Ore Geology Reviews 76 (2016) 211–228

Contents lists available at ScienceDirect

Ore Geology Reviews

journal homepage: www.elsevier.com/locate/oregeorev

Major crustal boundaries of Australia, and their significance in mineral systems targeting

R.J. Korsch, M.P. Doublier *

Resources Division, Geoscience Australia, GPO Box 378, Canberra, ACT 2601, Australia

ARTICLE INFO

Article history:
Received 18 September 2014
Received in revised form 1 May 2015
Accepted 14 May 2015
Available online 22 May 2015

Keywords:
Australia
Seismic reflection
Crustal boundary
Crustal architecture
Basement block
Mineral system

ABSTRACT

For over 35 years, deep seismic reflection profiles have been acquired routinely across Australia to better understand the crustal architecture and geodynamic evolution of key geological provinces and basins. Major crustal-scale breaks have been interpreted in some of the profiles, and are often inferred to be relict sutures between different crustal blocks, as well as sometimes being important conduits for mineralising fluids to reach the upper crust. The widespread coverage of the seismic profiles now allows the construction of a new map of major crustal boundaries across Australia, which will better define the architecture of the crustal blocks in three dimensions. It also enables a better understanding of how the Australian continent was constructed from the Mesoarchean through to the Phanerozoic, and how this evolution and these boundaries have controlled metallogenesis. Starting with the locations in 3D of the crustal breaks identified in the seismic profiles, geological (e.g. outcrop mapping, drill hole, geochronology, isotope) and geophysical (e.g. gravity, aeromagnetic, magnetotelluric) data are used to map the crustal boundaries, in plan view, away from the seismic profiles. Some of the boundaries mapped are subsurface boundaries, and, in many cases, occur several kilometres below the surface; hence they will not match directly with structures mapped at the surface. For some of these boundaries, a high level of confidence can be placed on the location, whereas the location of other boundaries can only be considered to have medium or low confidence. In other areas, especially in regions covered by thick sedimentary successions, the locations of some crustal boundaries are essentially unconstrained, unless they have been imaged by a seismic profile. From the Mesoarchean to the Phanerozoic, the continent formed by the amalgamation of many smaller crustal blocks over a period of nearly 3 billion years. The identification of crustal boundaries in Australia, and the construction of an Australia-wide GIS dataset and map, will help to constrain tectonic models and plate reconstructions for the geological evolution of Australia, and will provide constraints on the three dimensional architecture of Australia. Deep crustal-penetrating structures, particularly major crustal boundaries, are important conduits to transport mineralising fluids from the mantle and lower crust into the upper crust. There are several greenfields regions across Australia where deep crustal-penetrating structures have been imaged in seismic sections, and have potential as possible areas for future mineral systems exploration.

1. Introduction

Many major mineral systems lie on, or adjacent to, major deeply-penetrating, fault systems, suggesting that the faults acted as important fluid migration pathways to transport mineralising fluids from the upper mantle or lower crust, and are ideal for focussing fluid flow into the upper crust (e.g. Drummond et al., 2000a; Barnicoat, 2007; Willman et al., 2010; Johnson et al., 2013; McCuaig and Hronsky, 2014). Certain types of these mineral systems are related to major crustal boundaries. For lode gold deposits in the Archean Yilgarn Craton, Western Australia, for example, Groves et al. (1989) noted the close spatial relationship between the major gold deposits and major shear zones. Deep seismic reflection profiling in the Yilgarn Craton has contributed to the understanding that a major shear zone, the Ida Fault, is an east-dipping deep crustal penetrating structure, and that it is an important terrane boundary in the craton (Drummond et al., 1993, 2000b; Swager et al., 1997; Cassidy et al., 2006). The Bardoc Shear Zone was interpreted as a west-dipping backthrust soling onto the Ida Fault in the upper crust. Numerical modelling demonstrated that fluid flow from the lower crust could have accessed the Ida Fault, before utilising the Bardoc Shear Zone as a pathway to the upper crust (e.g. Upton et al., 1997; Sorjonen-Ward et al., 2002; Drummond et al., 2004).

Other mineral systems, such as iron oxide–copper–gold (IOCG) and orthomagmatic Ni–Cu are also related to major crustal boundaries (see Groves et al., 2010, and Begg et al., 2010, respectively). Deep seismic reflection data have been used to assess the crustal-scale architecture and geodynamic setting of several major mineral deposits in Australia (e.g. Drummond et al., 2000a), including the Kalgoorlie gold deposits (see above). As another example, in the vicinity of the Olympic Dam

* Corresponding author at: Geoscience Australia, GPO Box 378, Canberra, ACT 2601, Australia.
E-mail addresses: russell.korsch@ga.gov.au (R.J. Korsch), michael.doublier@ga.gov.au (M.P. Doublier).

http://dx.doi.org/10.1016/j.oregeorev.2015.05.010
0169-1368/

deposit in the Gawler Craton, deep seismic reflection data imaged a deep crustal-penetrating structure, the Elizabeth Creek Fault beneath the deposit (Drummond et al., 2006). Thus, deep crustal penetrating faults have been important pathways of fluids, and have played an important role in the formation of many types of mineral systems. The recognition of these structures in deep seismic reflection traverses in greenfields areas might point to possible fluid pathways from the lower crust, and help focus mineral exploration in the future.

2. Crustal boundaries in Australia

The geology of Australia (Raymond, 2009) was built from the Eoarchean to the Cenozoic (Fig. 1a). Over a period of nearly 3 billion years, from the Mesoarchean to the Phanerozoic, the continent of Australia formed by the amalgamation of many smaller crustal blocks (e.g. Myers et al., 1996; Betts et al., 2002; Tyler, 2005; Cawood and Korsch, 2008). This amalgamated pattern of crustal blocks can be seen in the overall irregular pattern and termination of anomalies observed in both the aeromagnetic (Milligan et al., 2010) and gravity (Bacchin et al., 2008) maps of Australia (Fig. 2). Plumb (1979) produced a series of paleotectonic maps of Australia showing the distribution of key crustal blocks through time. This was based essentially on outcrop mapping, although an attempt was made to predict the subsurface distribution of the crustal blocks; this attempt was limited by the problem that much of Australia is covered by Mesozoic and Cenozoic sedimentary basins (Fig. 1a), as well as frequently thick regolith. Thus, at that time, tectonic maps of Australia did not provide an accurate distribution of basement units which underlie the sedimentary basins; nor did they provide useful information on the third dimension (depth).

Using new gravity and magnetic maps for the continent, combined with surface geology, Shaw et al. (1995) produced a more integrated interpretation of basement crustal elements than was possible previously, as the potential field data allowed the crustal elements mapped at the surface to be tracked in the subsurface, beneath the younger sedimentary basins and regolith. Shaw et al. (1995) outlined the crustal elements of Australia, and the geodynamic evolution of Australia can be interpreted, in part, using the geographic distribution of these elements (e.g. Myers et al., 1996; Betts et al., 2002; Tyler, 2005; Cawood and Korsch, 2008; Huston et al., 2012; Blewett et al., 2012).

Here, we report on a new GIS dataset (Appendix A) showing the distribution of key crustal boundaries of Australia, which uses, as the starting point, boundaries to the crustal blocks, as interpreted in deep seismic reflection data that have been collected routinely across Australia since 1980. We have used this GIS dataset to generate the maps shown below, but note that the dataset contains much additional information which cannot be displayed at the scale of the maps. Note also that, in Australia, a variety of terms are used to describe fundamental geological units. The basic unit is a 'province', and this has several synonyms, including craton, terrane and basin. A domain or a zone is a subunit of a province, so that there can be several domains or zones within a province. The term 'region' is used to describe the surface distribution of geological units, which, when combined with their subsurface extensions, form a province. Several provinces have been combined to form the three major cratonic units in Australia: the West Australian, North Australian and South Australian Cratons (e.g. Myers et al., 1996; Cawood and Korsch, 2008) (Fig. 1b).

3. Deep seismic reflection data in Australia

Beginning in 1957, Geoscience Australia (then named the Bureau of Mineral Resources) conducted experimental recordings of deep seismic reflection data to 16–20 s two-way travel time (TWT), during routine acquisition of shallow seismic reflection data to 4 s or 6 s TWT, mainly in sedimentary basins across Australia (Moss and Mathur, 1986; Moss and Dooley, 1988). The success of the deep seismic reflection experiments led to deep seismic reflection profiles (usually acquired to 20 s TWT, about 60 km depth) being acquired routinely by Geoscience Australia since 1980 (Kennett et al., 2013), with the main aim being to better understand the crustal architecture and geodynamic evolution of key geological provinces and basins. The first significant acquisition of deep seismic reflection data occurred in southern Queensland between 1980 and 1986 (e.g. Finlayson, 1990), and there is now widespread coverage of deep seismic reflection data across Australia (Fig. 3), with over 17,000 line km of data having being acquired to mid-2014.

Major crustal-scale breaks have been interpreted in many of the deep seismic profiles, and are often inferred to be relict sutures between different crustal blocks (e.g. Korsch et al., 1997, 2012; Cayley et al., 2011; Glen et al., 2013; Johnson et al., 2013). Also, significant changes in the seismic character of the mid to lower crust have been mapped; these lower crustal units are frequently unable to be tracked to the surface (see, for example, Korsch et al., 2010a; 2012; 2014). Hence the term 'seismic province' was used to refer to a discrete volume of middle to lower crust, which cannot be traced to the surface, and whose crustal reflectivity is different to that of laterally or vertically adjoining provinces (Korsch et al., 2010a). Seismic provinces, seismic domains and seismic subdomains have the same hierarchy as provinces, domains and subdomains described above. The widespread coverage of the seismic profiles now provides the opportunity to assess the relationship between the three major cratons in Australia (Fig. 1b), and to construct a map of the major crustal boundaries across Australia, which will allow a better understanding of how the Australian continent was constructed from the Mesoarchean through to the Phanerozoic, and how this evolution and these boundaries have controlled metallogenesis. Although this map is presented here as a two-dimensional image, the use of the deep seismic reflection lines provides the third-dimensional (depth) constraint, which forms the basis for a 3D map of the major crustal blocks of Australia currently being constructed by Geoscience Australia.

In places, the deep seismic reflection data have shown that the fault mapped at the surface is frequently not the actual crustal boundary between the basement blocks, which can be covered by younger sediment, and that the boundary can be many kilometres away in the subsurface. To illustrate this, we use two examples. Firstly, we examine the Baring Downs Fault, which is the boundary between the Bandee Seismic Province and the Pilbara (granite–greenstone) Craton (Johnson et al., 2013). The contact between these two provinces occurs at a depth of about 4.7 s TWT (~14 km), and is concealed below rocks of the Neoarchean Fortescue Group and younger units (Fig. 4). Due to later reactivation, the Baring Downs Fault has propagated to the current surface (Johnson et al., 2013). For the boundary of the crustal blocks, we map the contact point between the Bandee Seismic Province and the Pilbara Craton at 4.7 s TWT in seismic line 10GA-CP1 (Fig. 4; see also Johnson et al., 2013). On the crustal boundaries map, this point is projected vertically to the surface, and hence is some distance from the mapped position of the fault on the surface (Fig. 4). Secondly, the boundary between the Davenport and Aileron provinces (Fig. 5) is the Atuckera Fault (Fig. 6), which is now covered by Neoproterozoic–Devonian sedimentary rocks of the Georgina Basin (see detailed discussion below). Thus, to map the position of this crustal boundary, the position of the fault on seismic line 09GA-GA1 is taken as the point at the base of the Georgina Basin. This is at a depth of about 1 s TWT (~3 km), and on the crustal boundaries map this point is projected vertically to the surface. Hence, it is not possible to use the detailed surface mapping undertaken mostly by state geological surveys to locate the positions of the crustal boundaries in our digital dataset and map.

Below, we present three case studies, as examples of how crustal boundaries have been mapped in the seismic data, before elaborating on the development of the new map of the major crustal boundaries of Australia.

4. Crustal boundary between Davenport Province and Aileron Province

In 2009, Geoscience Australia, in conjunction with the Northern Territory Geological Survey, acquired 373 line km of vibroseis-source,

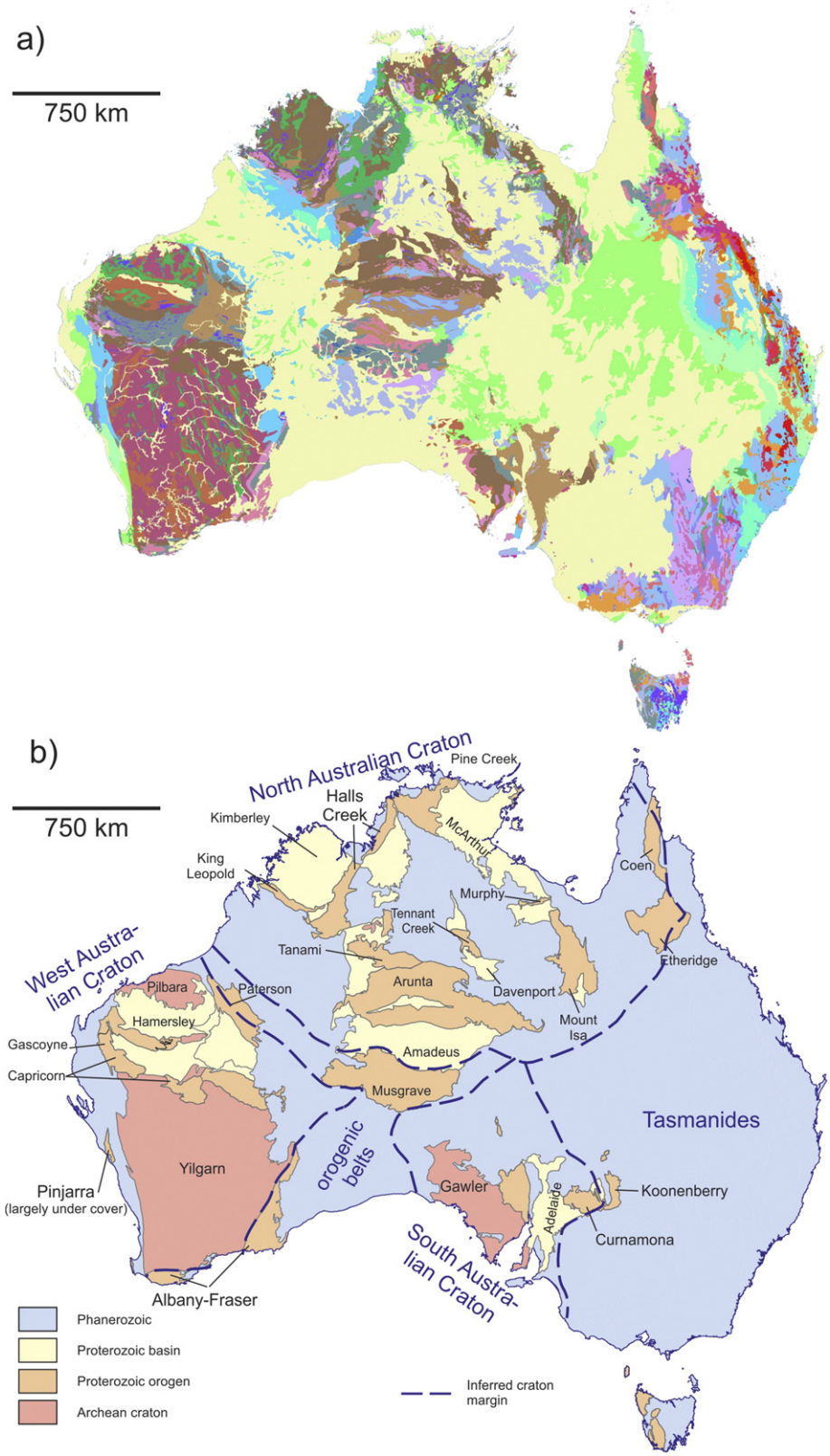

Fig. 1. (a) Simplified map of the surface geology of Australia (after Raymond, 2009). The light green and yellow colours represent Mesozoic and Cenozoic rocks, respectively, and cover much of the surface of Australia. Other colours represent Archean to Paleozoic rocks. (b) Simplified map of Australia showing the inferred distribution of Archean, Proterozoic and Phanerozoic age rock units and geological units within the West Australian, North Australian and South Australian Cratons.
Adapted from Myers et al. (1996).

