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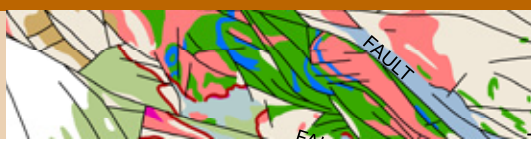
Dating Australia's uranium deposits

Chemical dating of uraninite to encourage explorers



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Australia hosts the largest uranium reserves in the world, boasting 23 per cent of the global total, and is currently the third ranked uranium producer behind Kazakhstan and Canada. Nevertheless, there are only scarce geochronological data on the timing of formation for the majority of Australian uranium deposits.

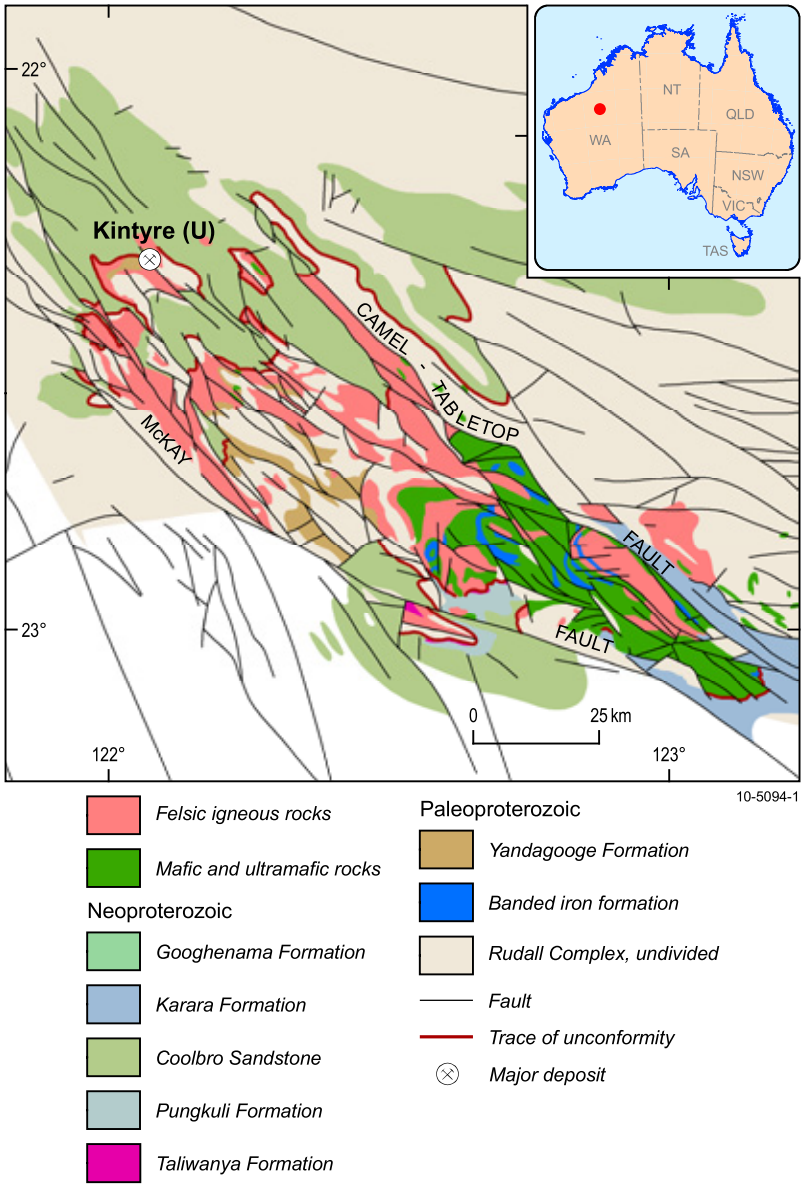

Figure 1. Generalised geological map of the Paterson region (modified after Roach 2010).

Because uraninite is commonly a major ore constituent of many primary uranium deposits its geochronology has the potential to provide a direct age of mineralisation. This contrasts with other geochronological studies of mineral deposits where the age of mineralisation is based on the inference that the dated mineral (such as muscovite, biotite, monazite and xenotime) crystallised at the same time as the ore. Additionally, the high concentration of uranium in uraninite requires only a relatively short time period for the accumulation of significant concentrations of radiogenic lead.

To encourage exploration for uranium, Geoscience Australia researchers undertook dating of selected uranium deposits as a part of its Onshore Energy Security Program (2006 to 2011; Skirrow 2011). This article outlines the results from the Kintyre deposit in Western Australia and the Oasis deposit in Queensland where the timing of uranium mineralisation was directly dated using Electron-Probe Micro-analysis (EPMA) chemical uranium-thorium-lead (U–Th–Pb) uraninite analysis. This analysis measures the natural radioactive decay of uranium and thorium to lead to measure time.

