SHOCK METAMORPHIC FEATURES IN ZIRCON GRAINS FROM THE LAKE MIEN IMPACT STRUCTURE IN SWEDEN J. Martell, C. Alwmark, P. Lindgren, L. Johansson. Dept. of Geology, Lund University, Sölvegatan 12, 22362 Lund, Sweden (josefin@martell.se)

Introduction: This is a study of zircon microtextures from the Lake Mien impact structure in Sweden. Zircon can contain a range of microtextures as a result of shock metamorphism during impact cratering. Examples are {100}-parallel deformation bands and mechanical twins along {112} [1], the development of granular textured zircon [2], and the conversion of zircon into its high-pressure polymorph reidite [3]. This study has focused on characterizing and comparing zircons from three different impact lithologies at Mien: (i) a clast-rich impact melt, (ii) a clast-poor impact melt and (iii) a melt-bearing suevite breccia. This study aims to describe any variations in quantity and textural features of zircon grains between the different lithologies, and determine the degree of shock.

Overview of the Mien Impact Structure: The Mien impact structure is located in Småland county in south eastern Sweden (56.41812°N 14.85785°E). The original rim diameter (pre-erosion) is estimated to about 9 km [4] and the current topographic diameter is 6-7 km [5]. The target rock is composed of granite and gneiss as part of the ”Transscandinavian Igneous Belt”. No outcrops are available at Mien, but samples of impactites occur in the glacial till as boulders around the lake. Also, four drillings were carried out in 1973 at the small island Ramsö in the NW part of the crater lake. The drill cores are composed mostly of impact melt rocks of varying compositions, but they also contain a horizon of suevite breccia and lithic brecciated granitic gneissic sections at the base of the cores [8].

The latest dating of the structure was conducted in 1978 by [5] with the ^{40}Ar-^{39}Ar-method, and yielded a plateau age of 118±2.3 Ma for the impact event. Previous studies done in the late 70s confirmed shock-indicative textures in quartz such as planar deformation features (PDFs), and also its high-pressure polymorph coesite [8].

Samples: Impactites were collected during an expedition to Lake Mien in early fall 2017. Three samples were chosen for further analysis: (i) clast rich impact melt rock (CR), (ii) clast poor impact melt rock (CP) and (iii) suevite breccia. From these rock samples zircon grains could be extracted; 123 grains from CR, 75 grains from CP and 57 grains from the suevite breccia.

Methodology: Zircon grains were separated by handpicking and mounted on stubs with carbon tape. The grains were imaged and analyzed with backscatter imaging (BSE), secondary electron imaging (SE) and in some cases cathodoluminescence (CL) imaging in a Tescan Mira3 High Resolution Schottky field emission scanning electron microscope (FE-SEM) equipped with Oxford EDS detector at Lund University. After the analysis of the whole grains, a total of 131 grains including all lithologies, were chosen for further study and cast in epoxy mounts. These samples were polished to mid-section, and used for a second SEM analysis to study and describe the interior textures of the zircons. Three grains will also be dated using U/Pb LA-ICP-MS in future work. Thin sections of the three impactites were also studied in petrographic microscope.

Results: *Zircon grains:* Grains were categorized based on their external and internal texture. 30% of the un-polished grains from the CR had a granular texture with average neoblast diameters of 2 µm (Fig. 1; 2). This texture was found in 24% of the zircon grain from the CP and in 16% of the suevite breccia sample. Microporous texture (as described by [9]) was found abundantly in the impact melt rocks (70% in the CR and 53% in the CP), these could be either isolated pores or consist of larger confined microporous regions (Fig. 1; 2). In the suevite breccia, only 15% of the grains exhibited micropores, and when found these were covering smaller areas than in the impact melt rocks. A more common surface texture found in the suevite breccia is “corroded” areas. This texture is best described as smooth and shallow marks at the surface of the grains, as if the surface has been corroded.