75-fold, deep seismic reflection data to 20 s TWT, providing an image of the crust and upper mantle, to a depth of about 60 km, along a single north–south traverse in the southern Northern Territory (Scrimgeour and Close, 2011; Korsch et al., 2011b). This traverse, 09GA-GA1, referred to as the Georgina–Arunta seismic line, extends from the northeastern Amadeus Basin, across the Casey Inlier, the Irindina and Aileron

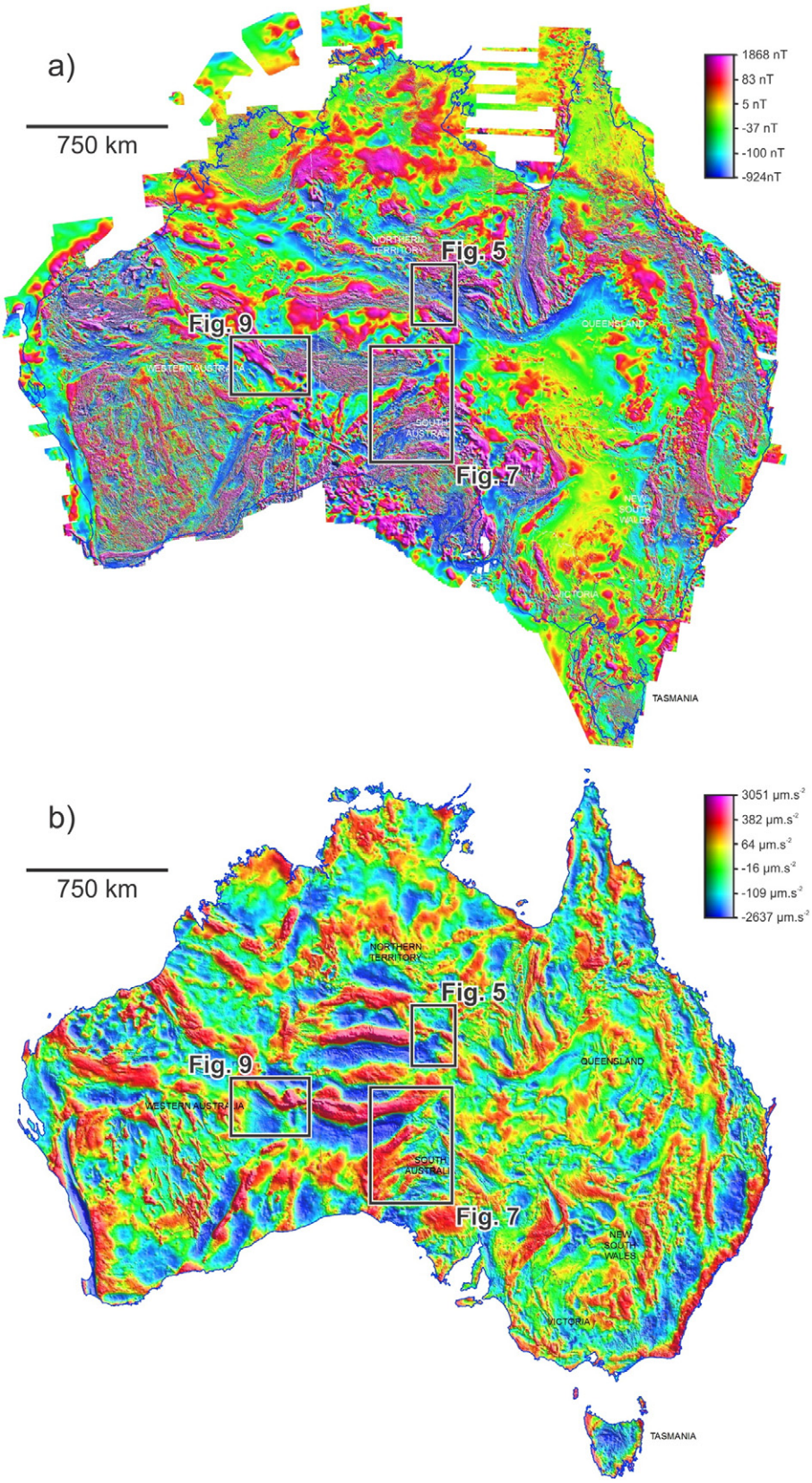

Fig. 2. (a) Map of aeromagnetic data for the Australian continent (after Milligan et al., 2010), and (b) map of gravity anomalies for the Australian continent (after Bacchin et al., 2008), with both datasets showing irregular patterns suggesting that Australia consists of an amalgam of several crustal blocks. Boxes show locations of areas covered in Figs. 5, 7 and 9.

provinces of the Arunta Region, and the Georgina Basin to the southernmost Davenport Province (Figs. 3, 5). For detailed descriptions of the geology of each of these units see Ahmad and Munson (2013). Of primary concern here, is the relationship between the Paleoproterozoic Davenport Province and the Paleoproterozoic–Mesoproterozoic Aileron Province. At the surface, the boundary

Fig. 3. Map of Australia showing the locations of the onshore deep seismic reflection lines collected since about 1980, draped on an image of grey scale aeromagnetic data. Key seismic lines mentioned in text are labelled (see also Fig. 11).

between these two provinces is covered by the Neoproterozoic–Devonian Georgina Basin (Fig. 5), and, farther to the south, the Irindina Province separates two parts of the Aileron Province. In seismic section 09GA-GA1, the Aileron Province is, in general, only weakly reflective,

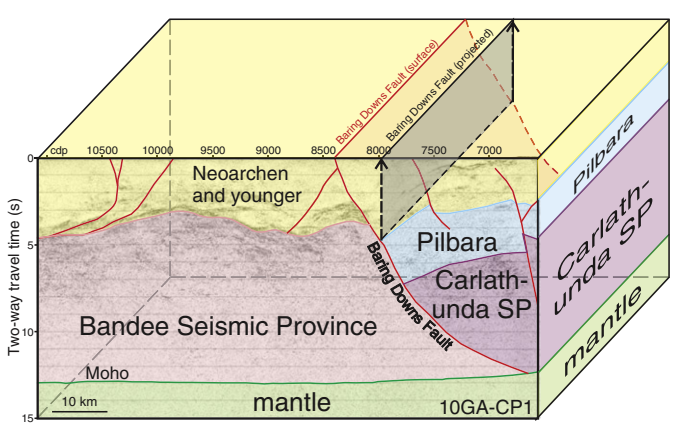

Fig. 4. Block diagram to illustrate how the major crustal boundaries have been mapped in the subsurface. This shows the difference between the surface trace of the Baring Downs Fault and its subsurface location, projected vertically to the surface. The example is taken from seismic line 10GA-CP1 (Johnson et al., 2013). Neoarchean and younger represents the Neoarchean Fortescue and Hamersley Groups and the Paleoproterozoic Wyloo Group.

with the middle crust tending to be slightly more reflective than the upper and lower crust (Fig. 6).

The northernmost end of seismic line 09GA-GA1, as far south as CDP 2020, was acquired on outcrop of the Davenport Province (Fig. 5). The Davenport Province has a distinctive, folded pattern in the total magnetic intensity image, and indicates that the magnetic pattern seen in the exposed part of the Davenport Province (CDP 2020 and farther north, to beyond the seismic line) continues to the south beneath thin cover of the Georgina Basin. The magnetic pattern becomes more diffuse as the sediment cover becomes thicker southwards.

Seismic section 09GA-GA1 shows a marked change in the seismic reflectivity of the crust at about CDP 7200, with the northern part of the section having a much stronger reflectivity, particularly in the middle crust (Fig. 6). Korsch et al. (2011b) termed the boundary at this change in reflectivity the Atuckera Fault, and interpreted it to be a steep, south-dipping structure, which cuts deeply into the crust (Fig. 6). Based on the seismic section, they considered that, in the subsurface, the Davenport Province extends beneath the Georgina Basin to as far south as the Atuckera Fault, with the Aileron Province interpreted to extend as far north as the fault, beneath a thin cover of the southern Georgina Basin (Fig. 6). Because of its crustal-scale, and the contrasting reflectivity across it, Korsch et al. (2011b) inferred that the Atuckera Fault (now beneath the Georgina Basin) is the site of an ancient suture between the two different crustal blocks.

The interpretation of seismic section 09GA-GA1 (Fig. 6) indicates that the fault has been reactivated at least twice since the initial suturing

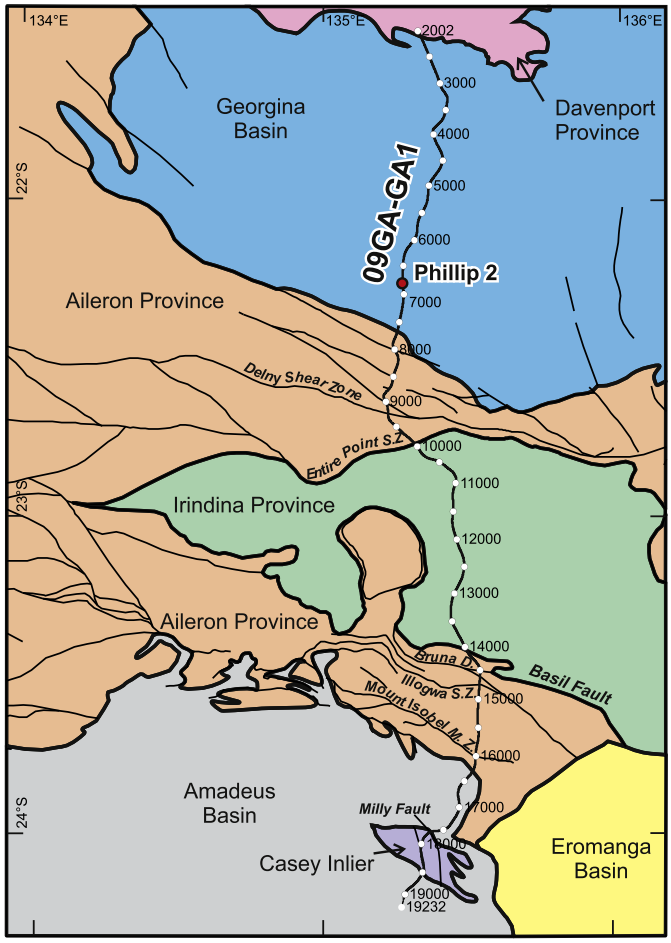

Fig. 5. Solid geology map of part of the southern Northern Territory, showing the geological provinces and basins, plus the location of deep seismic line 09GA-GA1. The solid geology is based on a simplification from Ahmad and Scrimgeour (2006). Faults are shown as thin black lines, with the province and basin boundaries shown as thick black lines.

(Korsch et al., 2011b). The first reactivation occurred after intrusion of 1802 ± 8 Ma granite (dated by Kositcin et al. (2011) in petroleum exploration well Phillip 2), which is interpreted to be truncated by the Atuckera Fault (Fig. 6), but before Neoproterozoic deposition of sediments in the Georgina Basin across the top of the fault. The second reactivation occurred after deposition of the Late Devonian Dulcie Sandstone in the Georgina Basin, as seen by the monoclinal uplift of the southern limb of the Dulcie Syncline above the Atuckera Fault (Fig. 6).

To the northwest of the Georgina–Arunta seismic survey, the 2005 Tanami seismic line 05GA-T1 imaged a structure, which was inferred to represent the collision zone between the Tanami Region and the Aileron Province (Goleby et al., 2009). Korsch et al. (2011a) considered that the Atuckera Fault, interpreted in seismic line 09GA-GA1, is the eastward continuation of the suture seen at the southern end of seismic line 05GA-T1.

Interpretation of seismic line 05GA-T1 by Goleby et al. (2009) indicated that the collision and formation of the suture occurred prior to deposition of the Killi Killi Formation (Tanami Region) and Lander Rock Formation (Aileron Province), as these formations overlie the suture. These units are considered to have been deposited between 1840 and 1810 Ma (Claoué-Long et al., 2008a), and are equivalent in time to the Ooradidgee Group in the Davenport Province. The older Warramunga and Stubbins formations, deposited at ca 1865–1860 Ma, have been interpreted by Huston et al. (2008) and Bagas et al. (2008), respectively, to have been deposited in backarc basins, associated with convergence between the Tanami–Tennant Creek regions and the Aileron Province. On this basis, it can be interpreted that the collision occurred within the interval of 1860–1840 Ma, possibly producing the ca 1850 Ma Tennant Event (Claoué-Long et al., 2008b).

Given that the Atuckera Fault, interpreted in seismic line 09GA-GA1, is considered to be the eastward continuation of the suture seen at the southern end of seismic line 05GA-T1, the magnetic and gravity images (Fig. 2) can now be used to join the structures in map form, and to track the structure farther to the east and to the west (see below).

5. Crustal boundary between Gawler Craton and Musgrave Province

In 2008, Geoscience Australia, in conjunction with AuScope, Primary Industries and Resources South Australia (now the Geological Survey of South Australia) and the Northern Territory Geological Survey, acquired 634 km of vibroseis-source, 75-fold, deep seismic reflection data to 20 s TWT, providing an image of the crust and upper mantle to a depth of ca 60 km. This was a single north–south traverse from about 25 km southeast of Erldunda in the southern Northern Territory to near Tarcoola in central South Australia (Figs. 3, 7) (Costelloe and Holzschuh, 2010; Korsch et al., 2010b). The traverse, 08GA-OM1, followed the Adelaide to Alice Springs railway line, utilising the railway access road, and is referred to as GOMA, as it traversed the northern Gawler Craton, eastern Officer Basin, eastern Musgrave Province and the southern Amadeus Basin (Fig. 7). Of interest here is the relationship between the Mesoarchean to Mesoproterozoic Gawler Craton, in the south, and the Mesoproterozoic Musgrave Province in the north (Figs. 1b, 7). The Nawa Domain, the northernmost domain of the Gawler Craton, is one of the largest in the craton, and extends, from sparse outcrops in the south, northwards under the younger Officer Basin (Fig. 7). In the vicinity of the GOMA seismic line, the Gawler Craton is almost entirely covered by younger sedimentary basins: the Neoproterozoic–Devonian Officer and southern Amadeus basins, the Permian Arckaringa Basin, the Jurassic–Cretaceous Eromanga Basin and surficial Cenozoic sediments (with the Permian and younger sedimentary rocks being essentially too thin to show individually on the scale of the seismic section in Fig. 8).

The southern boundary of the Musgrave Province traditionally has been mapped as the contact with the Officer Basin at the surface, at the Everard Thrust (Fig. 7), and the inferred northern margin of the Gawler Craton was postulated to be well south of the Everard Thrust (e.g. Ferris et al., 2002). Nevertheless, it was recognised that the boundary between the Musgrave Province and the Nawa Domain of the Gawler Craton occurred beneath the Officer Basin, but was poorly located (see Cowley, 2006a,2006b).

