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Review

A review of Australia's Proterozoic mineral systems and genetic models

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ABSTRACT

Australian Proterozoic rocks host significant mineral resources, some of which are amongst the largest in the world with about 50% of the value of Australian mineral production from iron and gold. Australia's Proterozoic mineral systems reviewed in this contribution include: (1) iron-formations or banded iron-formations (BIFs); (2) orogenic and intrusion-related systems; (3) orthomagmatic ore systems; (4) mineral systems associated with anorogenic magmatism; (5) rift-related stratiform and stratabound sedimentary-hosted; and (6) uranium deposits. These mineral systems formed in intraplate, plate margin, back-arc rift and collisional tectonic settings. The Hamersley Basin is endowed with largest Fe resources in the world, which are time equivalent (ca. 2400 Ma) of the Transvaal Group BIF in South Africa. The origin of BIF and of granular iron-formation (GIF) remains a contentious issue with models invoking subaqueous hydrothermal discharges in lakes and/or ocean basins or in Red Sea type brine pools. In all cases a density and oxic–anoxic stratified system is required to enable precipitation of Fe^{3+}. Orogenic and intrusion-related ore systems are very common in the Proterozoic rocks of Australia, with examples from the Pine Creek, Granites–Tanami and Arunta orogens in the North Australian Craton (NAC), and the Capricorn Orogen in the West Australian Craton (WAC). These deposits reflect collision and accretion events between ca. 1800 and 1790 Ma. Orogenic Au lodes are generally, but not always, temporally associated with granitic rocks, but a genetic relationship remains elusive. Orthomagmatic Ni–Cu–PGE and Fe–Ti–V ore deposits in mafic–ultramafic systems are present in the Halls Creek Orogen (NAC) and the ca. 1080 Ma Giles mafic–ultramafic intrusions in the Musgrave Complex (Paterson Orogen). Mineral systems associated with anorogenic magmatism encompass a wide range of hydrothermal deposits of which the economically most important are the Fe oxide–copper–gold or IOCG ore systems, such as the ca. 1580 Ma world-class Olympic Dam in the South Australian Craton (SAC). In the same group are the Abra Pb–Zn–Ag–Ba(–Cu–Au–W) (Capricorn Orogen) and the world-class Telfer Au–Cu (Paterson Orogen). The latter has been one of the largest Au producers in Australia. During 1100 and 800 Ma alkaline rocks, including carbonatites and diamondiferous lamproites, were emplaced in the NAC, SAC and WAC. The 1180 Ma Argyle lamproite pipe in the NAC is the world's largest diamond producer. Studies elsewhere suggest that these alkaline rocks are the distal expression of mantle plume events. Stratiform and stratabound sedimentary-rock hosted giant and world-class Zn–Pb–Ag sulfide deposits developed between ca. 1700 and 1500 Ma in the McArthur River-Mount Isa and Broken Hill rift systems. These deposits are all hosted in metamorphosed siliciclastics or organic-rich shales and associated with clastic–evaporitic successions and bimodal igneous activity. Conceptual models of ore genesis propose discharge of hydrothermal fluids along major basin faults, syn-sedimentary exhalations of these fluids in oxygen deficient pools and bacterial sulfate reduction in order to produce H_2S and precipitate sulfides. An unusual and large non-sulfide Pb carbonate ore deposit, Magellan, is hosted in clastic rocks of the ca. 1800 Ma Earaheedy Group. The lack of sulfides suggest that the deposit is related to paleoweathering processes, which induced oxidation and mobilization of Pb. Uranium ore systems, apart from U contained in IOCG deposits, include the unconformity stratabound deposits in the Pine Creek Orogen with the world-class Jabiluka as the main representative. We conclude that the several giant and world-class ore systems in Australia's Proterozoic were formed during intraplate tectonothermal and rifting events. Orogenic lodes were formed during collision and accretion of arc terranes that led to the amalgamation of the NAC, SAC and WAC.

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Contents

1. Introduction

Precambrian (Archean and Proterozoic) Australia is represented by terranes and tectonic units west of the Phanerozoic "Tasmanides" (Direen and Crawford, 2003). The Archean to Paleo-Mesoproterozoic cratonic framework of Australia consists of the West Australian Craton (WAC), North Australian Craton (NAC), and South Australian Craton (SAC; Myers, 1990; Myers et al., 1996). The WAC and NAC are separated by the Proterozoic Paterson Orogen, the WAC and SAC are separated by the ca. 1300–1100 Ma Albany-Fraser Orogen, with the ca. 1080 Ma Pinjarra Orogen on the western margin of the WAC (Fig. 1). Proterozoic rocks in southeastern Australia and Tasmania are not considered in this review because they are probably fragments of terranes that were accreted to the Australian plate during the Phanerozoic (Myers et al., 1996).

