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Glacial dispersion of hydrothermal monazite in the Prominent Hill deposit: An exploration tool

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ABSTRACT

Light rare earth elements (LREEs) are commonly enriched within iron oxide–copper–gold (IOCG) deposits within the Gawler Craton, South Australia. The LREEs are host within a number of phases including monazite, which is a resistate phase that can withstand processes of physical transport and weathering without significant chemical alteration. Recognition of this elevated LREE signature within rocks that have been transported away from mineralised zones can therefore be used as a geochemical vector towards potential IOCG mineralisation.

In the northern Gawler Craton, South Australia, monazite occurs within basement rocks within and proximal to the Prominent Hill IOCG deposit. These basement rocks have been physically transported and dispersed during glacial activity subsequent to the mineralisation event, and redeposited in the cover sequence as a glacial diamictite. Here we show that the hydrothermal monazite within the mineralised zone has a characteristic geochemical signature, and that this signature has been preserved within monazite grains within the overlying glacial diamictite. The hydrothermal monazite is characteristically enriched in La and Ce, and depleted in Y and Th. A chemical criterion for exploration is derived. Monazite chemistry showing concentrations of La + Ce >63 wt.% and Y and Th <1 wt.% is considered compelling. Concentrations of 57.5 wt.% < La + Ce < 63 wt.% are considered interesting, and compositions of La + Ce < 57.5 wt.% are considered background.

Using the assumption that all light rare earth elements in the cover sequence are host within monazite, this mineral chemistry signature can be recognised in whole rock geochemistry. Data showing La >75 ppm and Ce >155 ppm is considered anomalous. Data that also shows (La + Ce):Y ratios between 10:1 and 30:1 and (La + Ce):Th ratios between 16:1 and 32:1 is considered interesting. Ratios of (La + Ce):Y and (La + Ce):Th greater than 30:1 and 32:1 respectively are considered compelling. In the northern Gawler Craton, the scale of the footprint associated with the anomalous whole rock geochemical signature characteristic of Prominent Hill-style IOCG mineralisation is 2–3 times larger than the orebody itself. Dispersion of this signature is related to glacial processes and palaeotopography. This chemical criteria may potentially be used as a geochemical vectoring method towards Prominent Hill-style IOCG mineralisation, and may be applicable to exploration for other IOCG deposits within the Gawler Craton and further afield.

1. Introduction

Discoveries of economically viable ore systems have been declining as a result of having to explore deeper terranes. Mineralisation is hosted within basement rocks that are overlain by younger cover sequences, therefore an explorer is required to get as much information as possible using remote sensing techniques and from minimal rock samples. The cover sequences overlying mineralised basement rocks have previously been considered a hindrance to exploration, however the thinking of modern explorers is changing as the characteristics of these cover sequences are being constrained and their usefulness in mineral exploration is being learnt. In particular, the geochemistry of cover sequences has been demonstrated to be useful in mineral exploration, particularly where the geochemistry is linked with palaeotopography and landscape evolution (e.g. Anand et al., 2001; Hill, 2003; Hou et al., 2003; McClenaghan and DiLabio, 1993; Vanderhoek et al., 2012).

The Gawler Craton in South Australia (Fig. 1) is a region with high mineralisation potential, including iron oxide–copper–gold (IOCG) (e.g. Groves et al., 2010; Skirrow et al., 2002, 2007) and Au (e.g. Barns: Fig. 1; e.g. Drown, 2003; Ferris and Schwarz, 2003), and where the mineralised basement rocks are overlain by extensive cover sequences. These cover sequences include Permian basal glacial diamictites (Alley, 1995; Krieg, 1995) that stratigraphically sit at the base of cover sequences that are

