DEFORMATION MICROSTRUCTURES PRESERVED IN ZIRCON AND MONAZITE FROM THE YARRABUBBA IMPACT STRUCTURE, WESTERN AUSTRALIA. Timmons M. Erickson[1,2], Christopher L. Kirkland[3], and Nicholas E. Timms[3], [1]Center for Lunar Science and Exploration, Lunar and Planetary Institute, USRA, 3600 Bay Area Blvd., Houston TX 77058 USA (Erickson@lpi.usra.edu), [2]NASA Solar System Exploration Research Virtual Institute, [3]The institute for Geoscience Research, School of Earth and Planetary Sciences, Curtin University, Perth, WA 6102 Australia.

Introduction: The Yarrabubba impact structure is a deeply eroded feature located within the Murchison Terrane of the Archean Yilgarn Craton in Western Australia [1]. While no circular crater remains at Yarrabubba, the remnant structure is centered on a large exposure of granophyre known as Barlangi Rock (118˚50'E, 27˚10'S). Impactites of the Yarrabubba impact structure are predominantly the Yarrabubba Monzogranite (YM), the granitoid target, and the Barlangi Granophyre (BG), interpreted as an impact generated melt rock. Evidence for an impact origin of the Yarrabubba structure include shatter cones and shocked quartz grains within the YM and BG [1, 2]. In addition, large meter-wide pseudotachylite veins cross cut the YM and kink-banded biotite has been identified in minor breccia units [1]. The original dimensions of Yarrabubba are poorly constrained due to post impact tectonics and deep erosion of the structure, but an elliptical magnetic anomaly ~20 km N-S by ~11 km E-W centered on Barlangi Rock provides the minimum diameter of the original size of the structure.

The age of the Yarrabubba impact structure is nominally Proterozoic, but is very poorly constrained. The upper limit of the impact age is 2.65 Ga based on U – Pb zircon ages from the YM [3]. Zircon grains from the Barlangi Granophyre have a more complicated U – Pb age spread. Concordant zircon ages extend from 2.79 Ga to 2.58 Ga [3, 4]. A 1.13 Ga $^{40}Ar/^{39}Ar$ age from sericite in pseudotachylite veins records a minimum age for the Yarrabubba impact structure [5], although it is unclear whether this age reflects the impact event or overprinting by subsequent tectono-thermal activity.

During shock deformation, zircon and monazite behave crystal-plastically, which can result in Pb mobilization and variable resetting of the U – Th – Pb system (e.g., [6, 7, 8]). The development of planar and sub-planar microstructures by dislocation creep during shock can lead to partial resetting of the U – Th – Pb systematics. However, the nucleation of new zircon and monazite within the highly-strained shocked host and growth by grain-boundary migration can result in domains with ages reflecting the time of impact [6, 7, 8, 9]. While shocked zircon and monazite can be used to determine the age of an impact event, subsequent tecono-thermal activity can partially to completely overprint this signature (e.g., [10]). In order to address that complexity, this study undertakes a detailed microstructural examination of shock features in zircon and monazite from the YM and BG to identify targets for high-resolution U – Th – Pb analyses that will best determine the Yarrabubba impact age.

