IMPACT CRATER FORMATION: INSIGHTS FROM >6,500 METERS OF SHOCK ATTENUATION IN THE CENTRAL UPLIFT OF THE SILJAN IMPACT STRUCTURE, SWEDEN.

S. Alwmark[1,2], C. Alwmark[2], L. Ferrière[3], J. Martell[2], A. S. P. Rae[4], and G. Zachén[2], [1]Niels Bohr Institute, University of Copenhagen, Blegdamsvej 17, 2100 Copenhagen, Denmark (sanna.alwmark@geol.lu.se), [2]Department of Geology, Lund University, Sölvegatan 12, 22362 Lund, Sweden, [3]Natural History Museum Vienna, Burgring 7, A-1010, Vienna, Austria, [4]Department of Earth Sciences, University of Cambridge, Downing Street, Cambridge, CB2 3EQ, UK.

Introduction: In order to understand the major processes involved in the formation of impact craters, ground-truth data from terrestrial impact structures is crucial. Many aspects of the cratering process remain more or less elusive, for example how the energy released by the impact is distributed in the target rocks, how geologic materials behave upon shock compression, as well as a number of aspects relating to central uplift formation. Systematic studies of shock attenuation at the scale of an impact structure (i.e., both at surface and with depth) are limited, particularly for complex impact structures, and especially observations at greater depths than some hundreds of meters. Such information can yield important insight into faulting and displacements, as well as target rock deformation during central uplift or peak ring formation, and may also help to constrain the dynamics of complex crater collapse (see discussion in e.g., [1]). Shock barometry, i.e., establishing shock pressure estimates for rocks in impact structures, provides critical input for numerical models of crater formation (see, e.g., [2-4]), especially to test the validity of mechanisms invoked in numerical simulations, such as acoustic fluidization [5]. Previous studies in which the deformation of central uplift or peak ring rocks were investigated include e.g., [2-4,6-8], however, in only one of them [7], at the Puchezh-Katunki impact structure (Russia), the shock attenuation was investigated down to significant depth.

Here, we report on preliminary results of a shock barometric study of quartz grains from drill core cuttings samples obtained from the Stenberg-1 deep drill hole (>6,600 meters deep) which is located in the center of the ~52 km-in-diameter Siljan impact structure (in south-central Sweden; see review by [9]).

Results and Discussion: Measurements of optic axes and poles to planar deformation features (PDFs) in quartz grains from the investigated drill cuttings were obtained for four samples, and, then indexed following the method described e.g., in [10]. The samples investigated thus far (i.e., additional samples will be investigated in the coming months) span a depth between 1,698.7 to 6,617.8 m below the surface. Based on the PDF orientations in quartz, we estimate average shock pressures at which the samples were subjected to during the impact (see method in [11], all pressures reported here are the average of all shocked quartz grains measured in a given sample). Based on previous works [11,12], using the exact same methodology, shock pressures are known to be of ~16.2 GPa at the surface approximately where the Stenberg-1 drillhole is located. In the investigated samples, we have determined a shock attenuation with 13.4 GPa recorded at 1,698.7 m, 12.1 GPa at 1,839.5 m, 8.2 GPa at 3,678.9 m, and 6.2 GPa at 4,913.4 m depth. Quartz grains from shallow drill cuttings samples display between 1.7 and 2.1 PDF sets per grain, and the PDF population in these samples is dominated by sets parallel to the (0001) and $\{10\bar{1}3\}$-orientations, with less common PDFs parallel to the $\{10\bar{1}4\}$, $\{10\bar{1}2\}$, and $\{10\bar{1}1\}$-orientations. Quartz grains in the deeper investigated samples have PDFs parallel to only the (0001)-orientation, and the grains have only one set of PDFs/grain on average, with up to ~50% quartz grains in which no obvious shock metamorphic features were noted.

The distribution of shock effects in the central uplift of complex impact structures is expected to be modified by movements during uplift formation, yet we see a smooth decline in shock pressures with increasing depth, consistent with observations at other impact structures by e.g., [2-4,7]. Further work to obtain a comprehensive shock attenuation profile over the entire length of the drill hole will be combined with existing surface observations to build a unique three-dimensional model of shock attenuation at Siljan.

Acknowledgements: The authors are grateful to Linda Wickström and colleagues at the Swedish Geological Survey that provided the material. S. Alwmark was supported by the Swedish Research Council (grant #2017-06388).

References: [1] Kenkmann T. et al. (2013) in Osinski G. R. & Pierazzo E. (eds.), *Impact cratering: Processes and products*, Wiley-Blackwell Publishing, p. 60–75. [2] Ferrière L. et al. (2008) *Science* 322:1678–1681. [3] Holm-Alwmark S. et al. (2017) *Meteoritics & Planetary Science* 52:2521–2549. [4] Rae A. S. P. et al. (2017) *Meteoritics & Planetary Science* 52:1330–1350. [5] Melosh H. J. (1979) *Journal of Geophysical Research* 84:7513–7520. [6] Fel'dman V. I. et al. (1996) *Dokl. Akad. Nauk SSSR* 349:658. [7] Masaitis V. & Pevzner L. A. (1999*) Deep Drilling in the Impact Structure: Puchezh-Katunki, Russia*, VSGEI, St. Petersburg. [8] Feignon J.-G. et al. (2020) *Meteoritics & Planetary Science* 55:2206–2223. [9] Holm-Alwmark S. (2021) in Reimold W. U. & Koeberl C. (eds.) *Large Meteorite Impact and Planetary Evolution VI*, Geological Society of America Special Paper 550, p. 1–39. [10] Ferrière et al. (2009) *Meteoritics & Planetary Science* 44:925–940. [11] Holm-Alwmark S. et al. (2018) *Meteoritics & Planetary Science* 53:110–130. [12] Holm S. et al. (2011) *Meteoritics & Planetary Science* 46:1888–1909.