The GOMA seismic line shows that the Nawa Domain is composite, and that it can be subdivided into several distinctive seismic subdomains, based on differences in seismic reflectivity (Fig. 8). The seismic subdomains appear to be bounded by a series of crustal-scale thrust slices. The Wintinna Hill Seismic Subdomain (Korsch et al., 2010b) is the northernmost seismic subdomain, and is a relatively small domain between the Wintinna Hill Fault in the south at about CDP 21310 and the north-dipping Sarda Bluff Fault in the north at about CDP 22000 (Fig. 8).

Small isolated basement outcrops within the Officer Basin, to the east of about CDP 23200 on the GOMA seismic line, are termed the Yoolperlunna Inlier, and have affinities with the Gawler Craton (Fanning et al., 2007; Dutch et al., 2010; Jagodzinski and Reid, 2010; Reid et al., 2014). In the seismic data, the inlier, projected to the west, is interpreted to occur between the Sarda Bluff Fault at CDP 22000 and the Mount Johns Fault, which dips gently to the south at CDP 23400 (Korsch et al., 2010b) (Fig. 8). The Yoolperlunna Inlier is considered to be a thrust slice of the Wintinna Hill Seismic Subdomain, which has been backthrust to the north. This thrusting occurred before deposition of the Officer Basin, which extends continuously to both the north and south of the inlier. The Officer Basin above the Yoolperlunna Inlier is folded and faulted, with reactivation on the faults, which probably occurred during the Petermann Orogeny (580–530 Ma; Close, 2013).

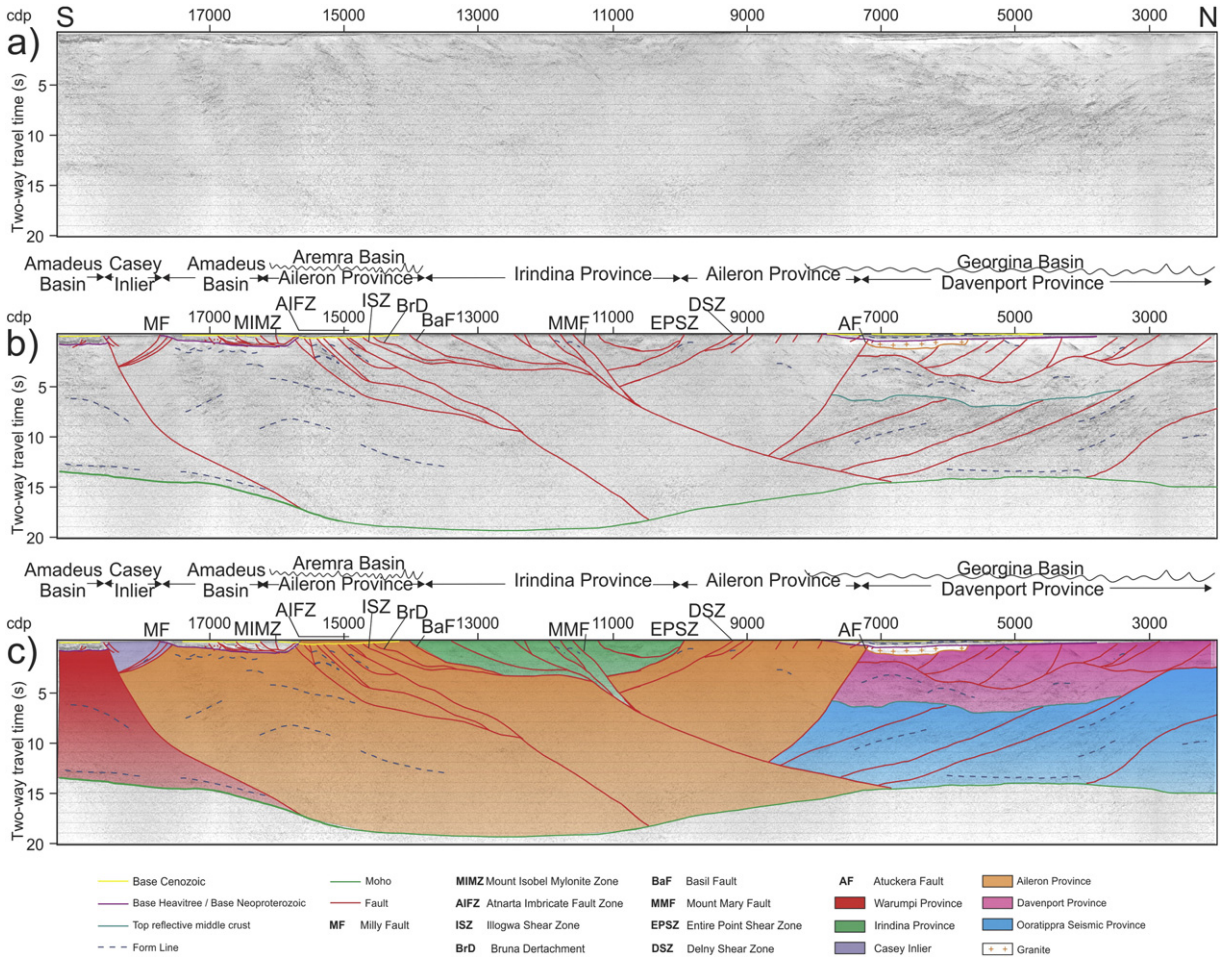

Fig. 6. Migrated seismic section for Georgina–Arunta seismic line 09GA-GA1, showing (a) uninterpreted section, (b) interpretation of major structures, and (c) overlay showing distribution of key provinces and basins. Display shows vertical scale equal to horizontal scale (assuming average crustal velocity of 6000 ms^{-1}).

On the GOMA seismic line, the Musgrave Province consists of a two-layered crust, with a moderately reflective upper crust and a weakly reflective lower crust, which is distinctly different in seismic character to that of the Gawler Craton to the south (Fig. 8). This upper reflective crust can be traced in the seismic section well to the south of the Everard Thrust, below the Mount Johns Fault, and is interpreted to terminate at the Sarda Bluff Fault. Thus, the Sarda Bluff Fault is important in that it marks the northern limit of the main Gawler Craton at depth below the Officer Basin (except for the thin sliver of Yoolperlunna Inlier), with the Musgrave Province occurring to the north of the fault and, thus, is the main crustal boundary between the basement provinces (Fig. 8). To map its position for the crustal boundaries dataset and map, the position of the fault on seismic line 08GA-OM1 is taken as the point below the Yoolperlunna Inlier. This is at a depth of about 4 s TWT (~12 km), and on the crustal boundaries map this point is projected vertically to the surface. Thus, in the crustal boundaries map, the fault is shown at least 10 km to the north of its surface position.

In the GOMA seismic section, the Musgrave Province is broadly V-shaped, being bound in the south by the north-dipping Sarda Bluff Fault, and to the north by the south-dipping Woodroffe Thrust. These faults have been interpreted to cut the Moho, displacing it upwards beneath the Musgrave Province (Fig. 8). The Woodroffe Thrust, at CDP 32370, is a south-dipping, planar fault which cuts the entire crust. Korsch et al. (2010b) interpreted the thrust to extend to a depth of about 16 s TWT (~48 km). At this locality, it is a basement structure forming the crustal boundary between the Musgrave Province and the Warumpi Province (Korsch et al., 2010b).

Wade et al. (2006) considered that, initially, the Musgrave Province was an island arc, with a south-dipping subduction zone to the north of the province operating from at least ~1607 Ma until ~1594 Ma (see also Korsch et al., 2010c; 2011a). Consumption of oceanic crust eventually led to the suturing of the Musgrave Province to the Warumpi Province (the southernmost part of the Arunta Region of the North Australian Craton, Fig. 1b). Korsch et al. (2010c; 2011a) considered that the initiation of the Chewings Event (ca. 1590–1560 Ma; Scrimgeour, 2013) in the southern Arunta Region might be a manifestation of this collision, and that the collision was probably initiated at about 1594 Ma. An oceanic backarc (marginal sea) was present to the south of the island arc. Following the initial contact of the Musgrave Province with the Warumpi Province, polarity of the subduction zone is inferred to have flipped, with the oceanic crust of the marginal sea being consumed in a north-dipping subduction zone which dipped beneath the Musgrave Province. Arc magmatism continued in the Musgrave Province until about 1565 Ma, when the Gawler Craton of the South Australian Craton was amalgamated with the expanded North Australian Craton.

6. Crustal boundary between Yilgarn Craton and Musgrave Province

In May and June 2011, Geoscience Australia, in conjunction with the Geological Survey of Western Australia, acquired 484 line kilometres of vibroseis-source, 75-fold, deep seismic reflection data to 22 s TWT, providing an image of the crust and upper mantle to a depth of ca 66 km, along a single, northeast–southwest oriented traverse. This traverse, 11GA-YO1, referred to as the YOM (Yilgarn Craton–Officer

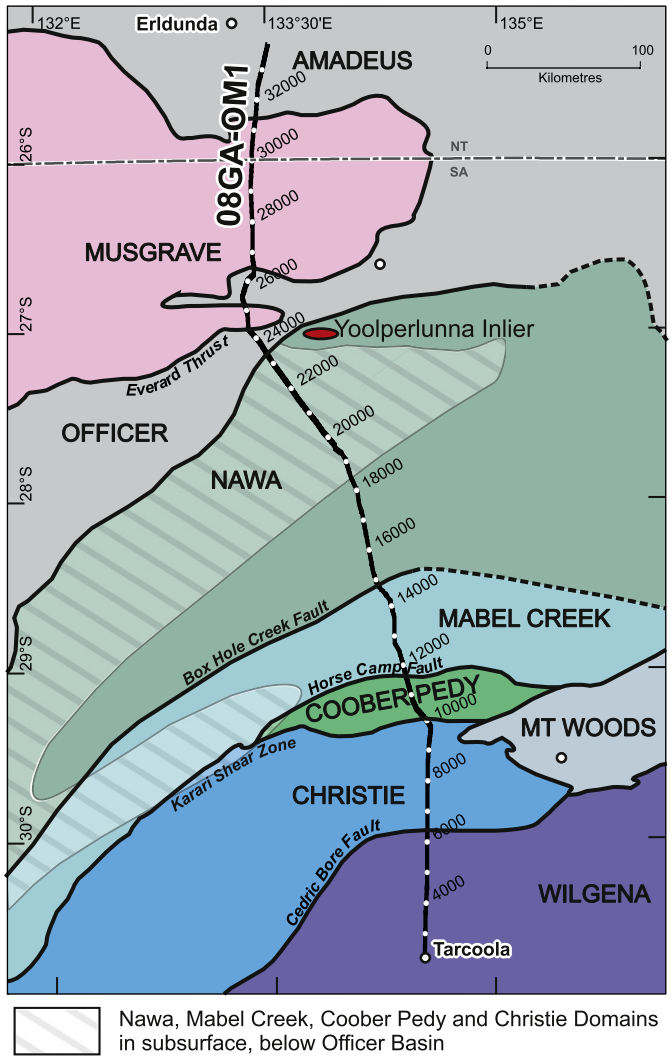

Fig. 7. Map showing the sub-Permian solid geology of the region covered by the GOMA seismic line (08GA-OM1) from the northern Gawler Craton to the southern Amadeus Basin. The diagonal lines represent that part of the Officer Basin covering the Nawa and other domains. The solid geology for South Australia is simplified from Cowley (2006a,b) and the Northern Territory part is based on Ahmad and Scrimgeour (2006). The seismic line has CDP stations labelled. Names in capitals refer to the key provinces and domains.

Basin–Musgrave Province) seismic survey, started in the western part of the Mesoproterozoic Musgrave Province and crossed the Neoproterozoic–Devonian western Officer Basin to the southwest (Fig. 9). The northeastern part of the Eoarchean to Neoarchean Yilgarn Craton is completely covered by the western part of the Officer Basin. Of interest here is the relationship, concealed beneath the Officer Basin, between the Yilgarn Craton, in the southwest, and the Musgrave Province in the northeast.

The Yilgarn Craton in Western Australia is a large (~1000 km by ~1000 km) area of Archean crust dominated by granite–greenstones, which forms a major part of the amalgamated West Australian Craton, and represents over 1.2 billion years of craton formation. The craton has been subdivided into several terranes and a superterrane (Cassidy et al., 2006; Pawley et al., 2012). The YOM seismic line crossed only the eastern, non-exposed half of the Yamarna Terrane, which is the easternmost terrane in the Yilgarn Craton (Korsch et al., 2013a).

The Musgrave Province is a large, east–west trending, Mesoproterozoic basement terrane surrounded by younger sedimentary basins (Edgoose et al., 2004; Howard et al., 2011a, 2011b, 2015). Magmatic rocks of the west Musgrave Province show little contribution from an Archean source, and are dominated by the addition of Paleoproterozoic juvenile material (Kirkland et al., 2014; Howard et al., 2015). The northeastern half of the YOM seismic line crossed outcrops of the west Musgrave Province, and surface geological control has been used to assist in the interpretation of this part of the seismic line (Howard et al., 2013).

In the vicinity of the YOM seismic section, the upper crust can be subdivided into several discrete provinces and basins, based primarily on surface geological mapping, drillhole data, and the interpretation of potential-field data (Fig. 10). These are the Yamarna Terrane of the Yilgarn Craton, the Officer Basin, the newly discovered Manunda Basin, and the west Musgrave Province (Korsch et al., 2013b). By comparison, the middle to lower crust appears to have a different seismic character, which strongly contrasts to that imaged in the upper crust immediately above it (Fig. 10). Thus, Korsch et al. (2013b) termed the middle to lower crust beneath the Yamarna Terrane, the Babool Seismic Province, and the lower crust below the Musgrave Province, the Tikelmungulda Seismic Province, because they have very distinctive seismic characters, which are very different laterally from each other (Fig. 10). All of the provinces, basins and seismic provinces interpreted in the YOM seismic section can be distinguished by their seismic character (Korsch et al., 2013a; Howard et al., 2013) (Fig. 10).

The Babool Seismic Province beneath the Yilgarn Craton can be tracked towards the northeast as far as about CDP 15600, and the Musgrave Province can be tracked towards the southwest as far as about CDP 13600 (Fig. 10). There is a gap of about 40 km beneath the Officer Basin where seismic resolution is poor, and it is not possible to determine definitively the nature of the boundary between the Yilgarn Craton and the Musgrave Province. Korsch et al. (2013b) defined the boundary between the two provinces as a fault with an apparent dip to the southwest, termed the Winduldarra Fault (Fig. 10). In the vicinity of the YOM seismic section, the fault is not exposed, but is interpreted to be the faulted boundary between the Neoproterozoic Townsend Quartzite, the basal unit of the Officer Basin, and the Mesoproterozoic Bentley Supergroup of the Musgrave Province. It truncates a near complete succession of the Bentley Supergroup before cutting deeper into the crust, reaching the Moho at about CDP 17600 (Fig. 10). Thus, if it is a major crustal boundary between the Yilgarn Craton and the Musgrave Province, it has been reactivated at least once, following the deposition of the Officer Basin. This interpretation is supported by the magnetotelluric conductivity model for the YOM seismic line (Duan et al., 2013), which shows that there is a significant change in conductivity in the vicinity of the fault. An alternative interpretation is that the boundary could be a broad zone of weak reflectivity, possibly due to extensive alteration and/or homogenisation of the crust. Irrespective of whichever alternative is valid, the boundary between the Yilgarn Craton and the Musgrave Province is a major crustal break separating provinces of distinctly different lithological ages and geological histories. As well, there is a major change in crustal architecture across the boundary, with the dominant structures in the southwest dipping predominantly towards the northeast, and the dominant structures in the northeast dipping predominantly towards the southwest (Fig. 10).

