FORMER REIDITE IN GRANULAR NEOBLASTIC ZIRCON (FRIGN ZIRCON) FROM THE LUIZI IMPACT STRUCTURE AND PROPOSED PANTASMA STRUCTURE. A. J. Cavosie[1], N. E. Timms[1], L. Ferrière[2], and P. Rochette[3]. [1]School of Earth and Planetary Science, Curtin University, Perth Australia (aaron.cavosie@curtin.edu.au), [2]Natural History Museum, Burgring 7, A-1010 Vienna, Austria, [3]CEREGE Aix en Provence, France.

Introduction: Minerals that record both extreme high-pressure and high-temperature conditions created by meteorite impact are rare, and until recently known only from meteorites. Here we report on new occurrences of a type of granular zircon that is the only terrestrial mineral known to record both high-pressure and high-temperatures diagnostic of impact. Granular zircon grains in impact melt rock from the Luizi impact structure (Democratic Republic of the Congo) and in glass from the recently described Pantasma structure (Nicaragua) consist of ~1 µm-sized neoblasts in multiple domains that are systematically oriented such that all (001) are orthogonal, and coincide with a {110} direction from another domain. The neoblast orientations are uniquely produced by transformation of zircon to the high-pressure polymorph reidite and its subsequent reversion to neoblastic zircon under high-temperature conditions (>1673°C), as evidenced by their occurrence with ZrO_2. We here refer to such granular grains that preserve orientation evidence for reversion from reidite as 'Former Reidite In Granular Neoblastic zircon', or FRIGN zircon, in order to distinguish this variety of granular zircon from those that do not record high-pressure conditions. In addition to localities described here, examples of what can now be classified as FRIGN zircon have been documented at Meteor Crater (Barringer crater, USA) [1], at Acraman impact structure (Australia) [2], and in Australasian tektites [3]. FRIGN zircon occurrences thus span five continents, range in age from Precambrian (~590 Ma) to recent (~49 ka), and serve as a diagnostic indicator of impact metamorphism that is present throughout much of the geological record, and has potential to be found in extraterrestrial samples where granular zircon has previously been reported.

Granular zircon in Earth and Planetary Materials: Granular zircon consisting of aggregates of neoblastic crystallites is important for identifying and dating high-temperature and/or high-strain processes [e.g., 4,5]. However, granular zircon from different settings can appear similar in secondary electron microscopy images, because neoblasts are commonly ~1 µm across [e.g., 6]. As a consequence, granular zircon from diverse environments, including tectonic shear zones [e.g., 4], impact melt rock [e.g., 7], shocked bedrock [e.g., 6], tektites [e.g., 3], lunar impact melt breccias [e.g., 8,9], meteorites [10], and detrital populations [11] can be difficult to distinguish based on general appearance. Here we use orientation analysis to describe new occurrences of a type of granular zircon that only forms in grains transformed to and from the high-pressure $ZrSiO_4$ polymorph reidite during meteorite impact, and that can be quantitatively distinguished from other varieties. Granular zircon, where crystallographic orientation analysis has identified 'Former Reidite in Granular Neoblastic Zircon' (FRIGN zircon), are the only known terrestrial minerals that preserve evidence of both high-pressure and high-temperature processes unique to meteorite impact. Minerals that record both high-pressure and high-temperature conditions diagnostic of impact are known from meteorites, including polymorphs of olivine, pyroxenes, and feldspars [e.g., 12], however, these phases have not been reported from Earth.

The Luizi Impact Structure: Luizi is a 17 km-wide impact structure located in Democratic Republic of the Congo [13]. Target rocks are Neoproterozoic (~574 Ma) arkosic sandstones that were deformed and locally melted; diagnostic evidence of shock deformation at the Luizi structure includes shatter cones, and shocked quartz and feldspar grains with planar deformation features (PDFs) [13]. The Luizi zircon is an 80 x 100 µm rounded grain. It has a granular texture consisting of ~1 µm-sized neoblasts and is pervasively disaggregated, consisting of 5 to 15-µm-wide clusters of neoblasts separated by glass. Some zircon neoblasts contain inclusions of ZrO_2. Zircon neoblasts are concentrically zoned as seen using cathodoluminescence (CL), with dark cores surrounded by bright rims. The neoblasts are systematically aligned in three mutually orthogonal crystallographic orientations, each showing >45° of dispersion (Fig. 1). Pole figures further reveal coincidence among (001) and {110} poles among the three dominant orientation clusters (Fig. 1). This observation is corroborated by quantification of misorientation axes for neighbour-pair pixels in the orientation map, which are dominated by high-angle clusters (85-95°) that are coincident with poles to {110} (not shown).

