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Dating fluid flow and Mississippi Valley type base-metal mineralization in the Paleoproterozoic Earaheedy Basin, Western Australia

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ABSTRACT

The ages of deposition and metamorphism of low-grade Precambrian metasedimentary sequences can be difficult to define in the absence of interlayered volcanogenic rocks. Monazite and xenotime can grow at temperatures below 400 °C and can give vital evidence for the timing of diagenesis, hydrothermal fluid flow, and low-grade deformation and metamorphism in Precambrian basins. The histories of sedimentary basins in the eastern Capricorn Orogen of the West Australian Craton are generally poorly constrained. However, sandstones and siltstones of the basal Yelma Formation in the Earaheedy Basin contain authigenic monazite and xenotime associated with sulphide minerals related to Mississippi Valley Type base-metal mineralization hosted within carbonate of the overlying Sweetwaters Well Member. In the Teague area, within the Earaheedy Basin, siliciclastic rocks overlying granites of the Yilgarn Craton contain authigenic monazite that gives an in situ SHRIMP $^{207}Pb/^{206}Pb$ age of 1811 ± 13 Ma. Monazite in weathered sandstones and siltstones of the Cano secondary Pb deposit on Magellan Hill, overlying the Yerrida Basin, gives an indistinguishable age of 1815 ± 13 Ma. The Cano monazite is interpreted to have been intergrown with primary sulphide minerals and therefore to record the age of mineralization. Xenotime outgrowths on detrital zircons from Cano have high common Pb but define an isochron with an age of 1832 ± 36 Ma. The isochron is co-linear with Pb isotope ratios from Pb ore at Magellan, suggesting that xenotime growth is also related to mineralization. The timing of fluid flow is synchronous with the 1820–1770 Ma Capricorn Orogeny, and is the first evidence for activity of this age in the eastern part of the Capricorn Orogen. The age of mineralization provides a firm minimum age for the Yelma Formation, and constrains its deposition to between ~2.0 Ga, the youngest age of detrital zircons, and the mineralization age.

1. Introduction

The ages of deposition and deformation of low metamorphic grade Precambrian sedimentary sequences, such as those exposed in the Capricorn Orogen of Western Australia, can be difficult to define in the absence of interlayered volcanogenic rocks that contain dateable minerals such as zircon. However, the rare earth element (REE) phosphate minerals monazite and xenotime can grow at temperatures below 400 °C and can give vital evidence for the timing of diagenesis, hydrothermal fluid flow, and low-grade deformation and metamorphism in such Precambrian basins.

The Capricorn Orogen (Fig. 1) was formed during assembly of the West Australian Craton by collision of the Pilbara and Yilgarn Cratons, and the Glenburgh Terrane (Cawood and Tyler, 2004), and its initiation coincides with the earliest phase of formation of the proposed Paleo- to Mesoproterozoic supercontinent Nuna (Columbia) (Hoffman, 2004; Rogers and Santosh, 2002; Zhao et al., 2001). The Capricorn Orogen subsequently experienced an extended intracontinental history, over ~1.0 billion years, of sedimentation, deformation and metamorphism, basaltic volcanism and voluminous granitic magmatism, particularly in the west.

The Earaheedy Basin is one of several Proterozoic sedimentary basins within the Capricorn Orogen (Fig. 1), although, robust ages for deposition and deformation are lacking. It is unusual in that it is host to Mississippi Valley Type (MVT) mineralization within the lowermost Yelma Formation, one of very few occurrences of MVT mineralization hosted in Precambrian rocks (Leach et al., 2010). Monazite and xenotime are associated with sulphide mineralization and their occurrence provides an opportunity to establish the timing and cause of a significant fluid flow event in the basin which has the potential not only to aid exploration for new resources but also contribute to understanding the geological evolution of the Earaheedy Basin and its role within the Capricorn Orogen.

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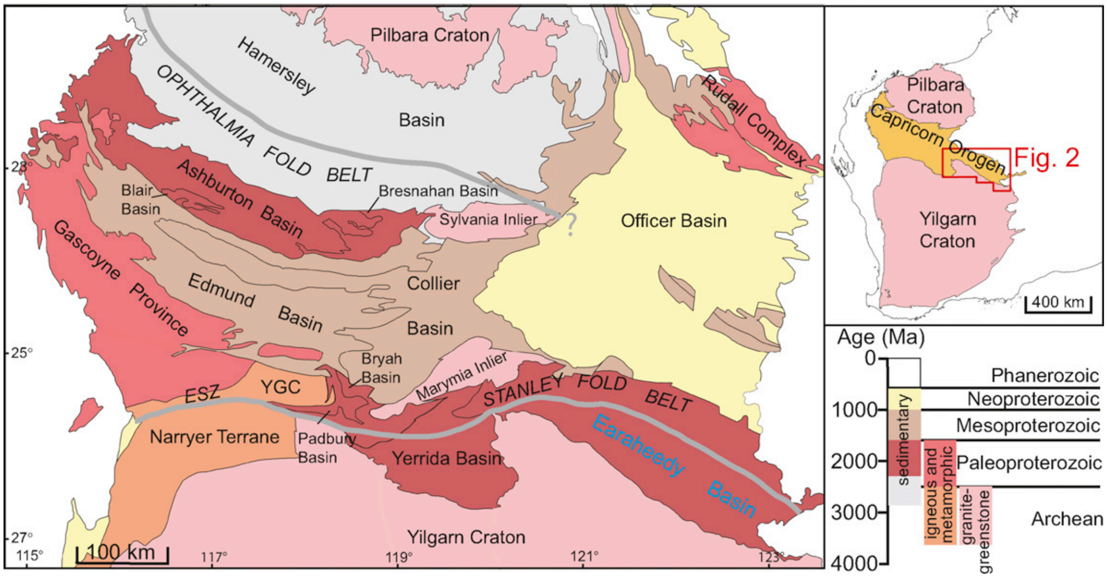

Fig. 1. Elements of the Capricorn Orogen and adjacent basins and cratons. Abbreviations: ESZ – Errabiddy shear zone; YGC – Yarlarweelor Gneiss Complex. The thick grey lines define the northern and southern limits of the orogen (after Johnson et al., 2011). Inset shows the components of the West Australian Craton.

