SIMS U-Pb Dating and EBSD Structural Analyses of Granular Zircon from the Mien Impact Structure, Sweden. M. Herrmann\(^1\), J. Martell\(^1\), C. Alwmark\(^1\) and M. J. Whitehouse\(^2\). \(^1\)Geology Department, Lund University, Sölvegatan 12, 22362 Lund, Sweden. maria.herrmann@geol.lu.se; \(^2\)Swedish Museum of Natural History, Box 50007, 10405 Stockholm, Sweden.

**Introduction:** Granular zircon is considered to represent the extreme P-T conditions of an impact event (e.g., [1]). It is made of sub-micrometer neoblasts that either recrystallize from amorphous ZrSiO\(_4\) or formed by the reaction between ZrO\(_2\) and a Si-rich impact melt [1] or due to the re-convertion of reidite to zircon [2]. Neoblasts are formed at temperatures above 1100-1200°C [1], [2] which exceeds the closure temperature for Pb diffusion in zircon (900-950°C, [3]), and thus, their formation should potentially be sufficient to completely, or partly, reset the U-Pb system [4]. Previous U-Pb analyses on granular zircon, e.g., from the Vredefort crater, South Africa (e.g. [5]), the Chicxulub crater, Mexico (e.g. [6]), the Sudbury crater, Canada (e.g. [7]) or the Manicougan crater, Canada [8] have yielded reliable impact ages.

Here we present the preliminary results of the U-Pb analyses by SIMS spot analysis and ion imaging combined with EBSD data of shocked zircon from impact melts of the Mien impact structure. Various shock features in zircon grains from the Mien impact structure, from non-granular through porous and partly to fully granular, have previously been described in detail by [9]. In this study, non-shocked to fully granular grains were analysed in order to see (1) to what extent the zircon grains show a reset of the U-Pb system, and (2) is there a link to the Mien impact event?

**Mien impact structure:** The Mien impact structure is located in the province Småland, southern Sweden. The diameter of the structure is 7 km [10]. Mien was formed in Precambrian crystalline basement consisting of gneissic granites and granodiorites (e.g. [11]). The bedrock is covered by glacial sediments. Along the southern shore are boulders of impact melts (e.g. [11]). Previous authors [10], [11], [12] described them as lava-like rocks. Drilling campaigns (e.g. [11]) confirmed the existence of a 20-25 m thick melt sheet that covers brecciated bedrock. Discoveries of shock features, e.g., planar deformation features in quartz [13], considered an impact-origin. Whole rock data of impact melts through \(^{40}\)Ar/\(^{39}\)Ar, K-Ar and fission track dating reveal a broad age range between 121 and 92 Ma [14], [15], [16], [17], where according to the Earth Impact Database (2019) the best-estimate of 121.0±2.3 Ma by [15] is the currently accepted impact age for Mien.

**Sample material and methods:** We separated several zircon grains from three different samples: melt-bearing breccia, clast-rich and clast-poor impact melt. For a detailed description of the sample material see [9]. The U-Pb analyses (n = 123 spots) and ion imaging (n = 49 images) were done by secondary mass spectrometry (SIMS) on a CAMECA IMS1280 ion microprobe of the NordSIMS group at the Swedish Museum of Natural History in Stockholm. The size for spot analysis was 10x10 \(\mu\)m and for ion imaging 1x1 \(\mu\)m, 91500 was used as reference material. The data reduction was carried out by an in-house developed software whereas the age calculations and Tera Wasserburg plots were made using Isoplot (version 4.15, [18]). Imaging of zircon grains by SE, BSE and CL detectors, in order to identify shock features, such as granular texture, and microstructural analyses of granular grains by electron backscatter diffraction (EBSD) were carried out on an FE-SEM with an accelerating voltage of 15 kV at the Department of Geology, Lund University.

