YARRABUBBA, WESTERN AUSTRALIA: A LARGE, DEEPLY ERODED, ANCIENT IMPACT STRUCTURE IN THE YILGARN CRATON.
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Introduction: Shock-metamorphic effects including shatter cones, planar deformation features (PDFs) in quartz grains, and both E- and S-type pseudotachylites were discovered in deeply eroded Archean granites near the Yarrabubba homestead in Western Australia (119°50'E, 27°10'S). Preliminary estimates indicate that the Yarrabubba impact structure is of a Paleoproterozoic age and at least 30 km in diameter.

Geological Observations: No circular craterforms can be discerned either from the ground, on aerial photographs or from satellite images. Considering the lack of topography, the Yarrabubba Granite is remarkably well exposed in the central region of the structure. The Yarrabubba Granite is a pale pink, medium- to coarse-grained monzogranite, consisting of quartz, albitic plagioclase and microcline, with subordinate muscovite and biotite. Aside from samples near the contact with the Barlangi Granophyre (impact melt), in which the quartz has been recrystalized, all of the samples of Yarrabubba Granite that we studied contained PDFs and planar fractures (PFs) in quartz, testifying to its shocked nature. Biotite is commonly altered to a mixture of chlorite and iron oxides, and it also appears that some muscovite may have formed from the alteration (impact-metasomatism?) of biotite. Shatter cones are also present in finer grained varieties of the Yarrabubba Granite to at least 4 km north of Barlangi Rock (the center of the structure).

The Yarrabubba Granite contains many melt rocks along faults, ranging from a few millimeters to over a meter thick. The thicker bodies are generally a flinty green aphanitic felsic rock with inclusions of granulated quartz. The fault melts often harbor mylonites and are baked when in contact with the Barlangi Granophyre; and thus, they appear not to be impact melt dikes, but rather, E-type pseudotachylites. In the northern Yarrabubba Granite outcrops, sub-millimeter S-type pseudotachylite veins occur that display the typical "cobweb" pattern [1]. These can be observed to at least 5 km from the center, but their distribution appears to be sporadic.

The Barlangi Granophyre was originally mapped at Barlangi Rock and an outcrop to the southwest, where it was described as soda-rhyolite hypabyssal granophyre, with bladed silica rather than cuneiform intergrowths [2]. Our field work revealed that there is substantially more of the Barlangi Granophyre in the area, as it stretches for nearly 10 km^2 in map view. Where contacts are exposed in the north and the west, the granophyre has an intrusive, shallow, sill-like relationship with the Yarrabubba Granite, which is sitting above the granophyre and is sometimes baked to several meters.

Discussion: The Barlangi Granophyre has a nearly identical geochemical composition to the Yarrabubba Granite; as it also has an intrusive relation with the surrounding shock-metamorphosed granites, we believe that the Barlangi Granophyre is a substructural impact-melt pod with radiating sills.

Aeromagnetic images reveal an ~11 X 15 km magnetic low that corresponds to the outcropping of the Yarrabubba Granite and is centered on a magnetic-high halo around the Barlangi Granophyre. Theoretical scaling relations, assuming an 11 km central uplift, suggest that the original diameter of the impact structure was between 30 and 50 km [4], but there are no obvious circular features in this range either in the aeromagnetics or the geology. We consider this size estimate to be a lower limit of the original size, as the structure appears deeply eroded, PDFs and PFs exist in quartz grains throughout the Yarrabubba Granite, and thick sequences of clast-poor impact melt and meter-sized E-type pseudotachylites are ubiquitous.

There is inconclusive isotopic evidence of a very early Proterozoic age of the Barlangi Granophyre which, if correct, would indicate that Yarrabubba is one of the oldest impact structures that has been discovered to date. This age is supported by the deep level of erosion and mafic dikes that cut the structure in aeromagnetic images, which are thought to be of a Proterozoic age [4]. If the Yarrabubba structure was formed during Paleoproterozoic times, current exposure may be more than ten kilometers below the original crater floor [5].

Conclusion: Archean terrains probably contain a rich record of ancient bombardment, but locating the unique shock features indicative of impact may stretch our detective capabilities. Searching the existing literature for anomalous felsic granophyres (impact melts) associated with syenitic granites (alkali metasomatism) and broad demagnetization zones may be a fruitful way to discover new impact structures in deeply eroded Archean terrains and better constrain cratering rates in ancient times.

References:
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