Primary Industries and Resources SA, University of Adelaide and Monash University, ARC Linkage Program: 2006 Reporting day abstracts

Anthony Reid

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Primary Industries and Resources SA, University of Adelaide and Monash University, ARC Linkage Program: 2006 Reporting day abstract volume

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INTRODUCTION

This report book, the third in the series thus far, presents abstracts form the Primary Industries and Resources SA, University of Adelaide and Monash University, ARC Linkage Program 2006 Reporting day. The 2006 meeting of people involved in the ARC Linkage program also included a one day field excursion to Yorke Peninsula (discussed in Report Book 2006/21). The abstracts are presented here in alphabetical order of the first author. In most cases a PDF of the original presentation is also available on an accompanying CD.

Deep crustal architecture and Moho depth offset beneath the Musgrave Province defined by a high resolution gravity survey

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The prevailing model of the crustal-scale architecture of the Musgrave Province proposes a Moho. depth offset of 20–25 km beneath the Musgrave Province to explain early teleseismic arrivals and a regional gravity high. This model does not explain the gravity field in full, with significant (~20 mGal) “short” wavelength (<50 km) residual anomalies. The assumption that the upper crust is homogenous in the model may explain the discrepancy between the observed and modeled gravity field.

To test this model, high resolution (1 km spacing) gravity data were collected along a profile crossing the regional gravity high, parallel to the teleseismic transect. Gravity and magnetic modeling along this profile (constrained by outcrop and petrophysics data) has shown that the heterogeneity of the upper crust - accurately reflecting changes in metamorphic grade and the effect of intrusions and shear zones - accounts for approximately half of the gravity field. Accordingly, the Moho. depth offset is much reduced, to 10–15 km.

The Moho. depth offset, rather than being accommodated by > 20 km throw on the Mann Fault and Lindsay Lineament, shows a more graduated mohography with smaller throws (2–8 km) on six crustal scale shear zones. The model derived along the new profile was tested along the teleseismic profile, 100 km to the west, and fitted the gravity anomaly well, after minor adjustments to the upper crustal density distribution and the re-location of shear zones.

This model of crustal architecture confirms the existence of a Moho. depth offset beneath the Musgrave Province, but the inclusion of a heterogeneous upper crust in modeling has reduced the magnitude of the offset by half. The shape of the Moho is also different with a more graduated offset along several shear zones.

Shuffling the cards through sedimentary provenance: is the Nawa the 'western Willyama' and the eastern Gawler the 'southern Pine Creek'?

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Sedimentary basin fill presents a detailed record of tectonic processes and palaeogeography of potential source regions. Detrital zircon ages provide an age spectrum of zircon-bearing sources, and youngest detrital zircon ages define the maximum depositional age of the sediment. The major disadvantages of detrital zircon geochronology are: 1) the loss of small zircons in separation; 2) the lack of contribution from fine-grained volcanic sources; and 3) the lack of contribution from less felsic sources that may be relatively zircon-poor, thus biasing data toward felsic rock types. Sm-Nd isotope studies are often combined with rare earth and trace element geochemistry. For example, once weathering and sorting processes are accounted for, the geochemistry of the sediment carries the record of the input of source material, and allows distinction between evolved crustal material and mantle-derived igneous rocks. It is assumed that Nd isotope data provides the average crustal residence age of all contributing protoliths, but the data are unable to distinguish ages of individual protoliths. We have applied these techniques to sedimentary sequences across the Gawler Craton, including metasedimentary material from drillholes in the northern Gawler Craton, the > 1850 Ma Corny Point Gneiss of Yorke Peninsula, and the Hutchison Group along the eastern Gawler Craton. These projects serve to provide constraints on paleogeographic reconstruction models involving Proterozoic Australia.

U-Pb detrital zircon analysis of the northern Gawler Craton Nawa Domain metasedimentary rocks indicates deposition between c. 1717 Ma and 1650 Ma. The combination of geochemical, Nd-isotope and U-Pb detrital zircon age data indicate the dominant source for the studied metasedimentary rocks is likely to be the Arunta region of the North Australian Craton. This indicates the Nawa Domain crustal segment was proximal to the North Australian Craton at this time. Correlations drawn between the Nawa Domain metasedimentary rocks and the lower part of the intracratonic Willyama Supergroup in the Curnamona Province suggest a large-scale extensional intra-continental tectonic regime.

