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Short communication

Uranium and gold deposits in the Pine Creek Orogen (North Australian Craton): A link at 1.8 Ga?

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ABSTRACT

The Pine Creek Orogen (PCO) in the North Australian Craton (NAC) hosts world-class unconformity-related U deposits and numerous orogenic or intrusion-related Au deposits, whose timing and genesis are the subject of ongoing controversy. This study reports new geochronology results for an unconformity-related U deposit, Ranger 1 Number 3 orebody, to constrain the timing of processes leading to alteration development and U mineralisation within a regional geological and metallogenic context. It also examines why some U deposits in the eastern PCO contain elevated Au concentrations, unlike their unconformity-related U counterparts in Canada and elsewhere. Key results are as follows. (i) The Ranger 1 deposit and the PCO Au deposits share several characteristics of hydrothermal mineralogy, including chlorite—white-mica—monazite—(±xenotime)-bearing alteration assemblages, some sulfides (pyrite, chalcopyrite), silica (quartz veining or silicification), and Au. (ii) The primary host structure at the Ranger 1 deposit is a shear zone which was reactivated at low-grade metamorphic conditions, as during formation of many of the syn-tectonic Au deposits in the PCO. (iii) Ion probe U–Pb dating of low-Th monazite in an assemblage of hydrothermal white-mica and Fe-rich chlorite from an outer alteration zone at the Ranger 1 No. 3 orebody yielded an age of 1800 ± 9 Ma. This age is ~60 million years earlier than the oldest previously reported age of unconformity-related U mineralisation in the PCO and is within error of several U–Pb ages reported for monazite and xenotime associated with Au mineralisation in the PCO. (iv) Iron-rich chlorite intimately associated with the dated monazite is similar compositionally and texturally to chlorites in alteration zones at other U deposits in the PCO.

Two scenarios for the formation of the Ranger 1 deposit are consistent with the available evidence. We prefer a two-stage model where an Fe-chlorite—white-mica—monazite hydrothermal alteration assemblage, with probable gold was introduced replacing medium-grade metamorphic assemblages within a reactivated shear zone at ca. 1800 Ma, contemporaneous with the formation of some Au deposits within the PCO. Subsequently, U ore was formed within this environment at ~1740 Ma and/or later, via the reaction of oxidised U- and Mg-bearing basin-derived fluids with chemical reductants in the basement.

The new U–Pb geochronology result for monazite points to an important hydrothermal event at the site of the Ranger 1 deposit during regional tectonothermal activity of the Shoobridge Event at ~1.8 Ga in the PCO, and suggests that this pre-ore alteration and tectonism was a key factor in localising later unconformity-related U mineralisation. The pre-ore alteration at ~1800 Ma at the Ranger 1 deposit therefore provides a link between the genesis of the unconformity-related U deposits and the orogenic or intrusion-related Au deposits that formed in the PCO during the Shoobridge Event. At the broader scale, the newly identified ~1800 Ma hydrothermal activity at the Ranger 1 deposit may be part of a craton-wide metallogenic and tectonothermal event at ~1.8 Ga that includes Au mineralisation in the PCO and in The Granites-Tanami Orogen, as proposed in other studies.

1. Introduction

The North Australian Craton (NAC) hosts some of the world's largest uranium deposits, numerous gold deposits including the world-class Callie deposit, several giant base metal deposits and many other mineral resources, of mainly Precambrian age (Huston et al., 2007; Pirajno and Bagas, 2008). Uranium and gold deposits

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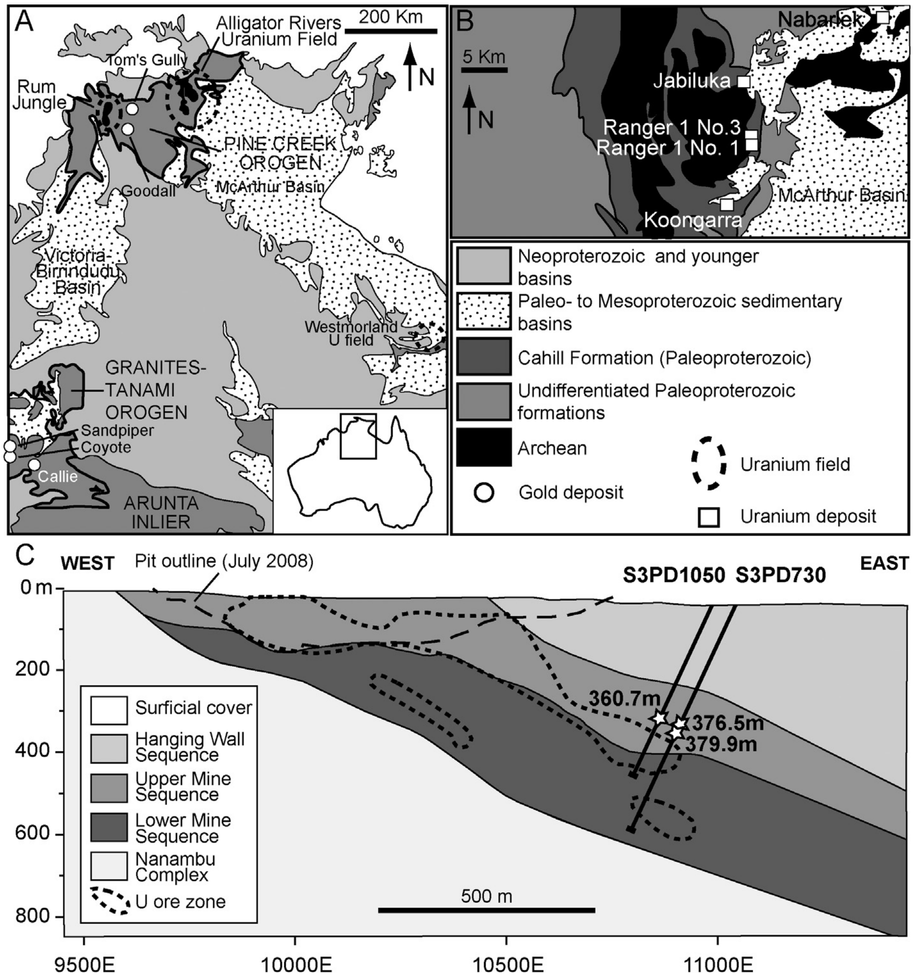