Magmatic rocks in the west Musgrave Province, aged between ca 1400 Ma and ca 1290 Ma, have been interpreted to be possibly subduction-related, with characteristics of an Andean-type continental margin magmatic arc (Smithies et al., 2010; Evins et al., 2012; Kirkland et al., 2012, 2013). The arc rocks suggest that, between ca 1400 Ma and ca 1290 Ma, the west Musgrave Province was on the upper plate. Kirkland et al. (2014) showed that the west Musgrave Province and the Albany–Fraser Orogen (Fig. 1b) had completely different basement compositions, but that, from at least 1345 Ma to at least 1140 Ma, they shared the same geological history. Given that the Albany–Fraser Orogen evolved at the outboard margin of the Yilgarn Craton (Spaggiari et al., 2014a,2014b; Korsch et al., 2014), the west Musgrave Province must have amalgamated with the Yamarna Terrane prior to 1345 Ma. The Winduldarra Fault is interpreted to be the current boundary between the west Musgrave Province and the Yilgarn Craton,

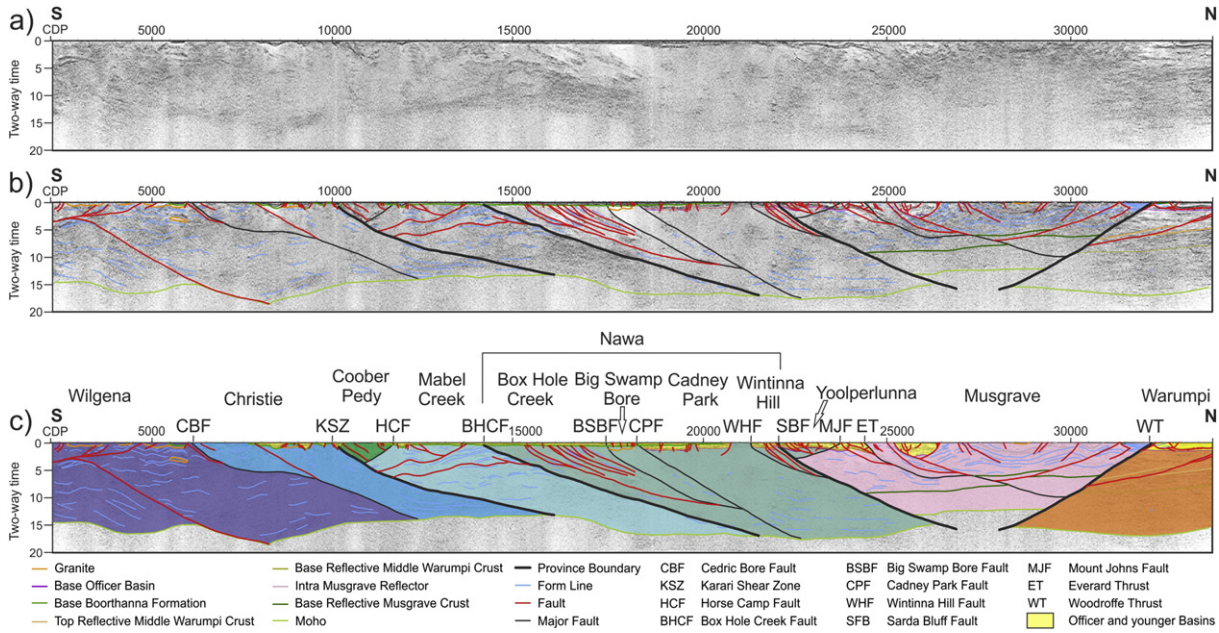

Fig. 8. Migrated seismic section for the GOMA (08GA-OM1) seismic line, showing (a) uninterpreted section, (b) interpretation of major structures, and (c) overlay with the names of the provinces, domains and seismic subdomains. The displays are to a depth of ~60 km, and show the vertical scale equal to the horizontal scale (assuming an average crustal velocity of 6000 ms^{-1}). Overlay colours according to Fig. 7.

but the issue of the timing of the amalgamation between these provinces is yet to be resolved.

7. Development of crustal-scale transects

The amount of deep seismic data now acquired across Australia has enabled the construction of major crustal transects which show the relationships between major crustal provinces and terranes. Many of the boundaries have been interpreted as crustal sutures, which formed during the amalgamation of the crustal blocks. One example is in Western Australia, where it is now possible to combine the interpreted seismic section from the YOM seismic survey, discussed above, with a network of seismic sections from earlier deep seismic surveys, to produce an ~1800 km transect across almost the entire southern half of Western Australia, from near the coast to within about 80 km of the border with the Northern Territory (Fig. 11).

The transect has been constructed using the following seismic surveys:

1. The southern Carnarvon and Youanmi surveys (lines 11GA-SC1, 10GA-YU1 and 10GA-YU2; Korsch et al., 2013c),
2. The Eastern Goldfields survey, acquired in 1991 (line BMR91-EGF01, commonly known as EGF1; Drummond et al., 1993, 2000b; Swager et al., 1997),
3. The Northeast Yilgarn survey, acquired in 2001 (lines 01AGS-NY1 and 01AGS-NY3; Goleby et al., 2004, 2006), and,
4. The YOM seismic survey, acquired in 2011 (line 11GA-YO1; Korsch et al., 2013b).

Although not continuous, the transect crosses all of the key provinces in this part of Western Australia, including most of the terranes in the Yilgarn Craton described by Cassidy et al. (2006) (Fig. 11). There is a gap of about 28 km between the eastern end of seismic line 11GA-SC1 and the northwestern end of line 10GA-YU1. Also, to construct the transect it has been necessary to project along strike using key geological structures between seismic lines. For example, the Ida Fault, which is the boundary between the Youanmi Terrane and the Kalgoorlie Terrane of the Eastern Goldfields Superterrane, has been used to link the eastern end of line 10GA-YU2 with the western part of line BMR91-EGF01 (Fig. 11). The Ockerburry Fault System, which is the boundary between the Kalgoorlie Terrane and the Kurnalpi Terrane in the Eastern Goldfields Superterrane, has been used to link the eastern part of line BMR91-EGF01 with the western end of line 01AGS-NY1 (Fig. 11). Because of the paucity of outcrop in the Yamarna Terrane, structural trends, as observed in the gravity and magnetic maps (Fig. 2), have been used to link the northeastern end of line 01AGS-NY3 with the southwestern end of line 11GA-YO1.

Using the network of seismic lines, the transect extends from the Pinjarra Orogen in the west, across the tip of the Glenburgh Terrane, the Errabiddy Shear Zone, and most terranes in the Yilgarn Craton, to the west Musgrave Province (Figs. 11, 12). The overall architecture observed in the transect is one of the Yilgarn Craton dominated by a central nucleus, consisting of the Youanmi Terrane and the underlying Yarraquin Seismic Province (Korsch et al., 2013c). Based on Nd isotopic data, it has been proposed that the Youanmi Terrane has behaved as a coherent crustal block since at least 3000–2900 Ma (Champion and Cassidy, 2010; Ivanic et al., 2012; Van Kranendonk et al., 2013). Following this, the Youanmi Terrane acted as a nucleus, or protocraton, onto which the Narryer Terrane was accreted in the northwest, and the Eastern Goldfields Superterrane developed to the east (e.g. Cassidy et al., 2006; Wyche et al., 2012). Terranes on either side of the Youanmi Terrane are seen to be bounded by crustal-scale faults, which dip away from the nucleus, towards the west and northwest on the northwestern side, and towards the east on the eastern side (Fig. 12; see also Korsch et al., 2013c). This pattern continues until the Winduldarra Fault is reached, which is the site of the interpreted suture between the Yilgarn Craton and the west Musgrave Province (see above).

Using a convergent plate tectonic model, based on analogies with modern day plate tectonic processes, several groups of workers (e.g. Barley et al., 1989; Myers, 1995; Krapez and Barley, 2008; Korsch et al., 2011a) have proposed geodynamic models for the Eastern Goldfields Superterrane of the Yilgarn Craton which involve the accretion of allochthonous continental slivers as discrete terranes. Cassidy et al. (2006) considered that formation of the Eastern Goldfields Superterrane by amalgamation of a series of terranes to form the composite Yilgarn Craton was completed by about 2655 Ma (see Korsch et al., 2013c). Alternatively, it has been proposed that, rather than a series of allochthonous continental slivers, the Eastern Goldfields Superterrane represents the extended margin of the Youanmi Terrane (Czarnota et al.,

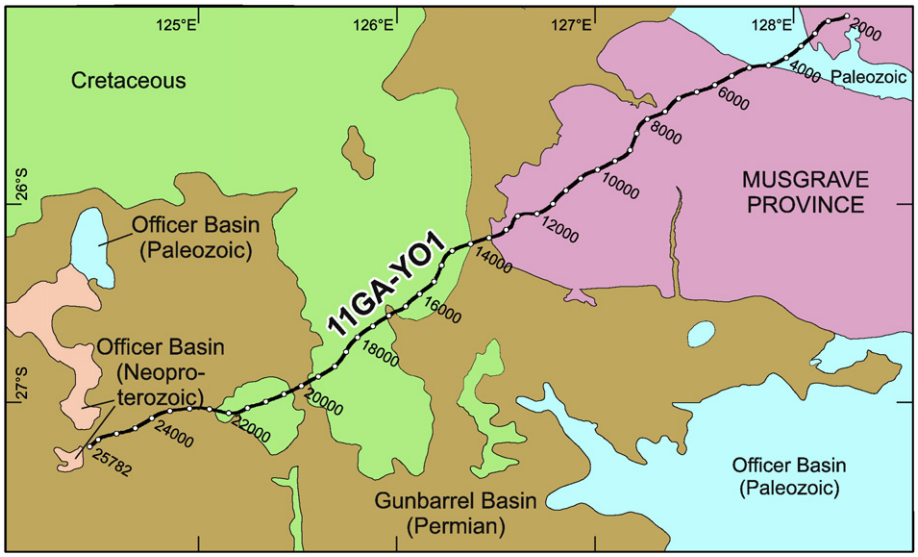

Fig. 9. Map showing the solid geology of the region covered by the YOM (11GA-YO1) seismic line, from the Yamarna Terrane in the northeastern Yilgarn Craton (beneath the western Officer Basin and younger sedimentary rocks) to the west Musgrave Province. The solid geology is based on the 1:500,000 scale solid geology map of Western Australia (Geological Survey of Western Australia, 2008; and unpublished data). The seismic line has CDP stations labelled.

2010; Pawley et al., 2012; Van Kranendonk et al., 2013). In this scenario, the older Burtville Terrane would be analogous to a horst of the basement, whereas the greenstone rocks of the younger terranes were deposited in a series of basins following <2720 Ma extension.

To the northwest of the Yilgarn Craton, the Glenburgh Terrane and the Pinjarra Orogen were then accreted to the Narryer Terrane in the Proterozoic, at about 1965 Ma and 1080 Ma, respectively (see references in Korsch et al., 2013c). To the northeast of the Yilgarn Craton, the Musgrave Province is inferred to have amalgamated with the Yilgarn Craton at some time prior to 1345 Ma (see above).

The deep seismic traverses provide an almost complete transect across southern Western Australia, and provides our first view of the present day crustal architecture of this part of the continent. It is seen to consist of a series of terranes which have been accreted over a period of nearly two billion years, to form the composite West Australian Craton.

Using the deep seismic lines in other parts of the country, it has been possible to construct other crustal scale transects, for example, from the western Gawler Craton in South Australia to the Koonenberry Belt in New South Wales (Korsch et al., 2010a), and from the Mount Isa Province to the Charters Towers Province (part of the Tasmanides) in north Queensland (Korsch et al., 2012).

8. Development of map of major crustal boundaries of Australia

As shown from the examples described above, the deep seismic reflection data have proved invaluable in defining the locations and geometries of many crustal-scale boundaries to different geological provinces across Australia. The widespread coverage of the seismic profiles (Fig. 3) now provides the opportunity to construct a new Australia-wide GIS dataset and map of these major crustal boundaries, which will allow a better understanding of how the Australian continent was constructed from the Mesoarchean through to the Phanerozoic, and also allow an assessment of the relationship between these boundaries and the locations of major mineral deposits in Australia. The 2015 version of this map, presented here, was constructed using seismic interpretations which, in general, were available in the public domain as of July 2013.

The starting points for the mapping of individual crustal boundaries, in plan view, are the locations of the crustal boundaries identified in the seismic profiles. For boundaries mapped at the surface, this is taken as the point on the surface where the boundary intersects the seismic line. As stressed above, in many cases, however, the boundary is covered by younger sediment or regolith (Fig. 13a), and, in these cases, the point on the map is taken as the vertical projection to the surface of the boundary beneath the younger cover (Fig. 4). Importantly, the nature and/or age of the cover, along with the apparent dip of the fault in the seismic section, is recorded in the digital GIS dataset (Korsch and Doublier, 2015; Appendix A), to allow the construction of the map in three dimensions, which is currently in progress at Geoscience Australia.

Next, the crustal boundary is mapped away from the point determined on the seismic line, using whatever data are available, for example, geological data (e.g. outcrop mapping, drillhole, geochronology, isotopes) and/or geophysical data (e.g. gravity, aeromagnetic, magnetotelluric). Hence, the boundaries on the map consist of several individual segments, mapped using different datasets, with over 300 individual segments interpreted across Australia. Each segment is attributed with specific information, provided in the dataset of Korsch and Doublier (2015; Appendix A). The main information is: segment number (unique feature (line) identifier); formal name of the geological structure, if defined; interpreter; name of seismic line (where relevant); confidence level of interpretation; apparent dip direction of the geological structure; nature and/or age of younger cover; key literature references; comments. For some of the crustal boundaries, a high level of confidence can be placed on the location, whereas the location of other boundaries can only be considered to have medium or low confidence. In other areas, especially in regions covered by thick sedimentary successions, the locations of some crustal boundaries are essentially unconstrained, and are thus assigned no level of confidence (Figs. 13, 14). We stress that the dataset is best used in a digital GIS environment, where the additional information for each of the line segments can be readily accessed. It is important to keep in mind that the boundaries on the maps presented here are 2D projections of a 3D architecture.