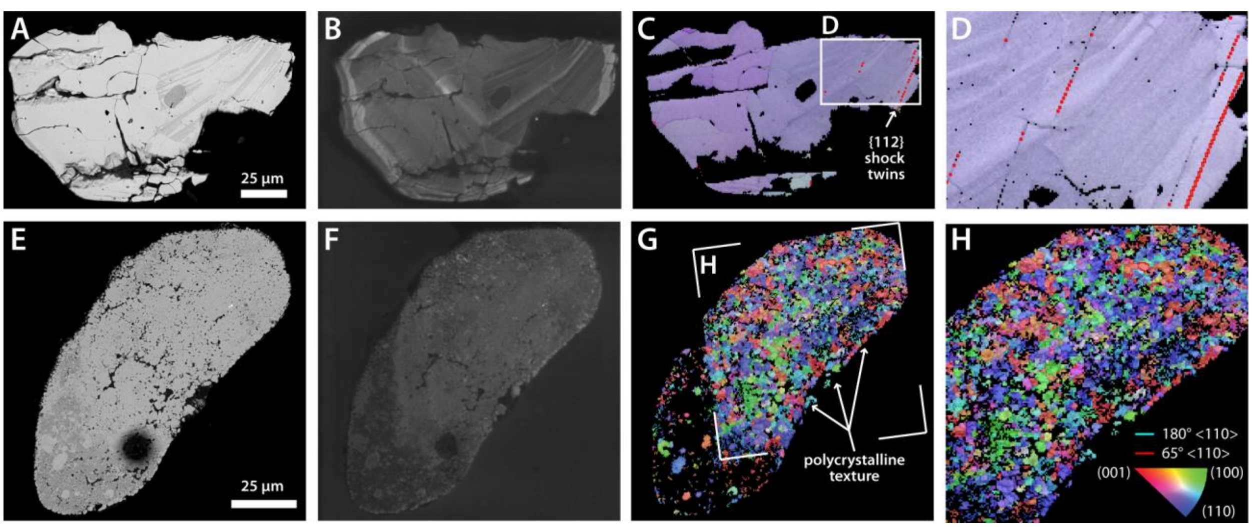

Figure 1. BSE, CL and EBSD images of shocked zircon from the Yarrabubba impact structure. (A-D) Shocked zircon recovered from the Yarrabubba Monzogranite displaying primary igneous zonation overprinted by crystal-plastic deformation and shock twins that are highlight in red in (C) & (D). (E-H) Polycrystalline zircon from the Barlangi Granophyre with crystallographic evidence for recrystallization after reidite and shock twin formation.

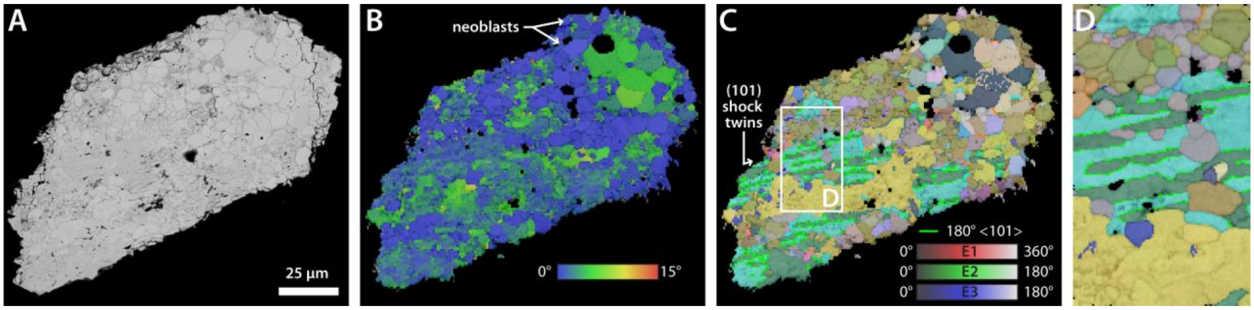

Figure 2. BSE and EBSD images of a typical shocked monazite from the Yarrabubba impact structure. The grain is derived from the Barlangi granophyre and contains {101} shock twins boundaries systematically misoriented 180° about <101>, highlighted in green in (C) & (D). Domains of strain-free neoblasts also occur within the grain, colored blue in (B).

Methods: Shocked zircon and monazite were extracted from samples of the YM and BG using a Selfrag electric pulse disaggregator. Grains were mounted in a 27.5 mm epoxy stub and polished. A chemical-mechanical polish with colloidal silica dispersion was used to achieve a final surface with <50 nm topography. Electron imaging was undertaken using a Mira3 field emission gun scanning electron microscope. Backscatter electron (BSE) and cathodoluminescence (CL) images were collected prior to electron backscatter diffraction (EBSD) microstructural analyses.