Ca 2020 Ma detrital zircons within the Corny Point Paragniess have relatively juvenile Hf isotope compositions of around +5. Whole rock initial eNd isotope values range from about -1 to -5. Possible ca 2020 Ma zircon sources within Paleoproterozoic Australia include the Western Australian Glenburgh Orogen, the Gawler Craton Miltalie Gneiss and the North Australian Craton Pine Creek Orogen. The intial Nd isotope composition of the Corny Point Paragneiss is too juvenile to have been eroded solely from rocks of the Glenburgh Orogen or the Gawler Craton. Additionally, ca 2020 Ma magmatic zircons from the Miltalie Gneiss are too evolved in Hf isotope space to account for the relatively juvenile detrital zircons of the same age in the Corny Point Paragneiss. In contrast, ca 2020 Ma zircons from tuffaceous sediments in the Pine Creek Orogen are juvenile, (εHf (2020 Ma) from +2 to +7), and provide a good match for the isotopic composition of detrital zircons in the Corny Point Paragneiss. It is possible that Paleoproterozoic sedimentary rocks east of the ca 1730–1690 Ma Kalinjala shear zone were derived from the north Australian craton.

The eastern Gawler Craton Hutchison Group is interpreted to be deposited between ~2000 Ma and ~1850 Ma in an N-S trending basin. U-Pb age data from detrital zircons and whole rock geochemistry and Sm-Nd isotopic data from type localities and sections indicate the Hutchison Group as it is currently known contains separate units of distinctly different provenance. Re-evaluation of the stratigraphy of Gawler Craton Archean-Paleoproterozoic sedimentary units is required.

What was opening where: dilation during the Hiltaba Mineralisation Event

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The Hiltaba Mineralisation event represents one of Australia's most economic significant era in which IOCG mineralisation occurred. The event spanned from ca 1600 Ma through to ca 1500 Ma and affected a large area of eastern Proterozoic Australia (Gawler, Curnamona, Mount Painter, Mount Isa). The Gawler Craton represents the largest of the geological provinces affected by this event and host the Olympic Dam and Prominent Hill deposits. IOCG mineralization is characterized by a strong structural control. In this presentation we assess the architecture and kinematics of the faults systems active during the Hiltaba Mineralisation Event and from this infer the regional stress regime during mineralisation at ca 1590–1580 Ma.

Three major fault systems were active during the Hiltaba Event. (1) The E-W oriented, dextral Yerda Shear Zone, (2) NE- to ENE-trending sinistral splays of the Yerda Shear Zone (e.g. Bulgunnia Fault), and (3) a series of NW-striking dextral transtensional faults that are restricted to the eastern part of the craton. Each of these fault systems can be demonstrated to be active at Hiltaba Mineralisation Event either by direct dating or using overprinting relationships. The kinematics along these fault systems suggests that the regional stress regime involved ENE-WSW extension. This regime suggests that large areas of the eastern Gawler Craton underwent extension or transtension during mineralisation, including regions surrounding the Olympic Dame deposit. The Prominent Hill deposit is located within a restraining bend of a prominent jog along the Bulgunnia Fault. The deposit appears to be hosted in an area of localised intense crustal shortening. An interesting spatial observation is that all know IOCG deposits occur along or proximal to the Yerda Shear Zone or a prominent splay of the shear zone.

The world's only felsic shield volcano: geodynamic constraints of the Mesoproterozoic Gawler Felsic Large Igneous Province, South Australia

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A multicomponent study of the 1592 ±2 Ma Upper Gawler Range Volcanics (GRV), South Australia, suggest that the Gawler Felsic Large Igneous Province (FLIP) is geo- and physico- chemically unique among the exclusive group of silicic large igneous provinces. The Gawler FLIP (GRV and Hiltaba Suite Granitoids (HSG)) rapidly formed (~15 Mry) in a highly unusual geodynamic setting involving the hindered ascent of a mantle plume and dynamic interaction with fertile Sub Continental Lithospheric Mantle. High temperature and elevated halogen concentrations promoted efficient assimilation-fractionation-crystalisation, which fed the majority of the felsic-dominated plutonism and subaerial volcanism. Field observation, physicochemical calculations and geophysical images suggest the climactic emplacement of voluminous high temperature, low viscosity, low density rhyolite-dacite magmas as lavas represents the world's only felsic shield volcano. The total initial volume of the GRV probably exceeded 2.5 x 105 km^3, and could have reached 5 x 105 km^3. This enormous volume of extrusive material, in addition to the batholithic dimensions of many HSG, is suspected to have imposed a strong control on the Gawler Craton's lithospheric and crustal response on the sourcing, ascent and emplacement of extreme volumes of magma over short time scales. The Gawler FLIP is an astonishing phenomena which informs the Proterozoic history of Australia, the generation of voluminous felsic melts on earth, the development of siliceous large igneous provinces and is best described by a geodynamic setting that has not been previously considered.