The 2015 version of the map of major crustal boundaries of Australia is stored as an ArcGIS file geodatabase Geographic GDA94 and as an ArcView shape file Geographic GDA94; this will allow the map to be progressively updated as new data and interpretations become available in the future. Within the GIS environment, the map of major crustal boundaries can be overlain on any thematic map of Australia, such as, topography, surface geology, solid geology, gravity, magnetics, radiometrics, Nd isotopes, or any other thematic map. As examples, we

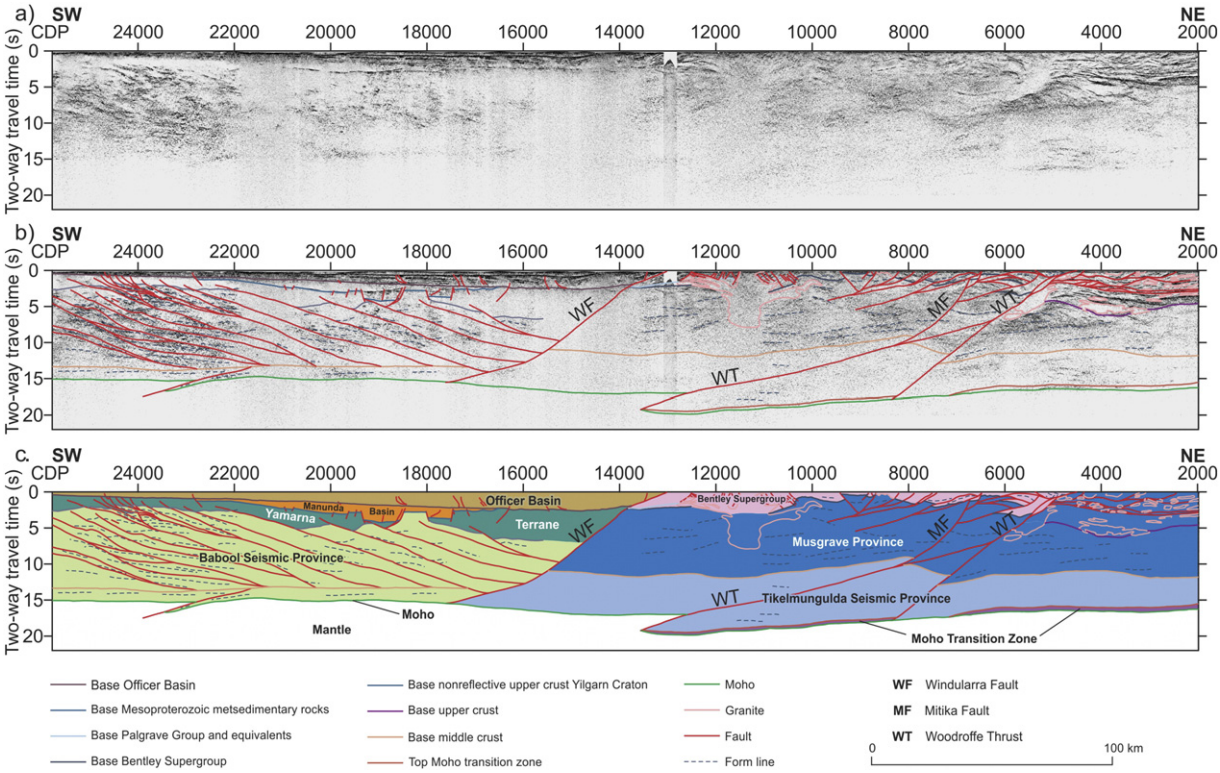

Fig. 10. Migrated seismic section for the seismic section 11GA-YO1, showing both (a) uninterpreted and (b) interpreted versions. Display is to 22 s TWT (~66 km) depth, and shows vertical scale equal to the horizontal scale, assuming an average crustal velocity of 6000 ms^{-1}. Panel (c) shows the distribution of the basins and provinces along the YOM seismic line.

show the current version of the map of major crustal boundaries of Australia overlain on the simplified surface geology (Fig. 13a), aeromagnetics of Milligan et al. (2010) (Fig. 14a), gravity of Bacchin et al. (2008) (Fig. 14b) and the Nd isotopic map of Champion (2013) (Fig. 13b).

9. Implications for mineral systems

Major, deeply-penetrating fault systems, especially major crustal boundaries, have acted as important fluid migration pathways to transport mineralising fluids from the upper mantle or lower crust, and are ideal for focussing fluid flow into the upper crust to form major mineral systems (e.g. Drummond et al., 2000a; Barnicoat, 2007; Willman et al., 2010; Johnson et al., 2013; McCuaig and Hronsky, 2014). Certain types of mineral systems, such as lode gold deposits (Groves et al., 1989), iron oxide–copper–gold (IOCG) (Groves et al., 2010), and orthomagmatic Ni–Cu (Begg et al., 2010), have a close spatial relationship with major crustal boundaries (Fig. 13b). There is also a temporal relationship between certain types of mineral systems and global tectonic events (e.g. Huston et al., 2012; Cawood and Hawkesworth, 2014, 2015; Hazen et al., 2014; Huston et al., 2016-in this volume). Nevertheless, there is not always a temporal relationship between the age of amalgamation of major crustal blocks and the age of mineralisation spatially associated with the crustal boundary. This is because many major mineral systems are related to fluid flow which occurred during later reactivation of the crustal-penetrating structures, and not during the amalgamation phase.

In the Eastern Goldfields Superterrane of the Yilgarn Craton, there is a close spatial relationship between the crustal boundaries and the major mineral deposits, but this is less obvious for the minor deposits (Fig. 15). There is evidence for several episodes of gold mineralisation in this Superterrane, but all major deposits are considered to have formed late in the tectonic history, later than the timing of amalgamation of the crustal blocks (Blewett and Czarnota, 2007; Blewett et al., 2010; see also Wyche et al., 2013).

In Victoria, deep seismic reflection data (Cayley et al., 2011) have been invaluable in understanding the role that crustal-scale structures have played in the genesis of the world-class gold deposits, such as Bendigo, Ballarat and Stawell, in the western Tasmanides (Willman et al., 2010; Fig. 14b). The distribution of gold deposits appears to be related to the geometry of the major crustal-penetrating faults, suggesting that these faults acted as major fluid conduits that tapped a common source area for gold in the lower to middle crust. These faults then provided a direct structural linkage between the lower fertile source region and the depositional sites in the upper crust. Following these examples, deep-crustal penetrating structures recognised in deep seismic reflection traverses, and then mapped regionally using other datasets, might point to possible fluid flow pathways from the lower crust and/or upper mantle, and thus help focus the search for undiscovered mineral systems in the upper crust, in greenfields areas. Several deep crustal penetrating structures were interpreted on the Georgina–Arunta seismic line in the Northern Territory (Fig. 6; Korsch et al., 2011b), and Huston et al. (2011) has outlined the significance of some of the structures for potential mineral systems. For example, in the general vicinity of the Atuckera Fault, there is potential for Tennant Creek–Rover IOCG-U type deposits along an extensive strike length to the north of this structure in the Northern Territory (Huston et al., 2011).

As mentioned above, in South Australia, the Elizabeth Creek Fault is probably related to the formation of the giant Olympic Dam IOCG deposit, and forms the boundary between two distinct crustal blocks within the Gawler Craton (Neumann et al., 2010a). To the south, the Kalinjala Mylonite Zone is possibly part of the same fault system (Neumann et al., 2010a). To the northwest, the Karari Shear Zone, mapped on the GOMA seismic line (Fig. 8) is also possibly part of the same fault system, separating mainly Archean–Paleoproterozoic crust to the southwest from mainly Paleoproterozoic–Mesoproterozoic crust to the northeast (Korsch et al., 2010b; Neumann et al., 2010b). Thus, this important crustal boundary has the potential to be a fundamental control on other IOCG deposits that could have formed at a

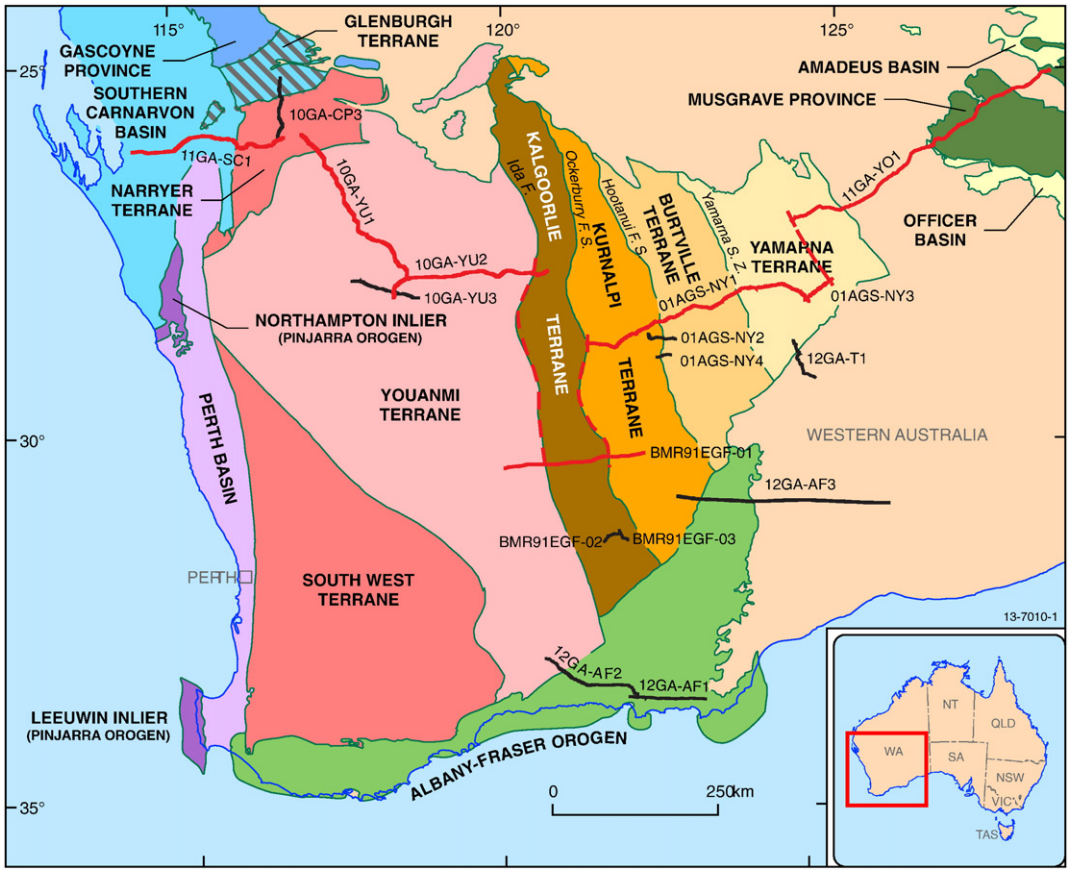

Fig. 11. Major tectonic subdivisions of the southern half of Western Australia, showing the locations of the major deep crustal seismic reflection lines (black) and those seismic lines (red) used to construct the crustal-scale transect in Fig. 12.

similar time to Olympic Dam (Neumann et al., 2010b). On the GOMA seismic line, several other deep crustal penetrating structures also have been interpreted (Fig. 8); most of these structures are province, domain or subdomain boundaries, and have the potential to be important structures controlling fluid flow.

In northwest Queensland, the Ernest Henry IOCG deposit is possibly related to the boundary between the eastern Mount Isa Province and the Kowanyama Seismic Province to the east, named the Gidyea Suture Zone by Korsch et al. (2012). This suture has the potential to be a fundamental control on other IOCG deposits, so that the region in the vicinity of this suture, to the north and south of Ernest Henry, could have potential for future IOCG discoveries (Huston et al., 2009).

In the Capricorn Orogen of Western Australia, a deep seismic reflection survey imaged three major suture zones, as well as several other crustal-scale faults; the suture zones separate four seismically distinct crustal blocks (Johnson et al., 2013). The location and setting of gold, base metal and rare earth element deposits across the Orogen are closely linked to the major crustal-scale structures, highlighting their importance for the transport of fluid from the mantle or lower crust to form mineral systems in the upper crust (Johnson et al., 2013).

Thus, as demonstrated above, deep crustal-penetrating structures, particularly major crustal boundaries, are important conduits to transport mineralising fluids from the mantle and lower crust into the upper crust. As shown on the map of crustal boundaries (Figs. 13, 14), and listed in the GIS dataset (Appendix A), there are several greenfields regions across Australia where deep crustal-penetrating structures have been imaged in seismic sections, and have potential as possible areas for future mineral systems exploration.

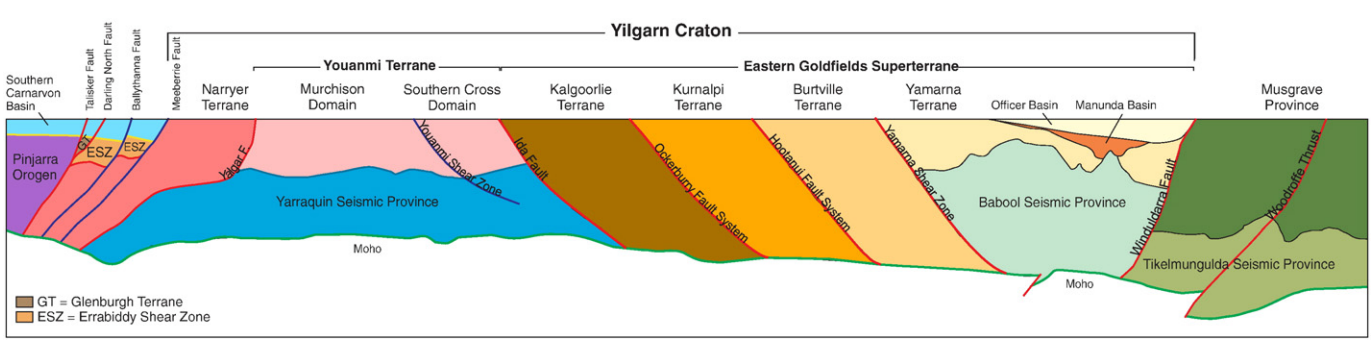

Fig. 12. Cartoon of the present day architecture of the crust in Western Australia, based on deep seismic reflecting profiling. The cross section extends from the Pinjarra Orogen near the coast in the west, across the Yilgarn Craton, from the Narryer Terrane to the Yamarna Terrane, and then to the west Musgrave Province in the east, showing the key provinces, terranes, basins and significant faults. Vertical exaggeration is approximately 3.5.

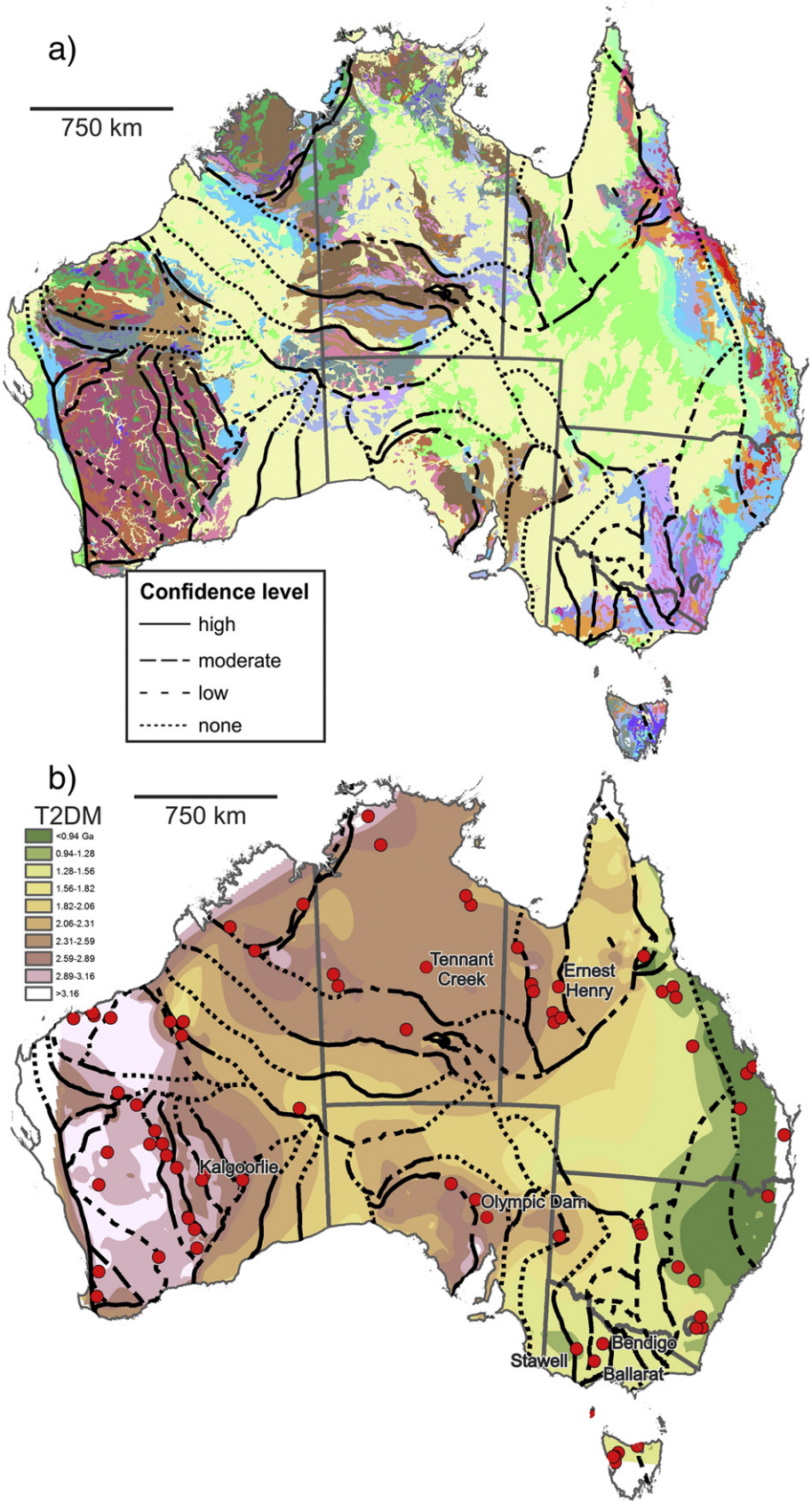

Fig. 13. (a) Simplified surface geology of Australia (after Raymond, 2009), with a drape of the major crustal boundaries, as mapped by Korsch and Doublier (2015). Note that many of the boundaries are hidden beneath Mesozoic or Cenozoic cover. (b) Gridded Nd two-stage depleted mantle model age (T2DM) map for Australia (Champion, 2013; Champion and Huston, 2016-in this volume) with a drape of the major crustal boundaries. Also shown are the major mineral deposits for the following commodities: Au, Ag, Pb, Zn, Cu, Ni and diamonds. Deposits named are mentioned in the text.