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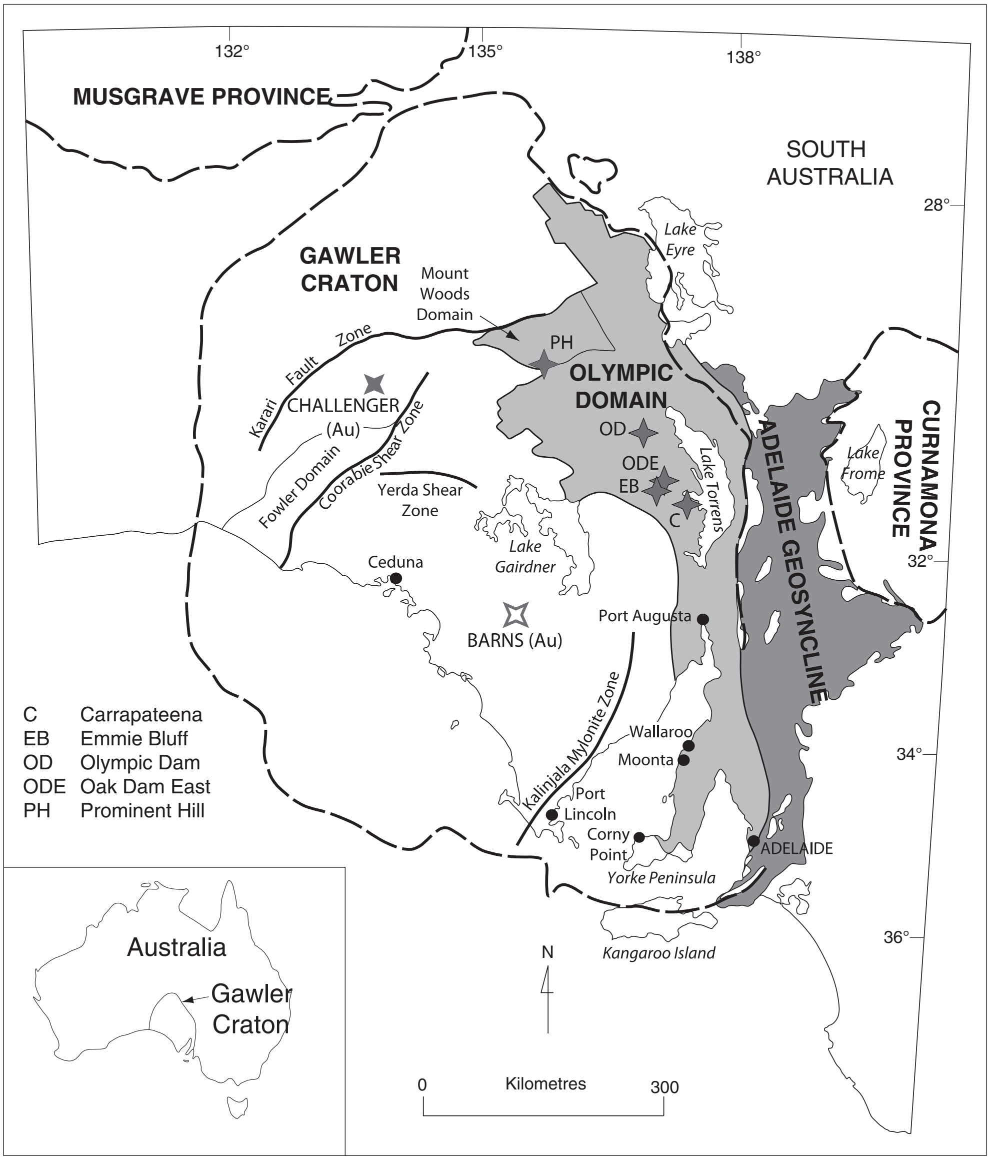

Fig. 1. Simplified geological map showing the location of the Olympic Domain and known major IOCG deposits including the Prominent Hill deposit. The Challenger Au deposit is also shown. Modified after Conor et al. (2010).

significantly younger than mineralised basement rocks. Geochemical sampling of glacial deposits has previously been demonstrated as a successful mineral exploration technique (e.g. McClenaghan and DiLabio, 1993; McClenaghan et al., 2000; Paulen et al., 2011; Sarapää and Sarala, 2013). This exploration tool uses the relationship between geochemical patterns and sedimentological criteria (primarily glacial flow directions) to provide vectors towards mineralisation in the underlying basement.

Here we give an example from the Prominent Hill region in the northern Gawler Craton (Figs. 1 & 2) where the chemistry of a resistate phase (monazite: $(Ce,La,Th)PO_4$) in basal glacial sequences can be used in geochemical exploration. Monazite was targeted as it hosts light rare earth elements (LREEs), particularly Ce and La, which are characteristically enriched within IOCG deposits in South Australia (e.g. Belperio and Freeman, 2004a, 2004b; Belperio et al., 2007; Davidson et al., 2007; Freeman and Tomkinson, 2010; Groves et al., 2010; Oreskes and Einaudi, 1990; Skirrow et al., 2007). Furthermore, monazite is a resistate phase to weathering and physical transport (e.g. Scott and Pain, 2008) and can therefore be carried into the cover sequence without or with slight alteration. We used chemical mapping to identify LREE-bearing phases and electron microprobe analysis to determine mineral chemistry of monazite within basement and the basal cover sequence in the Prominent Hill area. Criteria for exploration of Prominent Hill-style IOCG deposits using resistate phase and whole rock geochemistry are then discussed.

2. Geological setting

The Olympic Domain in the eastern and northern Gawler Craton of South Australia is host to numerous IOCG deposits (e.g. Olympic Dam, Prominent Hill, Carrapateena) and prospects (e.g. Oak Dam East, Emmie Bluff) (e.g. Belperio et al., 2007; Davidson et al., 2007; Freeman and Tomkinson, 2010; Gow et al., 1994; Johnson and Cross, 1995) (Fig. 1). These deposits formed during a major tectonothermal and magmatic event ca. 1.60–1.58 Ga (e.g. Belperio et al., 2007; Betts et al., 2009; Davidson et al., 2007; Forbes et al., 2008; Giles et al., 2002, 2004; Reid et al., 2011; Skirrow et al., 2007), and are hosted within Palaeoproterozoic