Putting some Munjeela in the Hiltaba Suite

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The Munjeela Granite consists of a series of plutonic to sub-volcanic gt-mu-bi bearing peraluminous intrusives that display rare rapakivi textures. The granite is exposed in coastal outcrops west of Ceduna and inland at Munjeela rockhole and Coorabie Quarry. In all localities the granite bodies correlate to well-defined magnetic lows on regional Total Magnetic Intensity (TMI) datasets. The intrusive at Point Sinclair also contains metasedimentary enclaves, the protolith of which is not elsewhere exposed or previously characterised.

Newly-obtained LA-ICP-MS U-Pb monazite geochronology reports a preliminary magmatic age of ~1585 Ma. Once confirmed, this syn-Hiltaba age can be incorporated into models for petrogenesis of the rapakivi Hiltaba Suite and tectonic and mineralisation frameworks for the Mesoproterozoic of the Gawler Craton.

U-Pb geochronology of detrital zircons from the metasedimentary enclaves indicates a maximum depositional age of c. 1630 Ma. Thus, the protolith sediments were deposited only shortly before the recorded amphibolite-grade metamorphism and subsequent Munjeela magmatism. Characterisation of the P-T conditions of metamorphism in the enclaves will determine if the observed mineral assemblages are related to a separate orogenic event or raised geotherms at the time of Munjeela-Hiltaba magmatism. This will have implications for models proposed by Swain et al. (in review) for the thrusting of the St Peter Suite magmatic arc over a back-arc basin at c. 1600 Ma.

A Revised Tectonothermal Evolution of the Peake and Denison Inlier

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The Palaeoproterozoic 'Peake Metamorphics' volcanic-sedimentary package is located throughout the Peake and Denison Inlier (northeast Gawler Craton) and has been correlated with similarly aged sequences of the Mt Isa Inlier (Queensland) and South Australia's York Peninsula (Wyborn et al., 1987). If these rocks are indeed analogous, their contemporary spatial distribution raises questions regarding the tectonic mechanisms driving their separation and transport. In the context of plate tectonic reconstructions, the Peake and Denison Inlier may represent the missing link between the Mount Isa Block and Gawler Craton which will allow reconciliation of conflicting theories for the amalgamation of Australia's cratonic elements.

The successful synthesis of a plate tectonic reconstruction relies on the correlation of evidence for similarly aged geological features or events that are preserved in separated cratonic elements (e.g., Karlstrom et al., 2001; Giles et al., 2004). It is dangerous to correlate separated geological provinces using a single feature such as a similarly timed orogenic event or like geochemical signatures as these may be coincidental. A far stronger relationship can be inferred from coincident lithological, structural, geophysical, thermal, chemical and temporal points of evidence.

In the first part of my research project a structural framework for the Peake and Denison Inlier has been developed using observations of field mapping and microstructure. Analysis of the older 'Unnamed Metamorphic' (Le1) series has recognized a high-strain deformation event considered to be analogous in style and metamorphic grade to the similarly aged Kimban Orogeny. The Kimban event in the Peake and Denison Inlier is characterized by at least two distinct phases of deformation; the first typified by recumbent isoclinal mildly to highly non-cylindrical folding with associated L-S type lineation and the second event is characterized by upright folding. Deformation is associated with upper amphibolite facies metamorphism and is thought to have occurred at ca. 1728 ± 28 Ma (Hopper, 2001). These two phases of deformation are overprinted by younger deformation events, likely to be the Late Kararan and Delamerian orogenies.

The second part of my project will include analysis of magnetic and gravity datasets, complementing the existing structural framework with a geophysical interpretation. Time permitting this will also include development of a regional 3d model for inversion analysis. While a partial temporal framework already exists including dating of volcanism (coincident with sedimentation), igneous intrusions and metamorphic events this database will be expanded with detrital zircon dating of quartzites from across the province. Populations of zircons have been separated from five different quartzite samples and these will be dated using laser ablation facilities at Macquarie University. These detrital populations will finger print the source of sediments and thus provide additional constraints for comparison between the Peake and Denison Inlier, Mt Isa Inlier and southern Gawler Craton.

Combining the evidence of this studies with that of previous workers (e.g., Hopper 2001; Ambrose et al 1981) I hope to produce a thorough framework that will explain how the Peake and Denison Inlier relates to other Australian geological provinces in the Proterozoic context.

Structural evolution of the polyphase Tallacootra Shear Zone and its influence on the evolution of Proterozoic South Australia

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The application of conventional methods for solving geological problems within many Archaean-Proterozoic basement geological provinces is hindered by a lack of outcrop and drillhole data. As a result oversimplified tectonic scenarios have been developed from poorly constrained geochronological and geochemical datasets and have become the subject of recent contention in light of proposed models for Australian continental growth and assembly (e.g. Betts and Giles, 2006; Wade et al. 2006). Central to these recent Australian tectonic reconstructions is the western Gawler Craton, which is poorly exposed but preserves evidence for several orogenic events within a geophysically well-defined belt termed the Fowler Domain. Within this region terrane-scale shear and fault systems clearly separate crustal elements of differing aeromagnetic and bouguer gravity response, and metamorphic history. Previously, interpretations of limited kinematic data have placed these structures within a dextral transpressional regime during Palaeoproterozoic accretion on the southern margin of the continent. However, overprinting and reworking of fabrics within these shear zones suggests a more complex tectonic history than inferred, with several reactivation events subsequent to accretion.

