ROYALTIES FOR REGIONS
EXPLORATION INCENTIVE SCHEME

What lies beneath — interpreting the Eucla basement

by

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The Precambrian basement beneath the Eucla Basin represents one of Western Australia's most mysterious and darkest corners, which, until now, remained relatively unexplored due to a lack of knowledge and inherent high risk factors. New geophysical data and Exploration Incentive Scheme (EIS) co-funded drilling are helping to uncover the secrets of this basement, presenting new challenges to understanding the formation of southwestern Proterozoic Australia. The basement is covered by up to 500 m of sedimentary rocks belonging to the Cretaceous and Cenozoic Bight and Eucla Basins, and more deeply to the north by Neoproterozoic, Paleozoic, and Mesozoic sedimentary rocks.

Using geophysical data, the basement was previously divided from west to east into the Madura, Forrest, Waigen, and Coompana Provinces (Fig. 1; Shaw et al., 1996). The Waigen and Coompana Provinces lie predominantly within South Australia, adjacent to the Gawler Craton, and are completely under cover and poorly understood. Granitic gneiss from the Coompana Province (sampled from the Mallabie 1 drillhole in South Australia) has been dated at 1505 ± 7 Ma, interpreted as the igneous crystallization age of the granite protolith, which intruded into an unknown basement (Wade et al., 2007). The Madura Province lies adjacent to the Albany–Fraser Orogen, part of which also underlies the Eucla Basin (Fig. 1). In Western Australia, the division of the basement into separate provinces distinct from the Albany–Fraser Orogen will be tested through the interpretation of new aeromagnetic and gravity data, and by EIS co-funded exploration and stratigraphic drilling that will be sampled for geochronology and geochemistry.

Linking the Albany–Fraser Orogen to the Eucla basement

Current work on the Albany–Fraser Orogen has shown that it is dominated by Paleoproterozoic and Mesoproterozoic rocks that formed along, or close to, the margin of the Yilgarn Craton, resulting in successive episodes of reworking of that margin. Fragments of Archean crust, ranging from the kilometre-scale through to grain-sized (i.e. the isotopic record preserved in zircon) are interpreted as the rifted remnants of the Yilgarn Craton preserved within c. 1800 to 1650 Ma crust of the Biranup Zone. These fragments may have contained sources of economic minerals or elements, such as gold. Paleoproterozoic magmatic rocks of the Biranup Zone are interpreted to have intruded into the southern Yilgarn Craton during margin extension and rifting, possibly in a backarc setting, producing a series of linked basins across the Northern Foreland and Biranup Zone (i.e. the Barren Basin; Spaggiari et al., 2011). At least one tectonothermal event has been recognized during this period — the c. 1680 Ma Zanthus Event, which took place during the c. 1710 to 1650 Ma Biranup Orogeny (Kirkland et al., 2011; Spaggiari et al., 2011).

Previous interpretations of the Albany–Fraser Orogen have suggested the collision or accretion of exotic terranes, such as the Mawson Craton, and the formation of a magmatic arc in the Fraser Zone during the Mesoproterozoic Albany–Fraser Orogeny. Current U–Pb geochronology, whole-rock geochemistry, and Lu–Hf and Sm–Nd isotopic data do not support these interpretations — no exotic components, nor Mesoproterozoic magmatic arcs, have been recognized within the orogen. In addition, recently dated Paleoproterozoic metagranitic rocks within the eastern Nornalup Zone indicate continuation of that substrate eastwards from the Biranup Zone. The Mesoproterozoic Albany–Fraser Orogeny is divided into two stages: the first was a long-lived, widespread, coeval felsic and mafic magmatic event accompanied by deformation, and high-temperature and moderate- to high-pressure metamorphism (Stage I; c. 1345 to 1260 Ma); whereas the second stage was dominated by intense deformation, high-temperature and moderate-pressure metamorphism, and mostly felsic magmatism after c. 1200 Ma (Stage II; c. 1215 to 1140 Ma; Clark et al., 2000; Spaggiari et al., 2011). The tectonic setting for Stage I is uncertain, but recent work suggests an extensional rift or backarc setting, rather than collision, whereas Stage II is likely to have occurred in an intracratonic setting. Understanding the tectonic components that make up the Eucla basement is therefore crucial to constraining the Albany–Fraser Orogen's geodynamic history, and to answer the questions: where is the edge of the orogen, and what lies beyond?

