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.

Crown Copyright © 2015 Published by Elsevier B.V. All rights reserved.

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/Crown Copyright © 2015 Published by Elsevier B.V. All rights reserved.

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,

Download English Version:

https://daneshyari.com/en/article/4697073

Download Persian Version:

https://daneshyari.com/article/4697073

Daneshyari.com