The Tallacootra Shear Zone (TSZ) forms a major crustal boundary within the western Gawler Craton and has revealed a complicated tectonic/kinematic evolution. Reworked Archaean mafic granulites and deformed arc-type equivalents of the ca. 1690–1680Ma Tunkillia Suite preserve a generally strong D2 mylonitic fabric developed at upper amphibolite grades by intense isoclinal folding. A component of sinistral shear is associated with flattening in the shear zone during this deformation. Spaced fabric reactivation occurs along D2 contacts where compositional contrasts are high (e.g. schist contact with pegmatite) by way of dextral slip and the development of dextral flow perturbation folds, which clearly overprint syn-D3 melt products. Overprinting mineral lineations within D2/D4 surfaces provide kinematic evidence to constrain the orientation of extrusion axes during shortening. The most well developed lineation plunges consistently NE and has been attributed to late dextral reactivation associated with small strike-slip movements and moderate pure-shear.

Regional bulk-kinematics can be interpreted from regional aeromagnetic data. Observations of terrane-scale folding, crustal boudinage, sinistral transport and dextral overprinting are comparable to detailed observations at outcrop. This kinematic evidence has been incorporated with the current geochronological framework to add vital temporal-kinematic constraints to Proterozoic reconstructions.

Dextral transpression of the Christie-Nawa Domains during the Early Kararan Orogeny (ca. 1690-1650Ma) is inferred in the Betts and Giles (2006) model of continental accretion. Our data suggest that the earliest strike-slip movement along the shear zones involves apparent sinistral movement, followed by dextral movement. If the Betts and Giles (2006) model of accretion is correct, then the sinistral movement must predate accretion, or alternatively accretion models inferred for the western Gawler Craton require revision. In either scenario, the interpretation impacts on accretionary processes for Proterozoic Australia.

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Insights into age and provenance of the Palaeoproterozoic Hutchison Group, southern Gawler Craton, South Australia

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The Hutchison Group is a variably deformed and metamorphosed mixed clastic and chemical sedimentary rock sequence that occurs as an arcuate belt along the eastern margin of the Gawler Craton, South Australia. The Hutchison Group is interpreted to be deposited between ~2000 Ma and ~1850 Ma in an N-S trending basin or shallow shelf system which deepens to the east. Sedimentary provenance is interpreted to be from the west, predominantly from the ~2400 Ma and 2000 Ma basement on which the basal quartzite of the Hutchison Group overlies (Parker and Lemon, 1982; Parker, 1993).

We present new U-Pb age data from detrital zircons and whole rock geochemistry and Sm-Nd isotopic data from type localities and sections in order to re-evaluate the provenance and stratigraphy of the Palaeoproterozoic Hutchison Group.

Preliminary detrital zircon ages and Nd isotopic data indicate the Hutchison Group as it is known contain separate units of distinctly different provenance. One unit contains exclusively Achaean (~3200 Ma and ~2650 Ma) age zircons, while others contain zircons as young as ~1790 Ma. These ages correspond to variations in εNd from evolved (-10) to relatively juvenile (-2) values respectively.

In light of these new results, careful reappraisal of Hutchison Group stratigraphy is needed in order to understand the tectonic evolution of the south-eastern Gawler Craton.

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Magnetotelluric observations across the western Gawler Craton

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2D inverse electrical modelling has been undertaken of a magnetotelluric transect extending from the eastern margin of the St. Peters Suite across the Fowler Domain into the western edge of the Gawler Craton (Fig. 1). An east-dipping conductive zone underneath the western edge of the Gawler Craton penetrates the entire crust to depths of about 50 km. This zone is overlain by shallow highly conductive cover, which thins out towards east. Underneath most of St. Peters Suite a resistive core is situated in the entire crust and is bound by shallow conductive sediments at the top.

Furthermore, new long-period magnetotelluric (MT) data have been collected on a 2D grid crossing the Western margin of the Gawler Craton in July 2006 (Fig. 1). 15 sites have site spacing of the order of 100 km, covering an area of 500x300 km north to the 2D Fowler line. Eventually, including the 2D line, a 500 x 400 km grid is available for 3D inverse modelling. Induction arrows suggest a resistive core underneath the eastern sites. The three westernmost sites show typical sedimentary basin responses. Period-dependent phase tensor inferred strike directions show a NEN-SWS general strike of stations across the eastern part of the survey. Western sites in the sedimentary basin sense 1D structure at shallow depths and 2D structure for longer periods (or equivalently farther away).