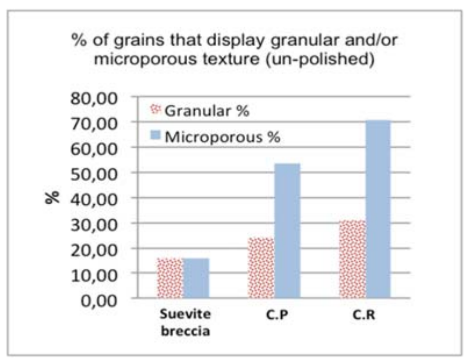

Figure 1. Diagram showing % of granular and microporous texture respectively for un-polished zircon grains in each impactite rock sample. Note that both textures can occur within the same grain, why the percentage may exceed 100%.

Grains that were polished to mid-section had in a few cases granular texture, and thus this texture can be penetrative. This texture was most common in the clast poor impact melt rock.

Microporous texture was found in the polished samples (in grains where it had also occurred at the surface) and had no obvious general pattern such as pores confined to the rims of the grains or along zoning. Granular texture together with micropores within the same grain occurred both in un-polished and polished samples.

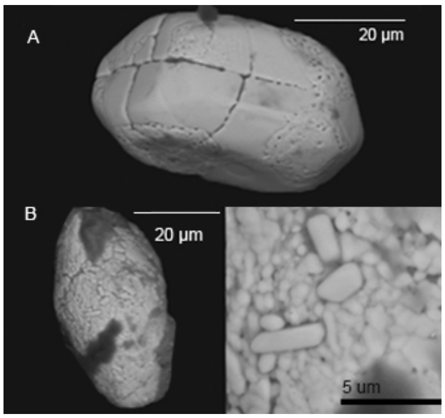

Figure 2. SEM-BSE micrographs showing A) a grain from clast poor impact melt rock with microporous patches, and B) a granular grain from clast poor impact melt rock, close up showing neoblasts.

Discussion and conclusion: In a compilation of case studies on shock metamorphic zircon by [10], all P-T paths show that granular textures in zircon form late in the P-T history experienced by the grain, and the formation could be either due to the reversion from reidite to zircon by heating above 1200°C [10] or where formerly dissociated zircon (at 1673°C [11]) is reconstituted through the process of ZrO_2 grains reacting with Si-saturated impact melt [10].

In order to determine the degree of shock experienced by zircon in this study, it is necessary to gain insight in orientations between neoformed zircon granules and the host zircon. If no lamellar or granular reidite is found, orientation analysis can be used to identify former presence of high-pressure phases, which would indicate pressures >30 GPa for shock metamorphism [10]. EBSD analysis is planned for future work on the Mien zircon.

Zircon grains in this study also exhibit microporous texture, which by [9] has been described as an "unusual vesicular texture" with grains consisting of smooth- and microporous regions. They suggested that this texture would be a result of the highest degree of shock, just below the melting temperature of zircon. In future work, Raman and EBSD analyses will be conducted on the microporous grains from Mien to further examine this texture.

In this study, ballen quartz was found in thin sections of both impact melt rocks. No ballen quartz was found in the suevite breccia sample. Ballen quartz can occur in both impact melt rock and in suevite breccia [12]. According to annealing experiments, the presence of ballen quartz provides indirect constrains on peak temperature- and pressure experienced by the rocks during impact, with temperature ~1200°C [13] and pressure ~30-35 GPa [14].

Based on abundance and size of granular- and microporous textures in the zircon, the impact melt rocks would have experienced higher shock pressure than the suevite breccia. The higher abundance of penetrating granular textures in the CP could possibly be an indication that these have been subjected to higher shock pressures. This is in accordance with the general stratigraphy of impactites (from bottom upwards): suevite breccia → clast rich impact melt rock → clast poor impact melt rock [15]. However, granular zircon is not by itself unique to impact environments as shown by [16]. Because of this, further information on the Mien zircon grains needs to be obtained.

One important application with recrystallized zircon is that it can enable dating of impact events [9]. U/Pb dating will be carried out on some of the zircon grains in future work. Since the granules in this study are small (<5 μm) and the LA-ICP-MS spot size is ~20 μm, the idea would be to use a fully granulized grain and focus at a bigger portion of the grain.

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