**Results:** The FE-SEM analyses revealed the presence of non-shocked, partly porous, fully porous, granular-porous and fully granular zircon in all three samples (e.g., Fig. 1a & d). The pores of the porous grains and the neoblasts of the granular grains, both have a maximum diameter of 5 \(\mu\)m. The pores occur in zones, which are often associated with simple or oscillatory zoning. Some zoning is related to metamict zircon. Some shocked grains show bright inclusions of ZrO\(_2\). Planar features are sporadic.

The U-Pb data of all three samples reveal discordant to concordant analyses scatter near a regression line with MSWDs between 26 and 218. Data points from non-zircon mineral phases (e.g. monazite) or points identified as outliers due to a high uncertainty in the \(^{207}\)Pb/\(^{206}\)Pb ratio are excluded. The upper intercepts range from 1741 ± 53 to 1697 ± 59 Ma whereas the lower intercepts lie between 143.0 ± 62.0 and 121.0 ± 9.2 Ma.

The ion imaging maps show a variable distribution of U and Pb which often has no correspondence to zoning observed in the CL derived images. Both elements can be either evenly distributed or concentrated in nodules and patches (Fig. 1b & e). The nodules can be correlated with the pores of porous zircon. It is notable that in granular grains both elements are often concentrated at the same site, whilst in most of the porous grains U and Pb occur at different sites within a grain. Here the U is mostly concentrated in porous zones and
thus, occur preferentially in nodules (Fig. 1b) whereas Pb is predominantly situated within the non-porous zones.

The microstructure of 17 zircon grains from the clast-poor impact melt, ranging from partly porous to fully granular, were analysed by EBSD. The porous grains look homogeneous without any sign of recrystallization by misoriented neoblasts (Fig. 1c), whilst the neoblasts of the granular grains show a variable orientation (Fig. 1f). Five of these granular grains can be identified as FRIGN zircon. In accordance to [19], our pole figures of the neoblastic grains are consistent between (110) and (001) showing two to three clusters with an ~90° orthogonal angle and high misorientations between the neoblasts (Fig. 2).

**Conclusion:** The data processing, especially of the ion imaging, is still in progress. Thus, the interpretation of the data is preliminary.

The upper intercepts of the U-Pb spot analyses are consistent with the 1.7 Ga crystallization age of the target rock [20]. The lower intercepts of the zircon from the clast-rich (124.2 ± 7.8 Ma) and clast-poor (121.0 ± 9.2 Ma) impact melts overlap temporally with the 121.0 ± 2.3 Ma impact age [15] and thus, indicate a linkage to the impact event. It is notable that the partly to fully porous grains tend to plot closer to the upper intercepts along the regression lines, whereas the porous-granular and fully granular grains occur closer to the lower intercepts. It might suggest that granular zircon experienced Pb loss to a larger extent compared to porous zircon. The ion imaging maps of the porous zircon grains, with the U concentrated in the porous and Pb in the non-porous zones (Fig. 1b), implies that U and Pb were fractionated without complete opening of the U-Pb system during the impact event where in consequence today the U is concentrated in the porous and Pb in the non-porous zones (Fig. 1b). According to FE-SEM analyses, no neoblasts are developed indicating that the porous grains did not exceed a temperature of 1100-1200 °C [1], [2] (Tc for zircon U-Pb = 900-950°C, [3]) and thus, the P-T conditions were not high enough to reset the U-Pb system properly. In contrast, the U and Pb within the granular zircon grains tend to be more evenly distributed. It seems not only Pb moved via diffusion, but likely U was mobile, too, during the impact event and thus, both elements occur at the same sites within the grains. FRIGN zircon together with ZrO₂, like in our case, indicates impact-generated temperature conditions above 1673 °C [19], which finally exceeded the closure temperature of Pb in zircon and caused Pb loss. One of the FRIGN zircon grains (Fig. 1d-f) is even concordant with the concordia curve at the lower intercept. It implies that the complete Pb loss of this grain was actually triggered by the impact event and thus, the lower intercept date of the clast-rich impact melt can be treat as a reliable impact age (121.0 ± 9.2 Ma).