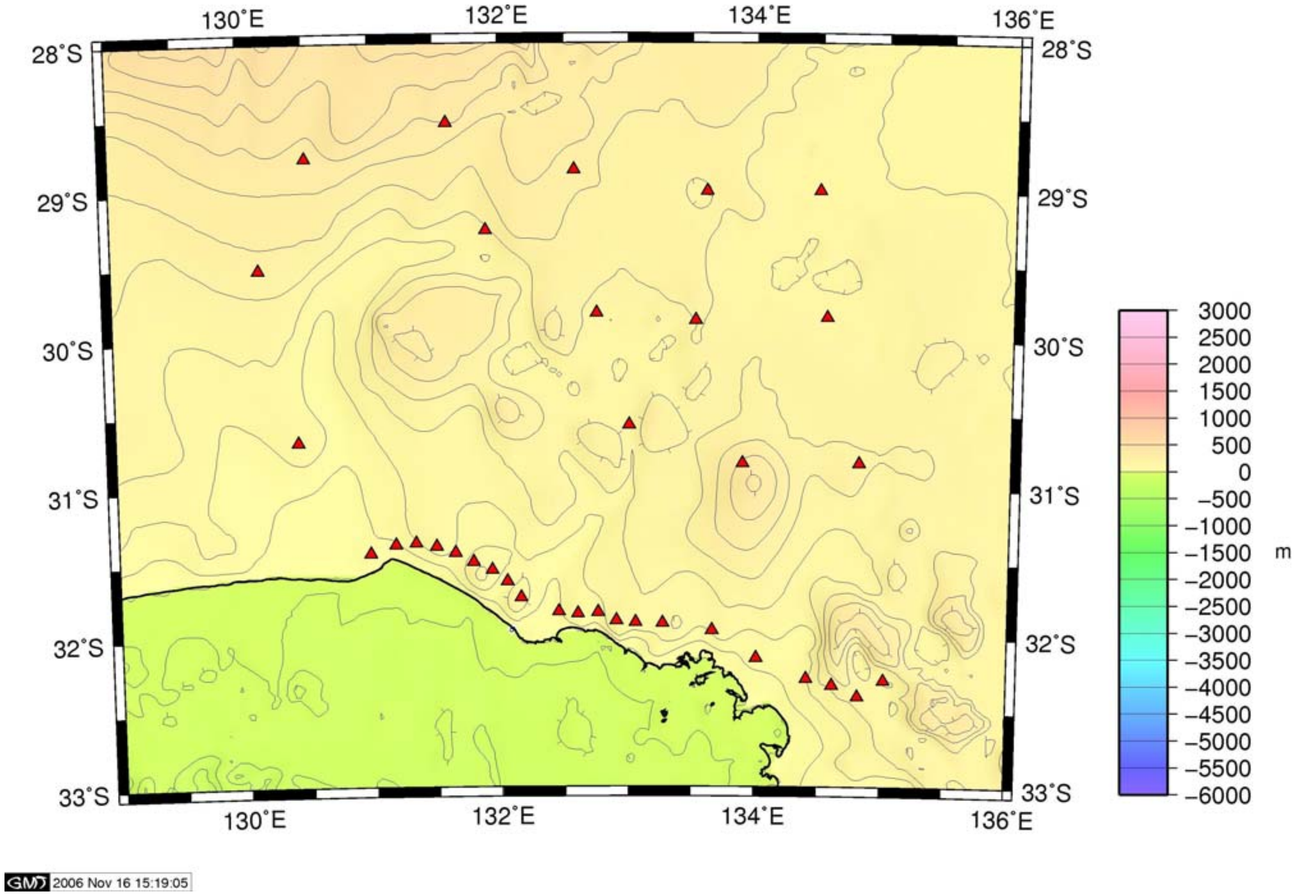

Figure 1. **Station locations on top of elevation map. Stations along the 2D line to the south have been deployed in November 2005. Sites to the north have been collected in July 2006.**