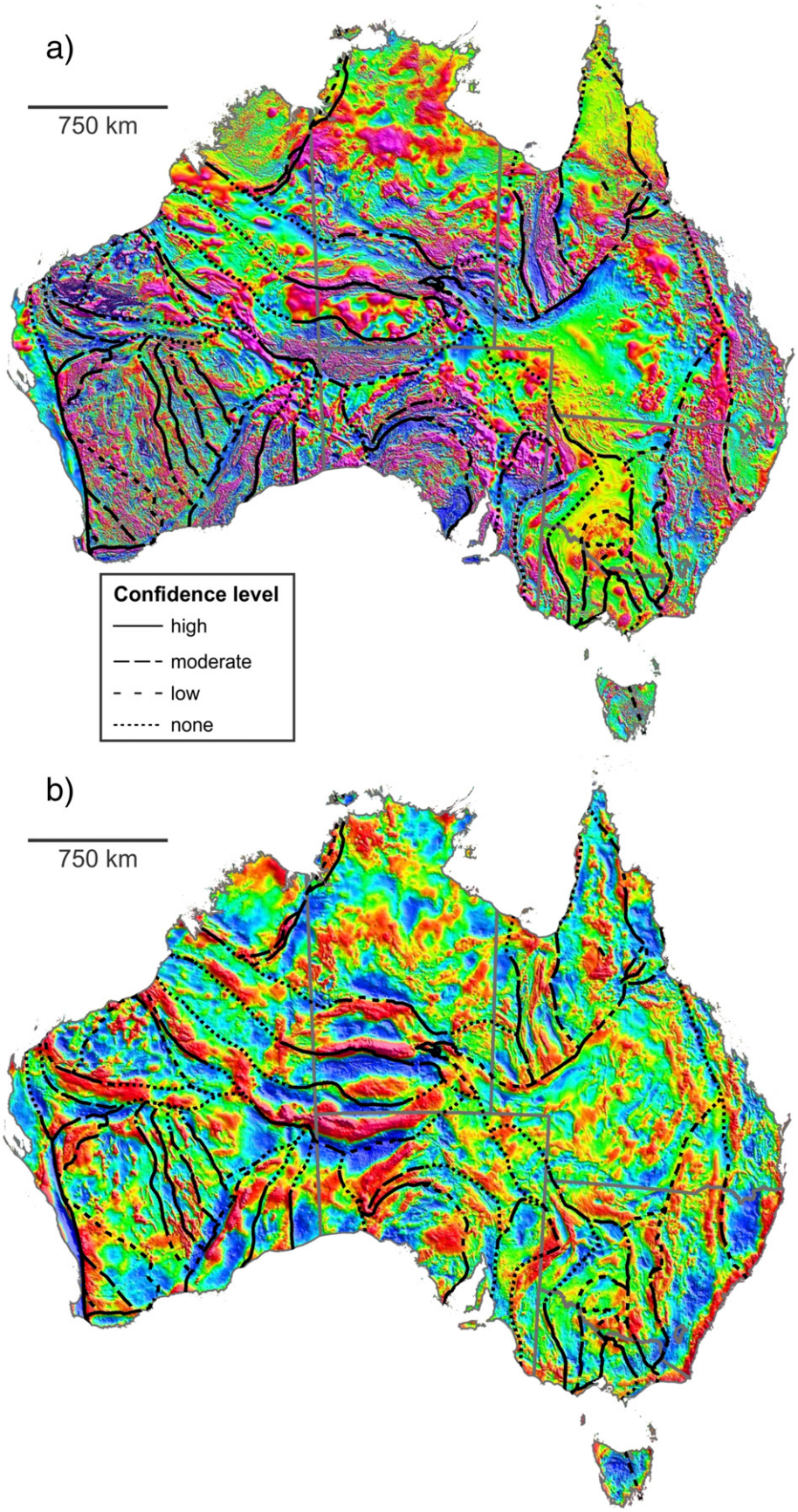

Fig. 14. (a) Aeromagnetic map of Australia (Milligan et al., 2010) with a drape of the major crustal boundaries, as mapped by Korsch and Doublier (2015). (b) Gravity map of Australia (Bacchin et al., 2008) with a drape of the major crustal boundaries.

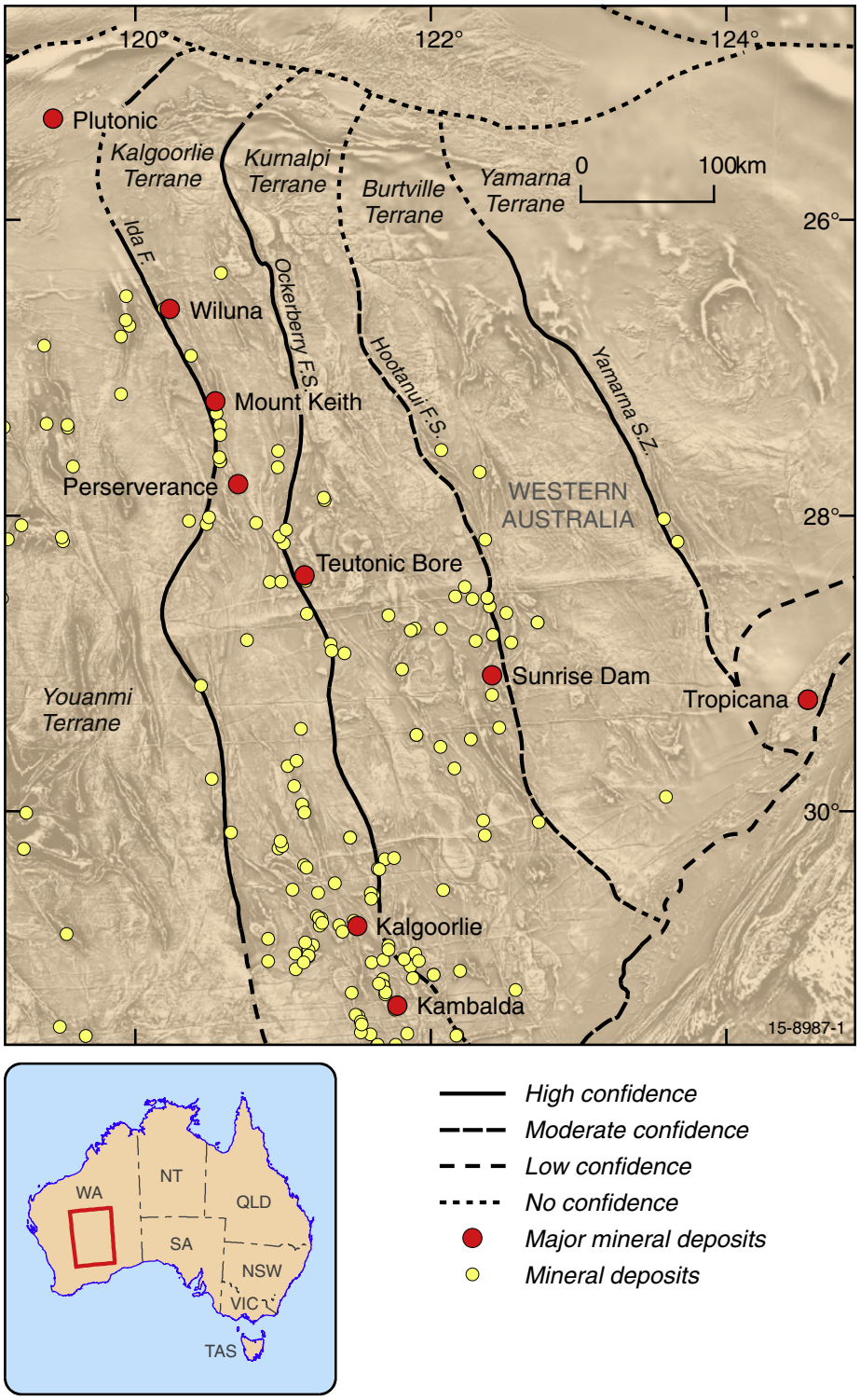

Fig. 15. Map of the Eastern Goldfields Superterrane (see Fig. 11) showing the major crustal boundaries, plus the locations of major and minor Au, Ni and base metal deposits draped on an image of grey scale aeromagnetic data.

10. Concluding remarks

Major crustal-scale breaks interpreted in some of the deep seismic reflection profiles that have been acquired routinely across Australia are often inferred to be relict sutures between different crustal blocks; some of these breaks have been suggested to be important conduits for fluids and help control the formation of certain types of mineral systems. The widespread coverage of the seismic profiles now provides the opportunity to construct a GIS dataset and map of major crustal boundaries across Australia, which will allow a better understanding of how the Australian continent was constructed from the Mesoarchean through to the Phanerozoic, and how this evolution and these boundaries have controlled the development of mineral systems. Starting with the locations of the crustal breaks identified in the seismic profiles, other geoscientific data are used to map the crustal boundaries, in plan view, away from the seismic profiles. For some of these boundaries, a

high level of confidence can be placed on the location, whereas the location of other boundaries can only be considered to have medium or low confidence. In other areas, especially in regions covered by thick sedimentary successions, the locations of some crustal boundaries are essentially unconstrained. The map of the major crustal boundaries of Australia shows the locations of some inferred ancient plate boundaries, and will provide constraints on the three dimensional architecture of Australia, which, in turn, will help to constrain tectonic models and plate reconstructions for the geological evolution of Australia. It will also suggest regions for future mineral system exploration in greenfields regions.

Acknowledgements

We thank David Huston and Richard Blewett for their encouragement to undertake this work and David Huston for the invitation to contribute this paper to this volume. We wish to acknowledge the substantial contributions of many colleagues in Geoscience Australia, the State and Territory geological surveys, cooperative research centres, universities and industry, who have been involved in the acquisition, processing and interpretation of the deep seismic reflection profiles over many years. In particular, colleagues from Geoscience Australia and the geological surveys of South Australia, Northern Territory and Western Australia contributed significantly to the work discussed here, and they are listed as coauthors in several of the references cited below. Without the input from these people, this paper would not have been possible. We thank Richard Blewett, Neil Symington, Peter Cawood and Ian Tyler for their constructive reviews of the manuscript. Published with permission of the Chief Executive Officer, Geoscience Australia.

Appendix A. Supplementary data

Supplementary data to this article can be found online at: http://www.ga.gov.au/metadata-gateway/metadata/record/83223.

References

Ahmad, M., Munson, T.J. (Comps.), 2013. Geology and mineral resources of the Northern Territory. Special Publication 5. Northern Territory Geological Survey.

Ahmad, M., Scrimgeour, I.R., 2006. Geological map of the Northern Territory, 1:2 500 000 scale. Northern Territory Geological Survey, Darwin.

Bacchin, M., Milligan, P.R., Wynne, P., Tracey, R., 2008. Gravity anomaly map of the Australian region (Third Edition), scale 1:5 000 000. Geoscience Australia, Canberra.

Bagas, L., Bierlein, F.P., English, L., Anderson, J.A.C., Maidment, D., Huston, D.L., 2008. An example of a Palaeoproterozoic back-arc basin: petrology and geochemistry of the ca. 1864 Ma Stubbins Formation as an aid towards an improved understanding of the Granites–Tanami Orogen, Western Australia. Precambrian Res. 166, 168–184.

Barley, M.E., Eisenlohr, B.N., Groves, D.I., Perring, C.S., Vearncombe, J.R., 1989. Late Archean convergent margin tectonics and gold mineralization: a new look at the Norseman–Wiluna Belt, Western Australia. Geology 17, 826–829.

Barnicoat, A.C., 2007. Mineral systems and exploration science: linking fundamental controls on ore deposition with the exploration process. In: Andrew, C.J., et al. (Eds.), Digging Deeper. Irish Association for Economic Geology, Proceedings of the Ninth Biennial Meeting of the Society for Geology Applied to Mineral Deposits vol. 2, pp. 1407–1411.

Begg, G.C., Hronsky, J.A.M., Arndt, N.T., Griffin, W.L., O'Reilly, S.Y., Hayward, N., 2010. Lithospheric, cratonic, and geodynamic setting of Ni–Cu–PGE sulfide deposits. Econ. Geol. 105, 1057–1070.

Betts, P.G., Giles, D., Lister, G.S., Frick, L.R., 2002. Evolution of the Australian lithosphere. Aust. J. Earth Sci. 49 (4), 661–695.

Blewett, R.S., Czarnota, K., 2007. Diversity of Structurally Controlled Gold Through Time and Space of the Central Eastern Goldfields Superterrane Time and Space. Geological Survey of Western Australia (Record, 2007/19, 65 pp.).

Blewett, R.S., Czarnota, K., Henson, P.A., 2010. Structural-event framework for the eastern Yilgarn Craton, Western Australia, and its implications for orogenic gold. Precambrian Res. 183, 203–229.

Blewett, R.S., Kennett, B.L.N., Huston, D.L., 2012. Australia in time and space. In: Blewett, R.S. (Ed.), Shaping a Nation: a Geology of Australia. Geoscience Australia and ANU E Press, Canberra, pp. 46–119.

Cassidy, K.F., Champion, D.C., Krapez, B., Barley, M.E., Brown, S.J.A., Blewett, R.S., Groenewald, P.B., Tyler, I.M., 2006. A Revised Geological Framework for the Yilgarn Craton, Western Australia. Geological Survey of Western Australia (Record 2006/8, 8 pp.).

Cawood, P.A., Hawkesworth, C.J., 2014. Earth's middle age. Geology 42 (6), 503–506.

Cawood, P.A., Hawkesworth, C.J., 2015. Temporal relations between mineral deposits and global tectonic cycles. In: Jenkin, G.R.T., Lusty, P.A.J., McDonald, I., Smith, M.P., Boyce, A.J., Wilkinson, J.J. (Eds.), Ore Deposits in an Evolving Earth. Geological Society, London, Special Publications 393, pp. 9–21.

Cawood, P.A., Korsch, R.J., 2008. Assembling Australia: Proterozoic building of a continent. Precambrian Res. 166, 1–38.

Cayley, R., Korsch, R.J., Moore, D.H., Costelloe, R.D., Nakamura, A., Willman, C.E., Rawling, T.J., Morand, V.J., Skladzien, P.B., O'Shea, P.J., 2011. Crustal architecture of Central Victoria: results from the 2006 deep crustal reflection seismic survey. Aust. J. Earth Sci. 58 (2), 113–156.