Fig. 1. (A) Regional geology of the Pine Creek Orogen and The Granites-Tanami Orogen showing the distribution of the major hydrothermal gold deposits and the Alligator Rivers Uranium Field (ARUF) which hosts the unconformity-related U deposits. (B) Location of the major unconformity-related U deposits in the ARUF including the Ranger 1 No. 3 and No. 1 orebodies. (C) Cross-section through the Ranger 1 No. 3 orebody at 11,700 N (see text), modified after Fisher et al. (2013). The location of the sample containing the dated hydrothermal monazite (labelled 730–376.5) in drill hole S3PD730 is highlighted. Some of the other samples in which monazite was identified are also labelled, in drill holes S3PD730 and S3PD1050 (projected from approximately 200 m to the north of the section).

are distributed mainly among two types of hydrothermal mineralisation: (1) unconformity-related U deposits in Alligator Rivers Uranium Field (ARUF) of the Pine Creek Orogen (PCO), and (2) orogenic or intrusion-related Au deposits in the PCO and The Granites-Tanami Orogen (Fig. 1). Several of the unconformity-related U deposits are characterised by significant gold enrichments (e.g. Jabiluka: 4.6 Mt ore at 3.07 g/t Au; Koongarra: 1.04 Mt ore at 3 g/t Au; Ranger: hundreds of ppb Au; Hegge et al., 1980; Snelling, 1990; Potma et al., 2012; Fisher et al., 2013), which is an atypical feature compared to unconformity-related U deposits worldwide, especially those in Canada (Kyser and Cuney, 2008).

The formation of the unconformity-related U deposits has been proposed to be linked to basin-derived brine infiltration into basement rocks after deposition of the Paleoproterozoic McArthur Basin (Wilde and Wall, 1987; Polito et al., 2004, 2005; Lally and Bajwah, 2006; Derome et al., 2007; Kyser and Cuney, 2008). The oldest reported age of unconformity-related U mineralisation in the PCO is 1737 ± 20 Ma for the Ranger 1 deposit, determined by U–Pb dating of uraninite-bearing whole-rock samples (Ludwig et al., 1987). The next oldest reported age is 1685 ± 17 Ma for an individual analysis of uraninite in the Jabiluka deposit, determined by $^{207}Pb/^{206}Pb$ laser-ICPMS (Polito et al., 2004, 2005). Massive uraninite ore formation was proposed to have occurred at ~1680 Ma and ~1640 Ma at the Jabiluka and Nabarlek deposits, respectively (Polito et al., 2004, 2005), followed by a number of younger events recorded in the uraninite ages. All these ages have however, no clear link to regional geodynamic events for the origin of different fluid migrations and metal deposition. Determination of the absolute timing of the mineralising process and hence the testing of the genetic hypothesis has proved difficult, due to the ease with which the U–Pb, K–Ar and $^{40}Ar/^{39}Ar$ isotopic systems of the most widely used geochronometers in unconformity-related U deposits, uraninite and white-mica (illite, sericite), may be reset by Pb and Ar losses, respectively (e.g. Lerman and Clauer, 2005; Chipley et al., 2007; Clauer, 2013). This is a relevant and serious problem especially in ore deposits where multiple fluid events have potentially occurred through time, which is typical for unconformity-related U systems (Kyser and Cuney, 2008).

The timing of Au mineralisation in the PCO is also problematic and three main periods have been proposed for the formation of the major Au deposits: (1) ~1730 Ma (Sener et al., 2005), (2) ~1780 Ma (Rasmussen et al., 2006), and (3) ~1810–1800 Ma (Compston and Matthäi, 1994; Bagas et al., 2009; Cross et al., 2005; Cross, 2009). These differing timings have underpinned opposing interpretations of the Au deposit type(s) (orogenic versus intrusion-related), and geodynamic settings of mineralisation (syn-collisional versus post-collisional or post-orogenic).