Recognising hydrothermal alteration through granulite facies metamorphism

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The Challenger gold mine, in the northwest Gawler Craton, is hosted in granulite-facies migmatitic gneisses. Lack of hydrous alteration minerals, evidence for remobilisation of Au-rich sulfide melts, and intense stretching of the ore package parallel to the regional gneissic fabric all point to a pre-metamorphic mineralisation event. A combination of textural, mineralogical, and lithogeochemical criteria are used to discriminate the effects of pre-metamorphic hydrothermal alteration from subsequent high-grade metamorphic processes. Hydrothermal alteration affected the host volcaniclastic sequence in a 50 m zone surrounding narrower Au-rich shoots. These geochemical fluxes significantly reduced the melting potential of these domains such that the altered rocks were transformed during metamorphism into mottled, granoblastic aluminous gneisses. In contrast, Au-rich zones host abundant relict quartz veins that underwent variable assimilation in voluminous K-feldspar-rich granitic melts generated through dehydration melting of quartz- and mica-rich layers. Geochemical trends attributable to this period of anatexis are distinct from those arising from premetamorphic hydrothermal alteration. These physical and geochemical observations are consistent with feldspar-destructive alteration and sericitization of proximal host rocks accompanied by phyllic (quartz veins + micas) alteration in the Au-rich horizons prior to prograde metamorphism. U-Pb geochronology of pristine magmatic zircon preserved in granoblastic proximal gneisses demonstrate that hydrothermal alteration occurred after deposition of the host volcaniclastic sequence (~2520 Ma) and before the onset of regional metamorphism (~2470 Ma). The evidence suggests an epithermal-style Au deposit that was reworked during collisional orogenesis. The short time interval between Au-deposition and subsequent basin inversion prevented erosive forces from erasing the deposit from the rock record prior to metamorphism.

Investigating the role of lithospheric architecture in the evolution of the Curnamona Province

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Significance of long-wavelength, linear potential field gradients

Long-wavelength potential field gradients and linear anomalies have long been observed and described, termed as lineaments, in literature spanning the last 50 years. Numerous authors have commented on the observed coincidence of these features with belts or corridors of ore deposits, magmatic provinces and active deformation zones leading to the implication that deep seated architecture in the component form of long, linear structures, has exerted control over the formation of these observed geological phenomena. More directly, these correlations imply that the observed features at the surface of the Earth are in fact surface counterparts to the deepest linear structures and that they are physically linked throughout the vertical strength profile of the lithosphere. However, the observation that these deep-seated structures connect through rocks of different ages causes difficulty when reconciling their apparently maintained linear geometries during repeated deformational events.

One of the challenges in tectonic theory is to explain the evolution of these shear zones in continental interiors when subjected to distal forces. This can be partially addressed by understanding the stress distribution of the continent today (e.g. Coblentz and Sandiford, 1994; Hillis and Reynolds, 2000) and by understanding the recent geomorphological responses of those stresses in the continent interior (e.g. Sandiford, 2003). These studies provide important contributions to solving the issue, but by their nature are merely snapshots of a continent as it is today. There is little emphasis on how the internal structure of a continent evolves through time in a plate tectonic context. The theory of plate tectonics was primarily developed from observations within oceanic lithosphere (e.g. Vine, 1966) and it has long been recognized that it provides an incomplete description of the deformation zones within continental lithosphere (e.g. Molnar, 1988; Holdsworth et al., 1997). This is not to say that plate tectonic theory is not applicable to the evolution of continents, but rather the response of continental lithosphere to plate tectonic processes is not as simple as the behaviour of the more rigid oceanic lithosphere. Placing the evolution of continental lithosphere in the context of plate tectonic theory has been more difficult because the strength profile of continental lithosphere is more complicated than that of oceanic lithosphere and is generally characterized by a strong upper crust, weak lower crust and a strong upper mantle (e.g. Molnar, 1988; Kohlstedt et al., 1995). This rheological profile influences the way stress is distributed and strain is accommodated. Furthermore, inefficient recycling of buoyant continental lithosphere results in the preservation of elements of protracted tectonic histories that can span billions of years. Superposition of these tectonic events produces an increasingly convoluted association of geological structures that become progressively harder to unravel.

The recognition that these shear zones affect rocks of different age suggests that they are long lived and prone to reactivation (e.g. Rathore and Hospers, 1986) however the mechanism by which these shear zones evolve spatially and temporally and how they may control the distribution of geological phenomena at the surface has not been systematically assessed. This can be attributed to a number of problems, including: 1) that due to the vertical strength profile of the continental lithosphere, the behaviour of deep-seated structures should be different to that of their surface manifestations. Such differences may include geometry, kinematics, width and connectivity; 2) that for the most part, these structures exist beneath the surface, under cover; and 3) the use of potential fields to image these links is an application, which has had little attention.