Champion, D.C., 2013. Neodymium Depleted Mantle Model Age Map of Australia: Explanatory Notes and User Guide. Geoscience Australia. http://dx.doi.org/10.11636/Record.2013.044 (Record 2013/44, 209 pp.).

Champion, D.C., Cassidy, K.F., 2010. Granitic magmatism in the Yilgarn Craton: implications for crustal growth and metallogeny. Yilgarn–Superior Workshop — Abstracts, Fifth International Archean Symposium, 10 September 2010. Geological Survey of Western Australia, pp. 12–18 (Record, 2010/20).

Champion, D.C., Huston, D.L., 2016. Radiogenic isotopes, ore deposits and metallogenic terranes: novel approaches based on regional isotopicmaps and theMineral Systems concept. Ore Geol. Rev. 76, 229–256 (in this volume).

Claoué-Long, J., Edgoose, C., Worden, K., 2008a. A correlation of Aileron Province stratigraphy in central Australia. Precambrian Res. 166, 230–245.

Claoué-Long, J., Maidment, D., Donnellan, N., 2008b. Stratigraphic correlation of the Davenport Province in central Australia: a basis for Palaeoproterozoic correlations. Precambrian Res. 166, 204–218.

Close, D.F., 2013. Chapter 21: Musgrave Province. In: Ahmad, M., Munson, T.J. (Comps.) (Eds.), Geology and Mineral Resources of the Northern Territory. Special Publication 5. Northern Territory Geological Survey, pp. 21.1–21.24.

Costelloe, R.D., Holzschuh, J., 2010. 2008 Gawler Craton–Officer Basin–Musgrave Province–Amadeus Basin (GOMA) seismic survey, 08GA-OM1: acquisition and processing. In: Korsch, R.J., Kositcin, N. (Eds.), GOMA (Gawler Craton–Officer Basin–Musgrave Province–Amadeus Basin) Seismic and MT Workshop 2010: Extended Abstracts. Geoscience Australia, pp. 1–6 (Record, 2010/39).

Cowley, W.M., 2006a. Solid geology of South Australia: peeling away the cover. MESA J. 43, 4–15.

Cowley, W.M. (Comp.), 2006b. Solid geology of South Australia. South Australia Department of Primary Industries and Resources, Mineral Exploration Data Packagep. 15 (version 1.1).

Czarnota, K., Champion, D.C., Goscombe, B., Blewett, R.S., Cassidy, K.F., Henson, P.A., Groenewald, P.B., 2010. Geodynamics of the eastern Yilgarn Craton. Precambrian Res. 183, 175–202.

Drummond, B.J., Goleby, B.R., Swager, C.P., Williams, P.R., 1993. Constraints on Archaean crustal composition and structure provided by deep seismic sounding in the Yilgarn Block. Ore Geol. Rev. 8, 117–124.

Drummond, B.J., Goleby, B.R., Owen, A.J., Yeates, A.N., Swager, C., Zhang, Y., Jackson, J.K., 2000a. Seismic reflection imaging of mineral systems: three case histories. Geophysics 65 (6), 1852–1861.

Drummond, B.J., Goleby, B.R., Swager, C.P., 2000b. Crustal signature of Late Archaean tectonic episodes in the Yilgarn craton, Western Australia: evidence from deep seismic sounding. Tectonophysics 329, 193–221.

Drummond, B.J., Hobbs, B.E., Goleby, B.R., 2004. The role of crustal fluids in the tectonic evolution of the Eastern Goldfields Province of the Archaean Yilgarn Craton, Western Australia. Earth Planets Space 56, 1163–1169.

Drummond, B., Lyons, P., Goleby, B., Jones, L., 2006. Constraining models of the tectonic setting of the giant Olympic Dam iron oxide–copper–gold deposit, South Australia, using deep seismic reflection data. Tectonophysics 420, 91–103.

Duan, J., Milligan, P.R., Fomin, T., 2013. Electrical resistivity distribution from magnetotelluric data in the Yilgarn Craton, western Officer Basin and western Musgrave Province. In: Neumann, N.L. (Ed.), Yilgarn Craton–Officer Basin–Musgrave Province (YOM) Seismic and MT Workshop. Geoscience Australia, pp. 9–23 (Record, 2013/28).

Dutch, R., Davies, M.B., Flintoft, M., 2010. GOMA Basement Drilling Program, Northern Gawler Craton. Primary Industries and Resources South Australia (Report Book, 2010/2, 228 pp.).

Edgoose, C.J., Scrimgeour, I.R., Close, D.F., 2004. Geology of the Musgrave Block, Northern Territory. Northern Territory Geological Survey (Report, 15, 44 pp.).

Evins, P.M., Kirkland, C.L., Wingate, M.T.D., Smithies, R.H., Howard, H.M., Bodorkos, S., 2012. Provenance of the 1340–1270 Ma Ramarama Basin in the West Musgrave Province, Central Australia. Geological Survey of Western Australia (Report 116, 39 pp.).

Fanning, C.M., Reid, A., Teale, G., 2007. A geochronological framework for the Gawler Craton, South Australia. Bull. Geol. Surv. S. Aust. 55 (258 pp.).

Ferris, G.M., Schwarz, M.P., Heithersay, P., 2002. The geological framework, distribution and controls of Fe-oxide and related alteration, and Cu–Au mineralisation in the Gawler Craton, South Australia. Part I: geological and tectonic framework. In: Porter, T.M. (Ed.), Hydrothermal Iron Oxide Copper–Gold And Related Deposits: a Global Perspective. Porter GeoConsultancy Publishing, Adelaide, pp. 9–31.

Finlayson, D.F. (Ed.), 1990. The Eromanga–Brisbane transect: a guide to basin development across Phanerozoic Australia in southern Queensland. Bureau of Mineral Resources, Australia, Bulletin 232 (261 pp.).

Geological Survey of Western Australia, 2008. 1:500 000 interpreted bedrock geology of Western Australia, 2008 Update. Geological Survey of Western Australia, Perth.

Glen, R.A., Korsch, R.J., Hegarty, R., Saeed, A., Poudjom Djomani, Y., Costelloe, R.D., Belousova, E., 2013. Geodynamic significance of the boundary between the Thomson Orogen and the Lachlan Orogen, northwestern New South Wales and implications for Tasmanide tectonics. Aust. J. Earth Sci. 60, 371–412.

Goleby, B.R., Blewett, R.S., Korsch, R.J., Champion, D.C., Cassidy, K.F., Jones, L.E.A., Groenewald, P.B., Henson, P.A., 2004. Deep seismic reflection profiling in the Archaean northeastern Yilgarn Craton, Western Australia: implications for crustal architecture and mineral potential. Tectonophysics 388, 119–133.

Goleby, B.R., Blewett, R.S., Fomin, T., Fishwick, S., Reading, A.M., Henson, P.A., Kennett, B.L.N., Champion, D.C., Jones, L.E.A., Drummond, B.J., Nicoll, M., 2006. An integrated multi-scale 3D seismic model of the Archaean Yilgarn Craton, Australia. Tectonophysics 420, 75–90.

Goleby, B.R., Huston, D.L., Lyons, P., Vandenberg, L., Bagas, L., Davies, B.M., Jones, L.E.A., Gebre-Mariam, M., Johnson, W., Smith, T., English, L., 2009. The Tanami deep seismic reflection experiment: an insight into gold mineralisation and Paleoproterozoic collision in the North Australian Craton. Tectonophysics 427, 169–182.

Groves, D.I., Barley, M.E., Ho, S.E., 1989. Nature, genesis, and tectonic setting of mesothermal gold mineralization in the Yilgarn Block, Western Australia. In: Keays, R.R., Ramsay, W.R.H., Groves, D.I. (Eds.), The Geology of Gold Deposits: The Perspective in 1988. Economic Geology Monograph 6, pp. 71–85.

Groves, D.I., Bierlein, F.P., Meinert, L.D., Hitzman, M.W., 2010. Iron oxide copper–gold (IOCG) deposits through earth history: implications for origin, lithospheric setting, and distinction from other epigenetic iron oxide deposits. Econ. Geol. 105, 641–654.

Hazen, R.M., Liu, X.M., Downs, R.T., Golden, J., Pires, A.J., Grew, E.S., Hystad, G., Estrada, C., Sverjensky, D.A., 2014. Mineral evolution: episodic metallogenesis, the supercontinent cycle, and the coevolving geosphere and biosphere (Society of Economic Geologists). In: Kelley, K.D., Golden, H.C. (Eds.), Building exploration capability for the 21sy century. 18. Special Publication, pp. 1–15.

Howard, H.M., Smithies, R.H., Evins, P.M., Kirkland, C.L., Werner, M, Wingate, M.T.D., Pirajno, F., 2011a. Explanatory notes for the west Musgrave Province. Geological Survey of Western Australia, 1:100 000 Geological Series, Explanatory Notes, 349 pp.

Howard, H.M., Werner, M., Smithies, R.H., Kirkland, C.L., Kelsey, D.E., Hand, M., Collins, A., Pirajno, F., Wingate, M.T.D., Maier, W.D., Raimondo, T., 2011a. The Geology of the West Musgrave Province and the Bentley Supergroup — a Field Guide. Geological Survey of Western Australia (Record, 2011/4, 119 pp.).

Howard, H.M., Quentin de Gromard, R., Smithies, R.H., Kirkland, C.L., Korsch, R.J., Aitken, A.R.A., Gessner, K., Wingate, M.T.D., Blewett, R.S., Holzschuh, J., Kennett, B.L.N., Duan, J., Goodwin, J.A., Jones, T., Neumann, N.L., Gorczyk, W., 2013. Geological setting and interpretation of the northeastern half of deep seismic reflection line 11GA-YO1: west Musgrave Province and the Bentley Supergroup. In: Neumann, N.L. (Ed.), Yilgarn Craton–Officer Basin–Musgrave Province (YOM) Seismic and MT Workshop. Geoscience Australia, pp. 51–95 (Record, 2013/28).

Howard, H.M., Smithies, R.H., Kirkland, C.L., Kelsey, D.E., Aitken, A.R.A., Wingate, M.T.D., Quentin de Gromard, R., Spaggiari, C.V., Maier, W.D., 2015. The burning heart — the Proterozoic geology and geological evolution of the west Musgrave Region, central Australia. Gondwana Res. 27, 64–94.

Huston, D., Scrimgeour, I., Tyler, I., Hutton, L., 2008. The geodynamics and metallogenesis of the North Australian Craton. Annual Geoscience Exploration Seminar (AGES) 2008. Record of Abstracts. Northern Territory Geological Survey, pp. 2–4 (Record, 2008-002).

Huston, D.L., Blewett, R.S., Champion, D.C., Henson, P.A., Korsch, R.J., Roy, I., Hutton, L.J., Withnall, I.W., 2009. Links between geodynamic evolution and energy and mineral potential in North Queensland. Aust. Inst. Geosci. Bull. 49, 185–190.

Huston, D.L., Whelan, J.A., Jaireth, S., Kirkby, A., Gerner, E., Close, D.F., Blewett, R.S., Scrimgeour, I.R., Korsch, R.J., 2011. Implications of the Georgina–Arunta Seismic Survey to Energy and Mineral Systems. Northern Territory Geological Survey, pp. 86–93 (Record, 2011-003).

Huston, D.L., Blewett, R.S., Champion, D.C., 2012. Australia through time: a summary of its tectonic and metallogenic evolution. Episodes 35, 23–43.

Huston, D.L., Mernagh, T.P., Hagemann, S.G., Doublier, M.P., Fiorentini, M., Champion, D.C., Jaques, A.L., Czarnota, K., Cayley, R., Skirrow, R.G., Bastrakov, E., 2015. Tectonometallogenic systems — the place of mineral systems within tectonic evolution. Ore Geol. Rev. 76, 168–210 (in this volume).

Ivanic, T.J., Van Kranendonk, M.J., Kirkland, C.L., Wyche, S., Wingate, M.T.D., Belousova, E.A., 2012. Zircon Lu–Hf isotopes and granite geochemistry of the Murchison Domain of the Yilgarn Craton: evidence for reworking of Eoarchean crust during Meso–Neoarchean plume-driven magmatism. Lithos 148, 112–127.

Jagodzinski, E.A., Reid, A.J., 2010. New Zircon and Monazite Geochronology Using SHRIMP and LA-ICPMS, From Recent GOMA Drilling, on Samples From the Northern Gawler Craton. Geoscience Australia, pp. 108–117 (Record, 2010/39).

Johnson, S.P., Thorne, A.M., Tyler, I.M., Korsch, R.J., Kennett, B.L.N., Cutten, H.N., Goodwin, J., Blay, O., Blewett, R.S., Joly, A., Dentith, M.C., Aitken, A.R.A., Holzschuh, J., Salmon, M., Reading, A., Heinson, G., Boren, G., Ross, J., Costelloe, R.D., Fomin, T., 2013. Crustal architecture of the Capricorn Orogen, Western Australia and associated metallogeny. Aust. J. Earth Sci. 60 (6-7), 681–705. http://dx.doi.org/10.1080/08120099.2013.826735.

Kennett, B.L.N., Saygin, E., Fomin, T., Blewett, R., 2013. Deep Crustal Seismic Reflection Profiling: Australia 1978–2011. ANU Press and Geoscience Australia, Canberra (180 pp.).

Kirkland, C.L., Smithies, R.H., Woodhouse, A.J., Howard, H.M., Wingate, M.T.D., Belousova, E.A., Cliff, J.B., Murphy, R.C., Spaggiari, C.V., 2012. A Multi-isotopic Approach to the Crustal Evolution of the West Musgrave Province, Central Australia. Geological Survey of Western Australia (Report 115, 47 pp.).

Kirkland, C.L., Smithies, R.H., Woodhouse, A.J., Howard, H.M., Wingate, M.T.D., Belousova, E.A., Cliff, J.B., Murphy, R.C., Spaggiari, C.V., 2013. Constraints and deception in the isotopic record; the crustal evolution of the west Musgrave Province, central Australia. Gondwana Res. 23, 759–781.

Kirkland, C.L., Smithies, R.H., Spaggiari, C.V., 2014. Foreign contemporaries — unravelling disparate isotopic signatures from Mesoproterozoic Central and Western Australia. Precambrian Res. http://dx.doi.org/10.1016/j.precamres.2014.12.001.

Korsch, R.J., Doublier, M.P., 2015. Major crustal boundaries of Australia, 1:2 500 000, 2015 edition. Geoscience Australia, http://www.ga.gov.au/metadata-gateway/metadata/record/83223.

Korsch, R.J., Johnstone, D.W., Wake-Dyster, K.D., 1997. Crustal architecture of the New England Orogen based on deep seismic reflection profiling. In: Ashley, P.M., Flood, P.G. (Eds.), Tectonics and Metallogenesis of the New England Orogen. Geological Society of Australia, Special Publication 19, pp. 29–51.

Korsch, R.J., Preiss, W.V., Blewett, R.S., Cowley, W.M., Neumann, N.L., Fabris, A.J., Fraser, G.L., Dutch, R., Fomin, T., Holzschuh, J., Fricke, C.E., Reid, A.J., Carr, L.K., Bendall, B.R., 2010a. Deep seismic reflection transect from the western Eyre Peninsula in South Australia to the Darling Basin in New South Wales: geodynamic implications. In: Korsch, R.J., Kositcin, N. (Eds.), South Australian Seismic and MT Workshop, Extended Abstracts. Geoscience Australia, pp. 105–116 (Record. 2010/10).

