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Geophysical anomalies and quartz microstructures, Eastern Warburton Basin, North-east South Australia: Tectonic or impact shock metamorphic origin?

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ABSTRACT

The Eastern Warburton Basin, Northeast South Australia, features major geophysical anomalies, including a magnetic high of near-200 nT centred on a ~25 km-wide magnetic low (<100 nT), interpreted in terms of a magmatic body below 6 km depth. A distinct seismic tomographic low velocity anomaly may reflect its thick (9.5 km) sedimentary section, high temperatures and possible deep fracturing. Scanning electron microscope (SEM) analyses of granites resolves microbreccia veins consisting of micron-scale particles injected into resorbed quartz grains. Planar and sub-planar elements in quartz grains (Qz/PE) occur in granites, volcanics and sediments of the >30,000 km-large Eastern Warburton Basin. The Qz/PE include multiple intersecting planar to curved sub-planar elements with relic lamellae less than 2 μm wide with spacing of 4–5 μm. Qz/PE are commonly re-deformed, displaying bent and wavy patterns accompanied with fluid inclusions. U-stage measurements of a total of 243 planar sets in 157 quartz grains indicate dominance of ∏{10–12}, ω{10–13} and subsidiary §{11–22}, {22–41}, m{10–11} and x{51–61} planes. Transmission Electron Microscopy (TEM) analysis displays relic narrow ≤1 μm-wide lamellae and relic non-sub grain boundaries where crystal segments maintain optical continuity. Extensive sericite alteration of feldspar suggests hydrothermal alteration to a depth of ~500 m below the unconformity which overlies the Qz/PE-bearing Warburton Basin terrain. The data are discussed in terms of (A) Tectonic–metamorphic deformation and (B) impact shock metamorphism producing planar deformation features (Qz/PDF). Deformed Qz/PE are compared to re-deformed Qz/PDFs in the Sudbury, Vredefort, Manicouagan and Charlevoix impact structures. A 4–5 km uplift of the Big Lake Granite Suite during ~298–295 Ma is consistent with missing of upper Ordovician to Devonian strata and possible impact rebound. The occurrence of circular seismic tomography anomalies below the east Warburton Basin, the Poolowana Basin and the Woodleigh impact structure signifies a potential diagnostic nature of circular tomographic anomalies.

1. Introduction

Geophysical and drilling exploration of the Australian continent and off shore continental shelves have led to the discovery of large circular structures some of which contain evidence of shock metamorphism, including Woodleigh (120 km-diameter; ~359±4 Ma; Glikson et al., 2005a,b; Iasky et al., 2001; Mory et al., 2000; Reimold et al., 2003; Uysal et al., 2001, 2002) and Talundilly (90 km-diameter; ~112–115 Ma; Gorter and Glikson, 2012; Longley, 1989). Possible impact structures include Gnargoo (D=75 km; Iasky and Glikson, 2005) and Mount Ashmore (>50 km-diameter; end-Eocene; Glikson et al., 2010). Here we consider the significance of magnetic, gravity and seismic tomography anomalies associated with the Eastern Warburton Basin, buried under the south-western Cooper Basin (Fig. 1), including the identification of planar and sub-planar microstructures in quartz grains in late Carboniferous granites and early Palaeozoic sediments and volcanic rocks in this terrain.

The Warburton Basin extends over an area ~400,000 km^2 in north-eastern South Australia (Fig. 1). It consists of a >4.5 km thick early Cambrian to early mid-Ordovician sequence, comprising a basal suite of felsic volcanic rocks overlain by late Cambrian carbonates and Ordovician pelagic to shelf clastic sediments (Gatehouse et al., 1995; Gravestock and Gatehouse, 1995; Radke, 2009; Roberts et al., 1990; Sun, 1997, 1998; Sun et al., 1994). Devonian sediments are mostly missing except in the north-west. The Eastern Warburton Basin underwent deformation in the late Devonian (part of the *Alice Springs Orogeny*) as well as deformation associated with intrusion of mid to late Carboniferous granitoids (*Big Lake Granite Suite*; 323±5 Ma to 298±4 Ma; Gatehouse et al., 1995). Emplacement of the granites was followed by rapid uplift by 4–5 km at ~298–295 Ma (Gravestock and Jensen-Schmidt, 1998), leading to deep erosion associated with end-Carboniferous glaciation, which accounts for a major unconformity and a lacuna of missing mid-Ordovician to upper

