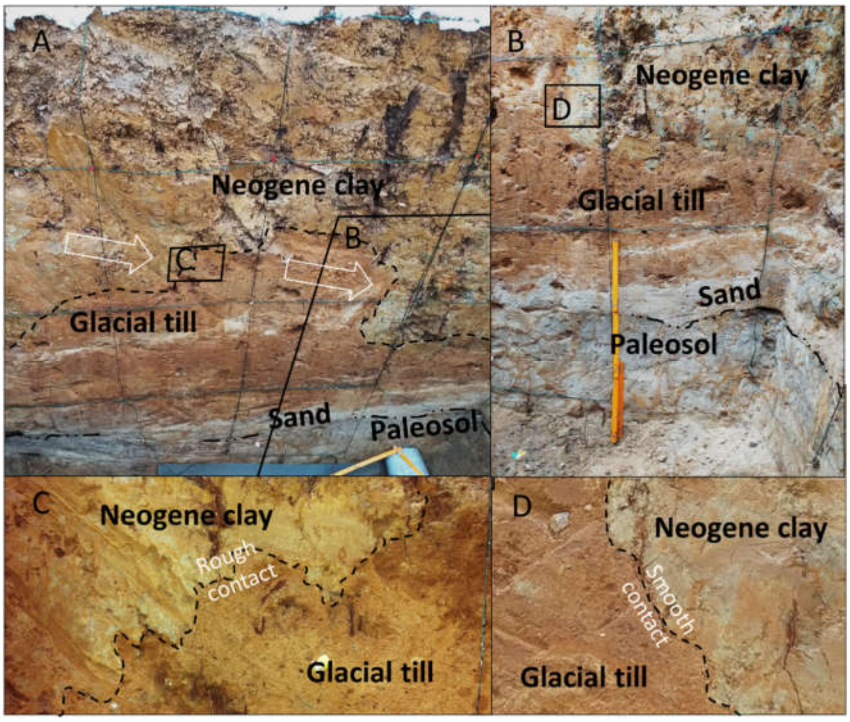

Fig. 2. The L-shaped 2021 trench within proximal ejecta, made at the current southern rim of the Morasko. All photos show the trench wall along the radial direction, the crater is to the left, white arrows show the direction of sediment movement. The reference grid is set up every 50 cm. A) A full section through the ejecta, paleosol is at the depth of 175 cm. B) The paleosol, with the preserved structure of roots-pseudomorphs. C) A section with a rough till-clay contact at the side of the till obstacle closer to the crater rim. D) Smooth outline of the till-clay contact at the side of the till-obstacle further away from the crater rim.