Korsch, R.J., Blewett, R.S., Giles, D., Reid, A.J., Neumann, N.L., Fraser, G.L., Holzschuh, J., Costelloe, R.D., Roy, I.G., Kennett, B.L.N., Cowley, W.M., Baines, G., Carr, L.K., Duan, J., Milligan, P.R., Armit, R., Betts, P.G., Preiss, W.V., Bendall, B.R., 2010b. Geological interpretation of the deep seismic reflection and magnetotelluric line 08GA–OM1: Gawler Craton–Officer Basin–Musgrave Province–Amadeus Basin (GOMA), South Australia and Northern Territory. In: Korsch, R.J., Kositcin, N. (Eds.), GOMA (Gawler Craton–Officer Basin–Musgrave Province–Amadeus Basin) Seismic and MT Workshop 2010: Extended Abstracts. Geoscience Australia, pp. 63–86 (Record, 2010/39).

Korsch, R.J., Kositcin, N., Blewett, R.S., Fraser, G.L., Baines, G., Kennett, B.L.N., Neumann, N.L., Reid, A.J., Preiss, W.V., Giles, D., Armit, R., Betts, P.G., 2010c. Geodynamic implications of the deep seismic reflection line 08GA-OM1: Gawler Craton–Officer Basin–Musgrave Province–Amadeus Basin (GOMA), South Australia and Northern Territory. In: Korsch, R.J., Kositcin, N. (Eds.), GOMA (Gawler Craton–Officer Basin–Musgrave Province–Amadeus Basin) Seismic and MT Workshop 2010: Extended Abstracts. Geoscience Australia, pp. 138–151 (Record, 2010/39).

Korsch, R.J., Kositcin, N., Champion, D.C., 2011a. Australian island arcs through time: geodynamic implications for the Archean and Proterozoic. Gondwana Res. 19, 716–734.

Korsch, R.J., Blewett, R.S., Close, D.F., Scrimgeour, I.R., Huston, D.L., Kositcin, N., Whelan, J.A., Carr, L.K., Duan, J., 2011b. Geological interpretation and geodynamic implications of deep seismic reflection and magnetotelluric line 09GA-GA1: Georgina Basin–Arunta region. Annual Geoscience Exploration Seminar (AGES) 2011, Record of Abstracts.Northern Territory. Northern Territory Geological Survey, pp. 67–76 (Record, 2011-003).

Korsch, R.J., Huston, D.L., Henderson, R.A., Blewett, R.S., Withnall, I.W., Fergusson, C.L., Collins, W.J., Saygin, E., Kositcin, N., Meixner, A.J., Chopping, R., Henson, P.A., Champion, D.C., Hutton, L.J., Wormald, R., Holzschuh, J., Costelloe, R.D., 2012. Crustal architecture and geodynamics of North Queensland, Australia: insights from deep seismic reflection profiling. Tectonophysics 572-573, 76–99. http://dx.doi.org/10.1016/j.tecto.2012.02.022.

Korsch, R.J., Blewett, R.S., Pawley, M.J., Carr, L.K., Hocking, R.M., Neumann, N.L., Smithies, R.H., Quentin de Gromard, R., Howard, H.M., Kennett, B.L.N., Aitken, A.R.A., Holzschuh, J., Duan, J., Goodwin, J.A., Jones, T., Gessner, K., Gorczyk, W., 2013a. Geological setting and interpretation of the southwest half of deep seismic reflection line 11GA-YO1: Yamarna Terrane of the Yilgarn Craton and the western Officer Basin. In: Neumann, N.L. (Ed.), Yilgarn Craton–Officer Basin–Musgrave Province (YOM) Seismic and MT Workshop. Geoscience Australia, pp. 24–50 (Record. 2013/28).

Korsch, R.J., Blewett, R.S., Smithies, R.H., Quentin de Gromard, R., Howard, H.M., Pawley, M.J., Carr, L.K., Hocking, R.M., Neumann, N.L., Kennett, B.L.N., Aitken, A.R.A., Holzschuh, J., Duan, J., Goodwin, J.A., Jones, T., Gessner, K., Gorczyk, W., 2013b. Geodynamic implications of the Yilgarn Craton–Officer Basin–Musgrave Province (YOM) deep seismic reflection survey: part of a ~1800 km transect across Western Australia from the Pinjarra Orogen to the Musgrave Province. In: Neumann, N.L. (Ed.), Yilgarn Craton–Officer Basin–Musgrave Province Seismic and MT Workshop. Geoscience Australia, pp. 168–196 (Record, 2013/28).

Korsch, R.J., Blewett, R.S., Wyche, S., Zibra, I., Ivanic, T.J., Doublier, M.P., Romano, S.S., Pawley, M.P., Johnson, S.P., Van Kranendonk, M.J., Jones, L.E.A., Kositcin, N., Gessner, K., Hall, C.E., Chen, S.F., Patison, N., Kennett, B.L.N., Jones, T., Goodwin, J.A., Milligan, P.M., Costelloe, R.D., 2013c. Geodynamic implications of the Youanmi and Southern Carnarvon deep seismic reflection surveys: a ~1300 km traverse from the Pinjarra Orogen to the eastern Yilgarn Craton. In: Wyche, S., Ivanic, I.J., Zibra, I. (Compilers) (Eds.), Youanmi and Southern Carnarvon seismic and magnetotelluric (MT) workshop. Geological Survey of Western Australia, pp. 141–158 (Record, 2013/6).

Korsch, R.J., Spaggiari, C.V., Occhipinti, S.A., Doublier, M.P., Clark, D.J., Dentith, M.C., Doyle, M.G., Kennett, B.L.N., Gessner, K., Neumann, N.L., Belousova, E.A., Tyler, I.M., Costelloe, R.D., Fomin, T., Holzschuh, J., 2014. Geodynamic implications of the 2012 Albany–Fraser deep seismic reflection survey: a transect from the Yilgarn Craton across the Albany–Fraser Orogen to the Madura Province. In: CV Spaggiari, C.V., Tyler, I.M. (Comps.) (Eds.), Albany–Fraser Orogen Seismic and Magnetotelluric (MT) Workshop 2014: Extended Abstracts, preliminary edition Geological Survey of Western Australia, pp. 130–156 (Record, 2014/6).

Kositcin, N., Magee, C.W., Whelan, J.A., Champion, D.C., 2011. New SHRIMP Geochronology From the Arunta Region: 2009–2010. Geoscience Australia (Record, 2011/14, 75 pp.).

Krapez, B., Barley, M.E., 2008. Late Archaean synorogenic basins of the Eastern Goldfields Superterrane, Yilgarn Craton, Western Australia. Part III. Signatures of tectonic escape in an arc-continent collision zone. Precambrian Res. 161, 183–199.

McCuaig, T.C., Hronsky, J.M.A., 2014. The mineral system concept: the key to exploration targeting. In: Kelley, K.D., Golden, H.C. (Eds.), Building Exploration Capability for the 21st Century. Society of Economic Geologists, Special Publication 18, pp. 153–175.

Milligan, P.R., Franklin, R., Minty, B.R.S., Richardson, L.M., Percival, P.J., 2010. Magnetic anomaly map of Australia (Fifth Edition), 1:5 000 000 scale. Geoscience Australia, Canberra.

Moss, F.J., Dooley, J.C., 1988. Deep crustal reflection recordings in Australia 1957-1973-1. Data acquisition and presentation. Geophys. J. 93, 229–237.

Moss, F.J., Mathur, S.P., 1986. A review of continental reflection profiling in Australia. In: Barazangi, M., Brown, L. (Eds.), Reflection Seismology: a Global Perspective. American Geophysical Union, Geodynamics Series 13, pp. 67–76.

Myers, J.S., 1995. The generation and assembly of an Archaean supercontinent: evidence from the Yilgarn Craton, Western Australia. In: Coward, M.P., Ries, A.C. (Eds.), Early Precambrian Processes. Geological Society, London, Special Publication 95, pp. 143–154.

Myers, J.S., Shaw, R.D., Tyler, I.M., 1996. Tectonic evolution of Proterozoic Australia. Tectonics 15, 1431–1446.

Neumann, N.L., Blewett, R.S., Fraser, G.L., Henson, P., Preiss, W.V., Korsch, R.J., Cowley, W.M., Reid, A.J., 2010a. Recent deep seismic reflection surveys in the Gawler Craton and Curnamona Province, South Australia: implications for regional energy mineral systems. In: Korsch, R.J., Kositcin, N. (Eds.), South Australian Seismic and MT Workshop 2010: Extended Abstracts. Geoscience Australia, pp. 117–124 (Record, 2010/10).

Neumann, N.L., Skirrow, R.G., Fraser, G.L., Korsch, R.J., Preiss, W.V., Cowley, W.M., Blewett, R.S., 2010b. Implications for regional energy and mineral systems of the 08GA-OM1 (GOMA) deep seismic reflection survey in the northern Gawler Craton to Amadeus Basin, South Australia and the Northern Territory. In: Korsch, R.J., Kositcin, N. (Eds.), GOMA (Gawler Craton–Officer Basin–Musgrave Province–Amadeus Basin) seismic and MT Workshop 2010: Extended Abstracts. Geoscience Australia, pp. 152–162 (Record, 2010/39).

Pawley, M.J., Wingate, M.T.D., Kirkland, C.L., Wyche, S., Hall, C.E., Romano, S.S., Doublier, M.P., 2012. Adding pieces to the puzzle: episodic crustal growth and a new terrane in the northeast Yilgarn Craton, Western Australia. Aust. J. Earth Sci. 59, 603–623.

Plumb, K.A., 1979. The tectonic evolution of Australia. Earth-Sci. Rev. 14, 205–249.

Raymond O.L. (Coordinator), Surface geology of Australia 1:1 million scale digital geology data: Geoscience Australia, Digital Geology Map, 2009, https://www.ga.gov.au/products/servlet/controller?event=GEOCAT_DETAILS&catno=69455.

Reid, A.J., Jagodzinski, E.A., Armit, R.J., Dutch, R.A., Kirkland, C.L., Betts, P.G., Schaefer, B.F., 2014. U–Pb and Hf isotopic evidence for Neoarchean and Paleoproterozoic basement in the buried northern Gawler Craton, South Australia. Precambrian Res. 250, 127–142.

Scrimgeour, I.R., 2013. Chapter 13: Warumpi Province. In: Ahmad, M., Munson, T.J. (Comps.) (Eds.), Geology and Mineral Resources of the Northern Territory. Special Publication 5. Northern Territory Geological Survey, pp. 13.1–13.21.

Scrimgeour, I.R., Close, D.F., 2011. Overview of the geology and tectonics along the Georgina–Arunta Seismic Traverse. Annual Geoscience Exploration Seminar (AGES) 2011, Record of Abstracts.Northern Territory. Northern Territory Geological Survey, pp. 57–62 (Record, 2011-003).

Shaw, R.D., Wellman, P., Gunn, P., Whitaker, A.J., Tarlowski, C., Morse, M., 1995. Australian crustal elements (1:5,000,000 scale map) based on the distribution of geophysical domains (v 1.0). Australian Geological Survey Organisation, Canberra.

Smithies, R.H., Howard, H.M., Evins, P.M., Kirkland, C.L., Kelsey, D.E., Hand, M., Wingate, M.T.D., Collins, A.S., Belousova, E.A., Allchurch, S., 2010. Geochemistry, Geochronology and Petrogenesis of Mesoproterozoic Felsic Rocks in the Western Musgrave Province of Central Australia and Implication for the Mesoproterozoic Tectonic Evolution of the Region. Geological Survey of Western Australia (Report, 106, 73 pp.).

Sorjonen-Ward, P., Zhang, Y., Zhao, C., 2002. Numerical modelling of orogenic processes and gold mineralisation in the southeastern part of the Yilgarn Craton, Western Australia. Aust. J. Earth Sci. 49 (6), 935–964. http://dx.doi.org/10.1046/j.1440-0952.2002.00969.x (Australia).

Spaggiari, C.V., Kirkland, C.L., Smithies, R.H., Occhipinti, S.A., Wingate, M.T.D., 2014a. Geological framework of the Albany–Fraser Orogen. In: Spaggiari, C.V., Tyler, I.M. (Comps.) (Eds.), Albany–Fraser Orogen Seismic and Magnetotelluric (MT) Workshop 2014: Extended Abstracts. Geological Survey of Western Australia, pp. 12–27 (Record, 2014/6).

Spaggiari, C.V., Occhipinti, S.A., Korsch, R.J., Doublier, M.P., Clark, D.J., Dentith, M.C., Gessner, K., Doyle, M.G., Tyler, I.M., Kennett, B.L.N., Costelloe, R.D., Fomin, T., Holzschuh, J., 2014b. Interpretation of Albany–Fraser seismic lines 12GA–AF1, 12GA–AF2 and 12GA–AF3: implications for crustal architecture. In: Spaggiari, C.V., Tyler, I.M. (Comps.) (Eds.), Albany–Fraser Orogen Seismic and Magnetotelluric (MT) Workshop 2014: Extended Abstracts. Geological Survey of Western Australia, pp. 28–43 (Record, 2014/6).

Swager, C.P., Goleby, B.R., Drummond, B.J., Rattenbury, M.S., Williams, P.R., 1997. Crustal structure of granite–greenstone terranes in the Eastern Goldfields, Yilgarn Craton, as revealed by seismic reflection profiling. Precambrian Res. 83, 43–56.

Tyler, I.M., 2005. Australia: Proterozoic. In: Selley, R.C., Cocks, L.R.M., Plimer, I.R. (Eds.), Encyclopedia of Geology vol. 1. Elsevier, Oxford, pp. 208–222.

Upton, P., Hobbs, B., Ord, A., Zhang, Y., Zhao, C., Drummond, B., Archibald, N., 1997. Thermal and deformation modelling of the Yilgarn deep seismic transect. In: Price, G. (Ed.), Geodynamics and Ore Deposits Conference, Abstracts. Australian Geodynamics Cooperative Research Centre, pp. 22–25.

Van Kranendonk, M.J., Ivanic, T.J., Wingate, M.T.D., Kirkland, C.L., Wyche, S., 2013. Long-lived, autochthonous development of the Archean Murchison Domain, and implications for Yilgarn Craton tectonics. Precambrian Res. 229, 49–92. http://dx.doi.org/10.1016/j.precamres.2012.08.009.

Wade, B.P., Barovich, K.M., Hand, M., Scrimgeour, I.R., Close, D.F., 2006. Evidence for Early Mesoproterozoic arc magmatism in the Musgrave Block, Central Australia: implications for Proterozoic crustal growth and tectonic reconstructions of Australia. J. Geol. 114, 43–63.

Willman, C.E., Korsch, R.J., Moore, D.H., Cayley, R.A., Lisitsin, V.A., Rawling, T.J., Morand, V.J., O'Shea, P.J., 2010. Crustal-scale fluid pathways and source rocks in the Victorian Gold Province, Australia: insights from deep seismic reflection profiles. Econ. Geol. 105, 895–915.

Wyche, S., Kirkland, C.L., Riganti, A., Pawley, M.J., Belousova, E., Wingate, M.T.D., 2012. Isotopic constraints on stratigraphy in the central and eastern Yilgarn Craton, Western Australia. Aust. J. Earth Sci. 59, 657–670.

Wyche, S., Ivanic, T.J., Zibra, I., Gessner, K., Doublier, M.P., Korsch, R.J., Blewett, R.S., 2013. The 2010 Youanmi deep-crustal seismic lines: implications for mineral systems. In: Wyche, S., Ivanic, I.J., Zibra, I. (Comps.) (Eds.), Youanmi and Southern Carnarvon Seismic and Magnetotelluric (MT) Workshop. Geological Survey of Western Australia, pp. 141–158 (Record, 2013/6).