The Pantasma (Proposed) Impact Structure: Pantasma is a 14.5 km diameter circular structure located in Oligocene felsic volcanic rocks in Nicaragua. The Pantasma structure has been proposed to have an impact origin based on the occurrence of lechatelierite (vesicular, fused SiO_2) and decomposed zircon in glass found in the Pantasma River within the structure [14]. The Pantasma zircon is a 10 x 15 µm grain with a granular texture consisting of ~1 µm-sized neoblasts embedded in glass. The zircon contains discrete irregular partings filled by glass. Inclusions of ZrO_2 in zircon neoblasts occur throughout the grain, although none indexed as zirconia polymorphs during electron backscatter diffraction (EBSD) analysis. Six distinct neoblast orientation clusters are present; pole figures show that both main domains are comprised of two interspersed neoblast orientations that are systematically misoriented by ~90° around <110>, with coincidence among (001) and {110} poles. In contrast to the Luizi grain, neoblast domains in the Pantasma grain show less dispersion (<45°) of crystallographic poles. High-angle (85-95°) misorientation axes for neighbour-pair pixels in the orientation map are coincident with poles to {110}.

High-pressure and high-temperature fingerprints in FRIGN zircon: Orientation relationships described here for neoblasts in granular zircon from the Luizi and Pantasma structures are only known to result from the formation of reidite, which forms during impact shock at 30 GPa [15,16], followed by reversion of reidite back to zircon. One consequence of the zircon-to-reidite transformation is alignment of $[001]_{zircon}$ with $<110>_{reidite}$ [2, 16-18]. Reversion of reidite back to zircon occurs along the reverse or a symmetrically equivalent path, resulting in up to three approximately orthogonal orientations of zircon with a predicted systematic dispersion of ~10° about each axis [18].

Occurrences of FRIGN zircon range in age from Precambrian (~590 Ma, Acraman, [2]) to recent (~49 ka, Meteor Crater, [1]), and they have also been found in ejecta [3]. FRIGN zircon is thus likely present at more of the 190 known terrestrial impact structures [19] and in ejecta deposits. Granular zircon has been reported at the two oldest known terrestrial impact structures, Vredefort Dome and Sudbury [e.g., 6,20], however, it is unknown if these occurrences represent examples of FRIGN zircon, as no orientation data is available for granular grains with µm-sized neoblasts [c.f., 5, 21]. Granular zircon has also been reported in extra-terrestrial samples, including meteorites [10] and lunar breccia [8,9].

We propose that FRIGN zircon represents a unique variety of shocked zircon that is unambiguously generated by impact. Documentation of FRIGN zircon requires quantification of crystallographic orientation relationships among neoblasts, which currently is only possible with EBSD.

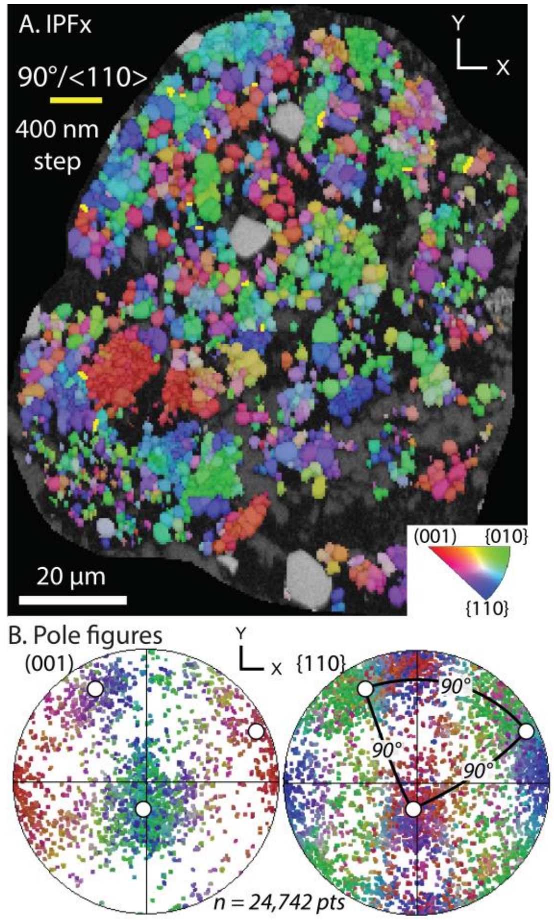

Figure 1. EBSD data for a FRIGN zircon from Luizi impact melt rock. A. Inverse pole figure (IPF), showing interspersed neoblasts. B. Pole figures showing the data in A. Three interspersed orthogonal orientations of zircon neoblasts are present. The centers of contoured pole clusters are indicated by the white circles.

References: [1] Cavosie et al. 2016 Geol. [2] Timms et al. 2017 ESR. [3] Cavosie et al. 2018 Geol. (*in press*). [4] Piazolo et al. 2012 Am Min. [5] Kenny et al. 2017 Geol. [6] Kamo et al. 1996 EPSL. [7] Wittmann et al. 2006 MAPS. [8] Grange et al. 2013 JGR. [9] Crow et al. 2017 GCA. [10] Zhang et al. 2011 MAPS. [11] Cavosie et al. 2010 GSAB. [12] Tomioka and Miyahara 2017 MAPS. [13] Ferrière et al. 2011 Geol. [14] Rochette et al. 2016 Met Soc. [15] Kusaba et al. 1985 EPSL. [16] Leroux et al. 1999 EPSL. [17] Cavosie et al. 2015a Geol. [18] Erickson et al. 2017 CMP. [19] Earth Impact Database 2018. [20] Betterton and Bohor 1992 LPSC. [21] Cavosie et al. 2015b Geol.