ZIRCON TO REIDITE AND BACK AGAIN: USING NANO-SCALE FABRICS TO CONSTRAIN TRANSFORMATION MECHANISMS

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Introduction: Zircon ($ZrSiO_4$) is widely used to study and constrain impact cratering events. At high pressure, zircon transforms to its polymorph reidite; at high temperature, reidite reverts to zircon [1]. Both the forward and backward transformation result in crystallographic orientation relationships between zircon, reidite, and back-transformed (FRIGN) zircon [2]. Most occurrences of reidite are μm-scale lamellae within zircon, but an increasing amount has been found in other forms such as granular, wedge, bladed, and massive, with reidite making up >90% of some $ZrSiO_4$ grains [3]. Many phase transition mechanisms have been proposed, but more nanoscale work on reidite and its back-transformation to zircon are needed to understand phase transition mechanisms and implications for impact age determination.

Samples and methods: Thin sections of the Chassenon suevite from Grosse Piéce quarry, Rochechouart impact structure (France) were used [3]. $ZrSiO_4$ grains were identified in thin section using elemental mapping and scanned for microstructures of interest using electron backscatter diffraction (EBSD). One electron-transparent section from each of three grains was prepared using a focused ion beam (FIB). Each FIB lamella was then analyzed using transmission electron microscopy (TEM), which included high resolution imaging and diffraction. Grain A was previously analyzed for U/Pb isotopes and was found to have extremely high common Pb.

Results: EBSD shows Grain A to be a mixture of zircon and reidite, with the polycrystalline zircon on the outer edges of the grain and intruding on the interior as wedges. The zircon is primarily ~1-3um crystallites with crystallographic preferred orientation. One zircon domain is made up of significantly smaller granules (<2um) oriented according to the previously described FRIGN relationship. The reidite is massive, not granular or lamellar, and hosts {112} twins, which are aligned in two sub-planar sets, ~1um wide, cross-cutting, and dispersed throughout the massive area. There also appears to be another twin relationship present which requires further investigation. Bright-field TEM shows the twins in reidite are lamellar, ubiquitous, and 5-70nm thick, which is beyond the resolution of EBSD. There is a clear boundary between the heavily twinned reidite and a granular domain, which is under further investigation.

Grain B, mostly zircon, is fully polycrystalline. Zircon crystallites are 0.2-1.6um, with the grain made up of domains of similarly sized granules. Reidite granules (0.8-2.6um) are in the grain interior. There is a general linear fabric to the entire grain. Zircon granules have the FRIGN orientation relationship, and reidite granules show twinning. Bright field TEM shows this grain is made up of ~200nm crystallites aligned in lamellar-like textures. Grain boundaries are complex, and the crystallites are strained. There is a weak planar fabric seen in diffraction contrast. In addition to the dominant polycrystalline texture, interstitial areas of much smaller granules were identified. The smaller granules are equant, clearly delineated, ~10nm in diameter, and are surrounded by a matrix of lighter contrast amorphous material. The nanogranules, minor occurrence of potential inclusions within crystallites, and crystallographic relationships between crystallites need further characterization.

Grain C is entirely polycrystalline zircon. Crystallites are 0.5-1.2um, but the size distribution is heterogeneous across the grain. Granules strongly show the FRIGN crystallographic orientation relationship, with one dominant and two sub-dominant orientations. Bright field TEM shows three textural variants, all with a distinct granular microstructure with low-contrast materials filling triple junctions between zircon granules. At one end of the foil granules range from 350 nm to ~500nm. The granules are elongated in a single direction and in diffraction contrast show three clusters of orientation. At the other end of the foil, zircon occurs as ~25nm nanogranules with vermicular texture. The nanogranules are equant, homogeneous, and very circular, while the larger granules in the rest of the section are full of small inclusions of material with varying diffraction contrast. These inclusions are currently being investigated further.

Discussion: Lamellar and granular zircon have been generally interpreted in the literature as products of different formation mechanisms, with more crystalline zircon undergoing a shear-dominated displacive transition to lamellar reidite while more metamict zircon transitions reconstructively to granular reidite. The grains investigated here show some evidence that granular reidite may instead be a post-lamellar product, rather than the two microstructures being formed independently of one another. At the scale of transmission electron microscopy, the similarities between these three grains become evident, whereas scanning electron microscopy (including EBSD) highlights their differences. We posit that the three grains investigated here may be snapshots of three points of the process that produces FRIGN zircon.

References: [1] Timms N. E. et al. (2017) *Earth-Science Reviews* 165:185-202. [2] Cavosie A. J. et al. (2018) *Geology* 46:891-894. [3] Plan A. et al. (2021) *Meteoritics and Planetary Science* 56:1795-1828.