The Rodona Shear Zone, a large, complex structure that may be truncated by the Mundrabilla Shear Zone to the

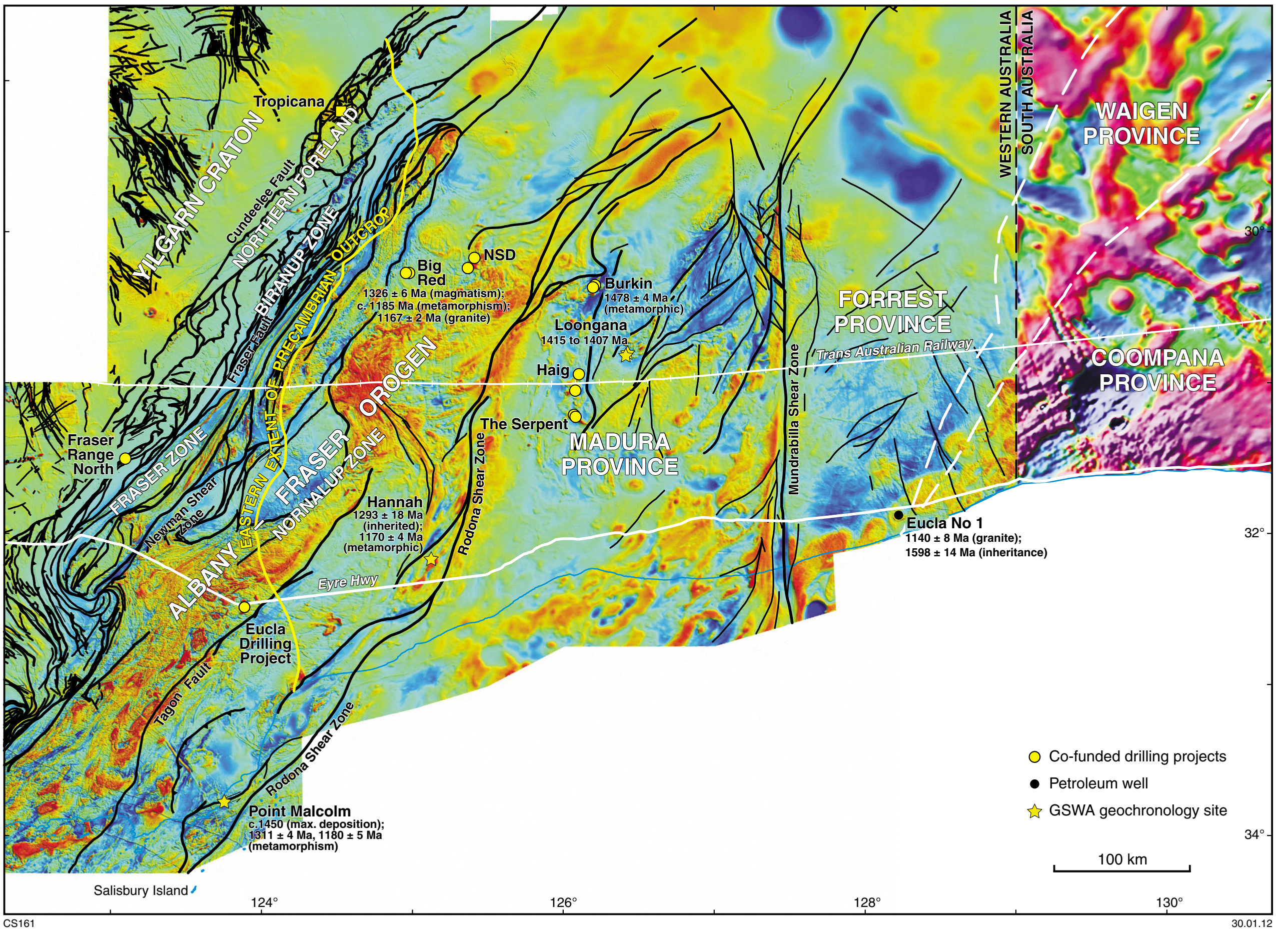

Figure 1. ***Reduced-to-pole aeromagnetic image, including preliminary data for Jubilee–Waigin–Mason (northeastern Eucla), over the eastern Albany–Fraser Orogen and Eucla Basin, showing major tectonic units and structures, and the locations of drilling and geochronology sites. The yellow line marks the approximate eastern outcrop limit of the Precambrian basement. Note that the Waigen Province should not be confused with the Waigen Sub-basin or Region of the Officer Basin, and the Madura Province is separate from the Madura Shelf of the Eucla Basin.***

northeast, is currently inferred to approximate the eastern edge of the eastern Nornalup Zone, and thereby the Albany–Fraser Orogen (Fig. 1). However, this is based on a small geochronology dataset that suggests differences in the ages of magmatic and metamorphic rocks on either side of the shear zone.

Madura Province

The Madura Province is defined as the area of basement bounded by the Rodona Shear Zone and the Mundrabilla Shear Zone (Fig. 1). The Mundrabilla Shear Zone is a prominent, north–south structure that abruptly loses its magnetic signature to the north under the Officer Basin. It is a wide, straight, shear zone, which suggests it is subvertical, with drag fabrics indicative of a sinistral shear sense, at least during its more recent history. The shear zone is coincident with a surface fault and present-day scarp through the Miocene limestones of the Eucla Basin. Other basement structures also cut these limestones, indicating that they were reactiviated. Aeromagnetic data indicate a complex structural architecture for the Madura Province, with a dominant northeasterly regional trend. So far, geochronology of drillcore samples from the Madura Province has yielded dates between c. 1480 and 1407 Ma, which are ages unlike those recorded in the Albany–Fraser Orogen, with exceptions being the detritus found in paragneiss from Point Malcolm in the eastern Nornalup Zone (Fig. 1; Adams, 2011), and in metasedimentary rocks of the Fraser Zone.