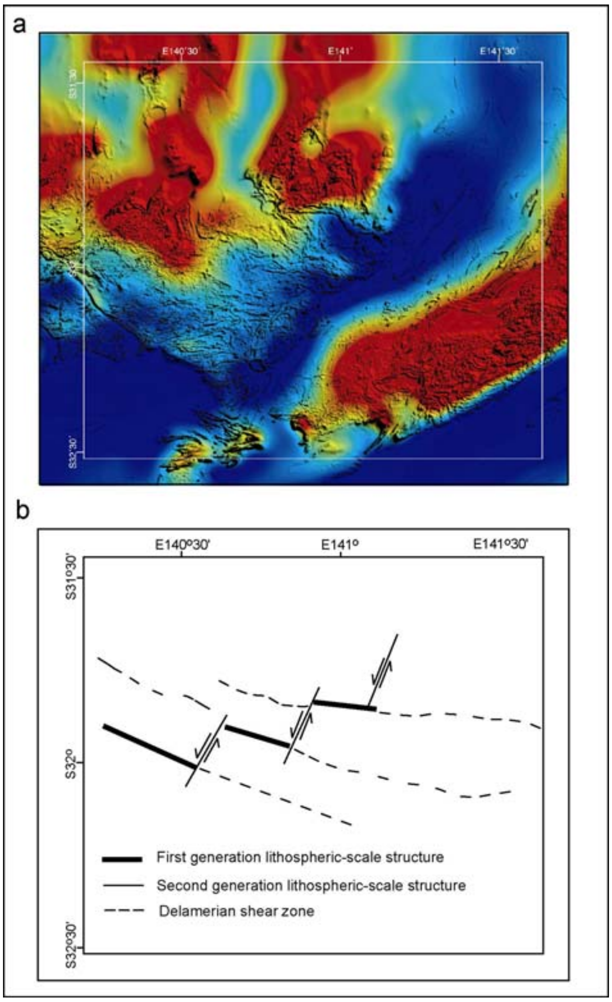

Figure 1. (a) Pseudocolor layer of aeromagnetic data upward continued to 4 km overlain by an intensity layer of the first vertical derivative of aeromagnetic data. We interpret this image as illustrating that a first-order, deep-seated structure has been overprinted by a later series of orthogonal NNE-oriented structures, which are expressed as long-wavelength magnetic gradients (i.e. are also deep-seated). In the intensity layer, high frequency anomalies associated with Delamerian shear zones at the surface (Dutch et al., 2005) can be seen to nucleate off segments of the first-order structure; (b) Structural interpretation.

Here, we image deep-crustal structure of the Proterozoic Curnamona Province, Australia, in aeromagnetic and gravity datasets, and establish spatial and temporal links between deep structures and near surface geological features by superimposing first vertical derivative responses on upward continued images. Upward continued gravity and aeromagnetic data show NW-SE, NE-SW E-W and N-S oriented long-wavelength gradients, interpreted as deep-seated structures. These structures pre-date the oldest known tectonic events recorded in outcropping rocks and appear to have been long-lived, influencing the tectonic history of the province. For example, outcropping Cambrian shear zones, evident in vertical derivative data, appear to have nucleated off displaced segments of a once continuous deep-seated structure of Proterozoic origin imaged in upward continued data (Fig. 1).

In another example, shown in Figure 2, a NW-SE oriented, long-wavelength, linear magnetic gradient, changes character along strike due to the range of surface geological phenomena and shallowly sourced potential field responses, which occur along its length. In the NW of the Curnamona Province (Mount Painter region), this interpreted deep-seated structure overprints Delamerian aged folds (ca. 500 Ma; Harrison and McDougall, 1981; Webster, 1996) within basement Willyama Supergroup rocks and overlying Adelaidean sediments. In the Central Curnamona Province (Benagerie Ridge region; Fig 2b), this same structure manifests as a 10 km wide, magnetically quiet corridor, which disrupts the high frequency magnetic texture associated with the Benagerie Volcanics. Here we interpret that the