Monazite [(LREE, Th)PO_4] and xenotime [(Y, HREE)PO_4] are both robust chronometers (e.g., Parrish, 1990; Hawkins and Bowring, 1997; Bingen and van Breemen, 1998) and have been used extensively for dating igneous rocks and metamorphism, from prehnite-pumpellyite facies (e.g., Cabella et al., 2001; Rasmussen et al., 2001, 2011) to granulite facies (e.g., Vry et al., 1996; Korhonen et al., 2011), while xenotime has also been used to date diagenesis (McNaughton et al., 1999; Vallini et al., 2005). Less frequently, they have been applied to dating hydrothermal mineralization, for example, gold (e.g., Rasmussen et al., 2006; McFarlane, 2006; Vielreicher et al., 2010; Sarma et al., 2011) and iron ore (Rasmussen et al., 2007a, 2010). Both geochronometers have closure temperatures of ~750 °C and are therefore resistant to resetting during post-crystallization retrograde events, and both tend to exclude common Pb during growth making them ideal for U–Th–Pb geochronology. This paper reports the application of U–Pb SHRIMP methods to dating monazite and xenotime related to MVT mineralization in the Earaheedy Basin. The results define the timing of a major episode of fluid flow within the basin and show that it is synchronous with the intracratonic Capricorn Orogeny. The mineralization age also provides a firm minimum for the deposition of sediments at the base of the Earaheedy Group.

2. Geological setting

2.1. Capricorn Orogen

The Capricorn Orogen is a Proterozoic collisional orogen that separates the Archean Pilbara and Yilgarn nuclei in the West Australian Craton (Fig. 1). It has a long history of sedimentation, deformation and metamorphism, and magmatism related to collision of the two Archaean cratons and the smaller Glenburgh Terrane, which is exposed in the southern Gascoyne Province (Cawood and Tyler, 2004). The orogen was initiated when the ~2.5 Ga Glenburgh Terrane collided with the southern margin of the Pilbara Craton in the Ophthalmian Orogeny at ~2.2 Ga (Rasmussen et al., 2005; Johnson et al., 2011). The combined Pilbara–Glenburgh continental mass collided with the northern margin of the Yilgarn Craton in the Glenburgh Orogeny at ~2.0 Ga, with the suture marked by the Errabiddy shear zone (Occhipinti et al., 2004; Sheppard et al., 2004; Johnson et al., 2011). The Gascoyne Province in the west of the orogen comprises the Glenburgh Terrane, granitic intrusions derived by reworking of continental crust, and belts of low- to high-grade metasedimentary rocks. The continental blocks are overlain by Proterozoic sedimentary basins, including the Ashburton, Blair, Bresnahan, Yerrida, Bryah, Padbury, Earaheedy, Edmund and Collier Basins (Fig. 1). Volcanic and tuffaceous rocks are generally lacking, so there are few direct determinations of depositional age from the sedimentary basins. Most ages are based on stratigraphic relationships, the ages of detrital zircons, and the ages of dolerite sills and dykes that intrude the sediments.

In addition to the Ophthalmian and Glenburgh Orogenies, the Capricorn Orogen experienced intracontinental tectonism in the Capricorn (~1.8 Ga) (Sheppard et al., 2010), Mangaroon (~1.6 Ga) (Sheppard et al., 2005), Mutherbukin (~1.2 Ga) (Johnson et al., 2011) and Edmundian (~1.0 Ga) (Sheppard et al., 2007) orogenies. The timing of the orogenic episodes has been derived from the bracketing ages of granitic rocks and the metamorphic ages of metasedimentary rocks in the Gascoyne Province. The depositional and deformational ages of the sedimentary rocks further to the east are very poorly constrained.

2.2. Earaheedy Basin

The geology of the Earaheedy Basin has recently been reviewed (Pirajno et al., 2009), so only those aspects of relevance to the depositional setting and timing of base-metal mineralization are described in this paper. The Earaheedy Basin forms the most easterly of the Proterozoic sedimentary basins that form the eastern part of the Capricorn Orogen, and is filled by sedimentary rocks of the Earaheedy Group (Fig. 2). The Yelma Formation at the base of the group unconformably overlies granite-greenstone rocks of the Yilgarn Craton, including the Marymia Inlier, and older sedimentary rocks of the Yerrida Basin (Fig. 2; Pirajno et al., 2009). The northern margin of the basin is overlain by sedimentary rocks of the Collier, Scorpion and Salvation Groups of the Bangemall Superbasin while to the east it is covered by Phanerozoic sediments (Fig. 2). Rocks in the southern part of the basin are relatively undeformed and flat-lying, but the northern margin is characterized by tight folding with the development of schistosity in the Stanley Fold Belt (Fig. 2). Metamorphic grade is generally low, probably of lower greenschist