Results: Within the Yarrbubba Monzogranite zircon and monazite preserve a range of microstructures. Zircon grains display primary oscillatory zonation that is crosscut by planar and sub-planar microstructures (Fig. 1A, B). Mapping by EBSD reveals low-angle grain boundaries, {112} shock twins and {100} planar deformation bands (Fig. 1C, D [6, 11, 12]). Monazite grains preserve a broader range of shock features including domains with low-angle grain boundaries and multiple sets of shock twins; (001), (100) and (101), and domains of strain-free granules or neoblasts [8, 13].

Within the Barlangi Granophyre, zircon and monazite are xenocrystic and contain a broad spectrum of shock features. The textures in shocked zircon range from minimally shocked grains preserving primary oscillatory zoning to grains containing planar microstructures, to polycrystalline aggregates, and to grains with ZrO_2 inclusions (Fig. 1 E-H). The polycrystalline zircon aggregates contain systematic misorientations indicative of formation after shock-produced {112} twins and the high-pressure polymorph reidite (Fig. 1 G, H; [14, 15, 16]). Zircon with ZrO_2 inclusions form by shock-driven dissociation to ZrO_2 and SiO_2 and subsequent reversion to zircon during cooling. This texture occurs in silica saturated melts, such as BG, above 1673 °C [15]. Monazite grains from BG preserve a similar range of shock features to those from YM, including low-angle boundaries, shock twins, and neoblastic domains (Fig. 2).

Conclusions: Due to scarcity, preservation bias, and complex subsequent tectonic reworking, only two Precambrian impact structures, Sudbury [17] and the Vredefort Dome [18, 19], have precise ages. U – Th – Pb zircon and monazite ages, both of which can be reset by shock but are resistant to metamorphic and hydrothermal alteration, offer the best potential for dating ancient impact structures. Here we identified a range of U – Pb geochronology targets for the Yarrabubba impact structure including polycrystalline zircon aggregates from the BG and monazite grains with neoblastic domains from the BG and YM. These grains not only help to further reveal the shock history of the Yarrabubba impact structure, much of which is thermally overprinted [1, 2], but also help constrain the impact age. Yarrabubba is potentially Earth's oldest preserved impact structure and determining its age will aid understanding of the history of the Yilgarn Craton and, importantly, will help chart the evolution of our planet's impact flux.

References: [1] Macdonald F. A. et al. 2003. *Earth Planet. Sci. Lett.*, *213*, 235–247. [2] Haines P. W. 2005. *Austral. J. Earth Sci. 52*, 481–507. [3] Fletcher I. R. & McNaughton N. J. (2002) *MERIWA report 222*. [4] Nelson 2005. *GSWA Report 178063*. [5] Pirajno F. 2005. *Austral. J. Earth Sci.*, *52*, 587–603. [6] Moser D. E. et al. (2011) *Can. J. Earth Sci.*, *48*, 117–139. [7] Cavosie, A. J. et al. (2015) *Geology*, *43*, 999–1002. [8] Erickson T. M. et al. (2017) *Con. Min. Pet.*, *172*. [9] Tohver et al. (2012) *GCA*, *86*, 214–227. [10] Schmieder M. et al. (2015) *GCA*, *161*, 71 – 100. [11] Timms N. E. et al. (2012) *MAPS*, *47*, 120–141. [12] Erickson T. M. et al. (2013) *Am. Min.*, *98*, 53–65. [13] Erickson T. M. et al. (2016) *Geology*, *44*, 635 – 638. [14] Cavosie A. J. et al. (2016) *Geology*, *44*, 703–706. [15] Timms et al. (2017) Earth-Sci. Rev., 165, 185–202. [16] Cavosie A. J. et al. (2018) *Geology*, *in press*. [17] Krogh T. E. (1984) *OGS Spec. V. 1*, 431–444. [18] Kamo S. L. et al. (1996) *Earth Planet. Sci. Lett.*, *144*, 369–387. [19] Moser, D. E. (1997) *Geology*, *25*, 7 – 10.