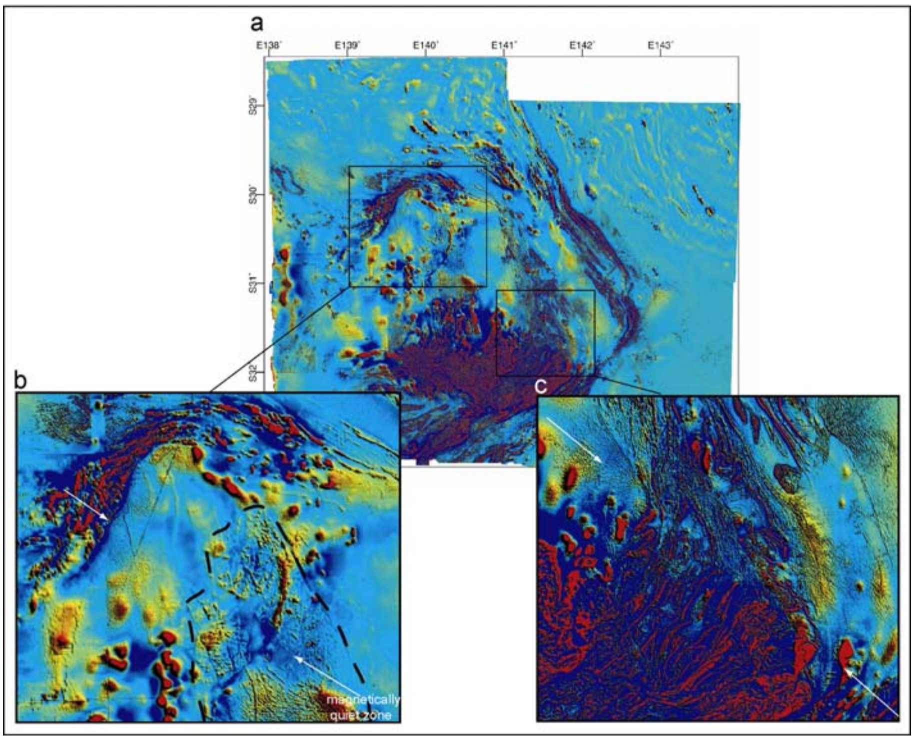

Figure 2. (a) First vertical derivative of aeromagnetic dataset of the Curnamona Province, with magnified images of: (b) the NW Curnamona Province, including the Benagerie Volcanics (characterized by high frequency stippled magnetic texture, boundaries annotated by dashed line) and (c) the northern Broken Hill Domain in the SE of the province. The continuation of a deep-seated NW-SE oriented structure can be seen in each area.

deep-seated structure may have acted as a control on the emplacement of the Benagerie Volcanics and the associated suite of granites (ca. 1580 Ma; Fanning et al., 1998). The southeastern section of this structure, in the Broken Hill Domain (Fig 2c), coincides with a NE-dipping normal fault at the surface, which separates basement Willyama Supergroup rocks, to the SW from Adelaidean sediments to the NE. At this location, the normal fault and surrounding rocks are folded placing important constraint on the age of normal faulting (i.e. pre-Delamerian Orogeny). Here, we interpret normal faulting to have occurred during or after deposition of the Adelaide Rift Complex (ca. 800 Ma; Powell et al., 1994; Preiss, 2000) and before the Delamerian Orogeny.

From our observations, the earliest activity along this structure, associated with the emplacement of the Benagerie Volcanics (~1600 Ma), occurs in the centre of the Curnamona Province. The next episode observed involved normal faulting in the SE (Broken Hill Domain), which juxtaposed Adelaidean sediments against Willyama Supergroup basement rocks and is probably associated with development of the Adelaide Rift Complex (~800 Ma). Following this, the next episode of activity is in the NW where Delamerian folds are clearly overprinted by this large-scale structure (i.e. movement on structure is either contemporaneous with or occurred after folding) (~500 Ma). Finally, the disruption of the high-frequency magnetic signature of the Benagerie Volcanics (i.e. magnetically quiet zone) implies activity along this segment of the structure after the emplacement of the volcanic rocks, whereby fluid flow has dissipated magnetic minerals within the shear zone. Interestingly, these observations imply that either propagation of the shear zone itself or of the activity along it has moved in a continuous direction over the last 1600 million years. Moreover, whilst the surface expression of this deep-seated structure has been deformed by ongoing tectonic events (e.g. it is folded in the Broken Hill region), the deepest extent of it apparently remains linear and continuous (as can be seen in upward continued potential field images). This generates a key question: how do lithospheric-scale shear zones propagate, both vertically and laterally?

When we consider the Curnamona Province in a plate tectonic context then we would not expect to see the continuation of long-lived deep-seated structures outside the Curnamona Province. Rather, we would expect to see these large structures truncated against the known boundaries of the province. However, on a continental scale, the deep-seated NW-SE oriented structure can be seen to persist beyond the Curnamona Province to the NW and continues into the Musgrave Province. This observation, which appears to contradict plate reconstructions for the South Australian Craton, actually highlights our limited understanding of the link between deep structural architecture and the shallow crust as well as the propagation mechanisms involved with the evolution of these lithospheric-scale shear zones.

Conclusions

Tectonic implications of this study include: (1) Deep-seated structures in the Curnamona Province have protracted histories; (2) These structures have controlled the location and distribution of younger shear zones, igneous activity, and possibly basin subsidence in the upper crust; (3) Geophysical lineaments are likely to have evolved and propagated during multiple tectonic cycles and hence record the protracted evolution of a geological province. These results show that lithospheric-scale structures can remain remarkably linear over long periods of geologic time. Hence, while periods of significant stress are known to have deformed mid- to upper-crustal rocks in a region (e.g. the Curnamona Province), the lower crust apparently remains relatively rigid and undeformed such that structures, which persist to lower crustal depths, are long-lived and prone to repeated reactivation. These observations imply a vertical partitioning of strain between the lower and upper crust, a factor, which requires consideration when unravelling the deformation history of a craton.

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