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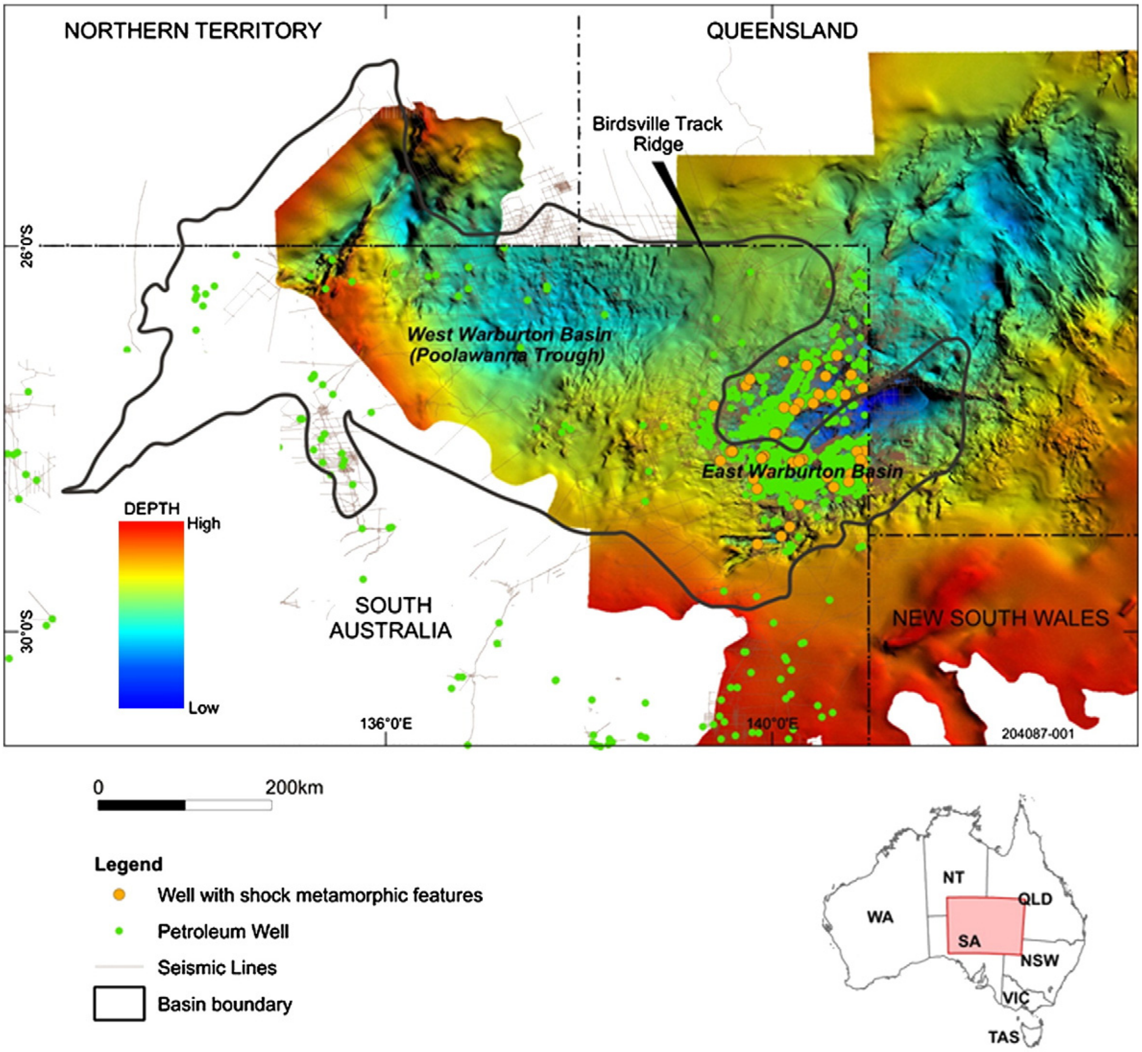

Fig. 1. Known extent of the Warburton Basin based on the 'C' seismic horizon (Cretaceous marker). The Birdsville Track Ridge divides the eastern Warburton Basin, which underlies the Cooper Basin, from the Western Warburton Basin, also termed Poolowana Basin.
From Fig. 9 of Radke (2009).

Carboniferous strata (Veevers, 2009). The Cooper Basin above the Eastern Warburton Basin comprises a ~2 km-thick sequence of late Carboniferous and Permian glacial deposits (Merimelia and Tirrawarra formations) deformed along NE–SW tectonic ridges (Gidgealpa–Merrimelia–Yanapurra, Innamincka, Nappacoongee, Murteree, Dunoon ridges) separated by paleo-depressions (Patchawarra, Nappamerri, Allunga and Tenappera troughs) (Fig. 2). The Cooper Basin, which hosts major geothermal, oil and gas deposits (Chopra, 2003; PIRSA, 2010a–d; Wyborn et al., 2004), is overlain by a 3 km-thick Mesozoic sequence of the Eromanga Basin.

Planar and sub-planar elements in quartz (Qz/PE)[1] grains in granites, sediments and volcanic rocks, identified in drill core samples (Appendix I), extend over an area ~220×195 km-large (between Walkillie-1 in the north, Cutapirrie-1 in the south, Kalladeina-1, and Jennet-1 in the west and Tickalara-1 in Queensland in the east) (Figs. 1, 2; Appendix I). The nature and significance of these microstructures will be considered in relation to magnetic, gravity, seismic and tomographic data from the Eastern Warburton Basin and underlying crust.

2. Structure of the Cooper and Eastern Warburton basins

2.1. Paleo-structure of the Warburton Basin

Isopach maps outline the south-western part of the Cooper Basin as an elongated NE–SW depression split into at least three troughs by arcuate tectonic ridges which separate end-Carboniferous to mid-Triassic depositories of the Cooper Basin (Figs. 1 and 2). These lineaments include from north to south the Birdsville Track Ridge, Gidgealpa–Merimelia–Innamincka (GMI) Ridge, Big Lake fault, Warra Ridge and the Dunoon–Murteree and Nappacoongee Ridges which separate the Cooper Basin into the Patchawarra, Nappamerri, Tenappera and Allunga troughs (Fig. 2) (Boucher, 2001, 2002; Gravestock and Jensen-Schmidt, 1998; Meixner et al., 1999, 2000; Sun, 1997). The pre-end Carboniferous unconformity, defined as the Z seismic horizon, is near-4000 m deep and is underlain by early Palaeozoic Warburton Basin sediments intruded by Big Lake Granite Suite (Gravestock and Jensen-Schmidt, 1998; Meixner et al., 1999, 2000; PIRSA, 2010a–d; Radke, 2009; Sun, 1997). The isopach maps (PIRSA, 2010a–d) suggest

[1] Terms used in this paper are defined as follows: Qz/PE — planar elements in quartz of no genetic connotation; Qz/MDL — metamorphic deformation lamella in quartz of known tectonic origin; Qz/PDF — Planar deformation features of shock metamorphic origin.