Exploration drilling in the Madura Province has intersected ultramafic, metagabbroic, and metagranitic rocks at the Loongana prospect; variably to strongly magnetic metagabbro at The Serpent prospect; and heterogeneous gneissic rocks, iron-rich layered quartz–chlorite–garnet schists, metamorphosed banded iron-formation, and amphibolite at the Burkin prospect (Fig. 1). Although not dated, it is possible that rocks of The Serpent prospect, which is defined by an elongate, northwesterly trending magnetic high (Fig. 1), may have formed during the same magmatic event as the nearby Loongana prospect. Granite, interpreted as either intrusive into, or coeval with, metagabbro from the Loongana prospect (LNGD0002), yielded a date of 1415 ± 7 Ma (GSWA 178070*), interpreted as the igneous crystallization age of the granitic protolith. Nearby fine-grained, equigranular, unfoliated biotite microtonalite from LNGD0001 yielded a date of 1408 ± 7 Ma (GSWA 178071), also interpreted as the igneous crystallization age. The age of the microtonalite is identical to the igneous crystallization age of 1407 ± 7 Ma obtained for medium- to coarse-grained, foliated biotite tonalite gneiss taken from the same core (GSWA 178072). Lutetium–hafnium data from the dated samples are consistent with mixed sources, including juvenile mantle and unradiogenic Archean material. This implies mantle input into the crust during the magmatic event at c. 1410 Ma. It is interesting to note that the juvenile lutetium–hafnium signature seen in the Loongana samples is similar to that of c. 1400 Ma detritus found in the c. 1300 Ma Fraser Range Metamorphics, suggesting that this detritus may have been derived from Loongana or related rocks.

Migmatitic gneiss from the Burkin prospect (GSWA 182485) yields a date of 1478 ± 4 Ma, interpreted as the age of migmatization and high-grade metamorphism. This indicates an older protolith than for the Loongana prospect, and an older metamorphic event. Leucosomes in the dated sample crosscut a folded fabric, indicating deformation prior to migmatization. Three zircon cores yielded dates of 2408–2293 Ma, which could be interpreted as the age of detritus, provided the gneiss has a sedimentary protolith. Four other zircon cores yielded a mean date of 1538 ± 17 Ma, which could represent a maximum depositional age.

The presence of younger metasedimentary rocks in the Madura Province is indicated by the Salisbury Gneiss, exposed on Salisbury Island southeast of Esperance and east of the Rodona Shear Zone (Fig. 1). The Salisbury Gneiss comprises pelitic gneiss, mafic granulite, porphyritic granitic gneiss, and two-pyroxene metagabbro (Clark et al., 2000). Migmatitic pelitic gneiss records granulite-facies conditions of approximately 800°C and >5 kbar (Clark et al., 2000). The depositional age of the pelitic gneiss' protolith is unknown, although a migmatitic leucosome yielded dates of 1214 ± 8 and 1182 ± 13 Ma, consistent with the range of metamorphic ages of Stage II of the Albany–Fraser Orogeny. The older date is interpreted as the crystallization age of the leucosome, whereas the younger date is interpreted as the age of decompression from peak metamorphic conditions (Clark et al., 2000).

Forrest Province

The Forrest Province is defined as the basement east of the Mundrabilla Shear Zone, but no obvious structure defines its eastern contact with the Waigen Province in Western Australia (Fig. 1). As with the Madura Province, aeromagnetic data indicate a complex structural architecture, and a dominant northeasterly regional trend that appears to be truncated by northwesterly trending structures. The latter structures also cut a series of interpreted, moderately to strongly magnetic granitic intrusions, which form a series of northeasterly trending plutons near the coast that continue into South Australia (Fig. 1).

The Eucla 1 petroleum well intersected one of these plutons — a distinct ovoid feature with high magnetic intensity (Fig. 1). Small rock chips from the base of the well, which are interpreted as derived from a granitic rock, contain oscillatory zoned zircons that yielded a date of 1140 ± 8 Ma, interpreted as the magmatic crystallization age of the granite (GSWA 194773). A single analysis of an unzoned zircon yielded a date of 1598 ± 14 Ma, interpreted as either the age of an inherited component within the granite, or the age of zircon incorporated from another rock unit (e.g. sedimentary rock) within the drillhole. The magnetic signature, together with the c. 1140 Ma age, of these rocks suggests that the intrusion is related to the Esperance Supersuite of the Albany–Fraser Orogen. Similar plutons are inferred in the Madura Province, suggesting a common link from the Albany–Fraser Orogen to as far east as the Forrest Province by at least this time. The plutons are cut by the Mundrabilla Shear Zone, indicating that at least one phase of movement on the structure post-dates these intrusions.

* GSWA geochronology reports are available online at <www.dmp.wa.gov.au/geochron/>.

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