An understanding of the geodynamic evolution of Proterozoic Australia is of paramount importance in order to examine and study the timing of the tectonic events that contributed to the formation of ore deposits and identify those factors that lead to the development of conceptual models of ore systems. Similarly, an understanding of ore-forming processes are essential for successful exploration and the discovery of new deposits. The tectonic models that best explain the geodynamic evolution of Proterozoic Australia include both convergent margin and intraplate tectonics (Tyler et al., 1998; Betts et al., 2002, 2003; Tyler, 2005; Betts and Giles, 2006). Plate tectonic models involving convergent margins are well documented for the Halls Creek Orogen, the Rudall Complex, the Albany-Fraser Orogen, Glenburgh Orogen, Arunta Orogen, and the northern margin of SAC (Li, 2000; Bagas, 2004; Betts et al., 2002; Betts and Giles, 2006 and references cited therein). Intraplate tectonics could be linked to mantle plume dynamics at ca. 1800, ca. 1500, ca. 1080 and ca. 830 and 755 Ma, all of which correspond with major igneous and rift forming events (Pirajno et al., in preparation). Mantle plumes are upwellings of hot mantle material that are typically associated with flood volcanism on the earth's surface, dyke swarms, sills complexes and layered intrusions at depth (Ernst and Buchan, 2003). Although felsic magmatism is usually associated with plate margins above subduction zones, igneous products of mantle plumes also include a variety of silicic rocks, so that the full magmatic range is typically bimodal in composition (Ernst and Buchan, 2003). Examples in Australia of mantle plume-related felsic magmatism include the ca. 1800 Ma granites in the Pine Creek Orogen (Wyborn et al., 1992), the ca. 1590 Hitalba granite suite in the SAC (Betts et al., 2002), and the ca. 1080 Ma felsic volcanic rocks and A-type granites of the Musgrave Complex (Glikson et al., 1996).

The geodynamic evolution of Proterozoic Australia has been discussed in some detail by Myers et al. (1996), Betts et al. (2002), Giles et al. (2004), and Betts and Giles (2006). Tyler (2005) provided an overview of the Proterozoic in Australia, and Veevers (2000) treated in detail the evolution of the Australian plate from the Neoproterozoic through to the Phanerozoic. An excellent volume details the Proterozoic geology, mineralization, and tectonic evolution of the SAC (Drexel et al., 1993).

The geodynamic history of the NAC, WAC and SAC began with the collision of the NAC and WAC, between ca. 1830 and ca. 1760 Ma during the Capricorn–Yapungku–Stafford–Early Strangways orogenies, along the Capricorn–Rudall–Arunta orogenic belts (Bagas, 2004; Betts and Giles, 2006). This also resulted in the inception of intracratonic back-arc basins on the NAC. In the next "snapshot", between ca. 1760 and ca. 1620 Ma, much of the tectonic activity is related to the collision of the Gawler Craton, coming in from Antarctica, with the NAC (Kimban-Late Strangway orogenies). This also produced the inversion of the Leichhardt Superbasin in the Mount Isa Inlier and renewed magmatism in the Arunta Orogen at about ca. 1640 Ma. Using new geochronological data, Şener et al. (2005) suggested that the amalgamation of the NAC, SAC and WAC was completed by ca. 1750–1720 Ma. The next stages saw the development of the McArthur River-Mount Isa, Broken Hill, Georgetown rift systems, accompanied by large-scale bimodal magmatism (e. g. Gawler Range Volcanics and Hiltaba Event in SAC; Giles, 1988). These rift systems are considered as being intracratonic back-arc extensional structures, which were formed as a result of regional and far-field tectonic stresses (Betts et al., 2002). Compressional events with further crustal or plate adjustments are recorded in the Paterson Orogen during the ca. 750 Ma Miles Orogeny and the ca. 550 Ma Paterson–Petermann Orogeny (discussed below).

Finally, anomalous high heat flow is recorded in the SAC and the NAC of central Australia, where average surface heat flow is in the order of ca. 80 mW m^{-2} (McLaren et al., 2003). The source