Chemical analysis of uraninite

It is just over 100 years since the very first U–Pb age determinations were carried out on uranium-bearing minerals. Although truly landmark studies in their time, the chemical U–Pb ages determined by Bertrum Boltwood and Arthur Holmes were done before the existence of isotopes was recognised. They had only rudimentary estimates of the U–Pb decay rate and were unaware that thorium also decays to lead (^{232}Th–^{208}Pb). Although the vast majority of all U–Pb age determinations undertaken currently are isotopic (that is, ^{235}U-^{207}Pb, ^{238}U-^{206}Pb), chemical U–Th–Pb dating has also been used to determine the timing of geological events since the early 1990s. The chemical analyses are almost exclusively undertaken by EPMA and the vast majority of geochronological work has been carried out on monazite (Suzuki & Adachi 1991; Montel et al 1996; Cocherie et al 1998; Williams et al 1999). This method, however, can also be affectively applied to date uraninite (Bowles 1990, Förster 1999, Kempe 2003).

Chemical U–Th–Pb dating is based on the premise that all lead in the sample is radiogenic in origin, derived solely from the radiogenic decay of ^{235}U, ^{238}U and ^{232}Th. A composite age equation combining all three decay schemes is then used together with the EPMA-derived concentrations for uranium, thorium and lead. The equation is then solved by iteratively substituting a value for *t* (time) into each of the equations until a solution is reached (for a full explanation of the technique see Cross et al 2011 and Montel et al 1996). Cross et al (2011) recently highlighted the potential of this method for dating uraninite by demonstrating a strong agreement between the existing and/or inferred ages of the uraninites studied, with the Chemical U–Th–Pb ages and independent SHRIMP ^{207}Pb/^{206}Pb results. A potential drawback of the method however, is that common or environmental lead cannot easily be detected and accounted for. Although Bowles (1990) and Cross et al (2011) note very low common lead contents in some natural uraninites, this should not be assumed to be the case for all uraninite. However, Cross et al (2011) concluded that EPMA chemical dating of uraninite is able to provide relatively inexpensive, robust reconnaissance-level age determinations.

EPMA analyses were undertaken using a Cameca SX100 electron microprobe located at the Research School of Earth Sciences (RSES) at the Australian National University (ANU) in Canberra. The uraninite grains were analysed for uranium, thorium, lead, yttrium, silicon, calcium, titanium and iron using a 15 kV electron beam regulated at 100 nA. Full details of the analytical procedures and methodology are described in Cross et al (2011). The uraninite standard U6897 (~1058 to ~1043 Ma (Bill Davis, Geological Survey of Canada, personal communication) was used as an internal check for the EPMA U–Th–Pb chemical dating results.

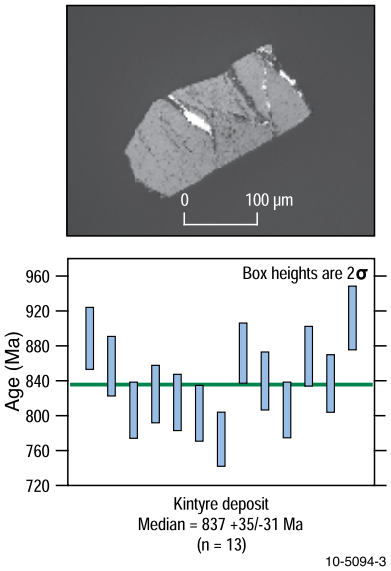

Figure 2. Representative reflected light image of Kintyre uraninite grain (top) and plot of EPMA chemical U–Th–Pb ages for the Kintyre deposit. The highly reflective area in the centre of the uraninite is galena.

Kintyre deposit

The Kintyre unconformity-related uranium deposit (latitude: 122.0709°E, longitude: 22.3387°S) is located about 420 kilometres southeast of Port Hedland, in the Paterson Orogen, Western Australia. It is jointly owned by Cameco Corporation (70 per cent) and Mitsubishi Development Pty Ltd (30 per cent). It is one of the largest unconformity-related deposits in Australia outside the Pine Creek Orogen with a resource of 24 000 tonnes of U_3O_8 (OZMIN database).

The Kintyre deposit is hosted by the Paleo– to Mesoproterozoic Rudall Complex (figure 1), comprising carbonaceous metasediments of the Yandagooge Formation adjacent to the unconformity with the Neoproterozoic Coolbro

Sandstone, the basal unit of the overlying Yeneena Basin (McKay & Miezitis 2001). The Coolbro Sandstone and Rudall Complex were subsequently folded and deformed during the ~840 to ~810 Ma Miles Orogeny (Huston et al 2010). Uranium typically occurs as uraninite in carbonate–chlorite veins which tend to be concentrated in the hinges of folds and have an orientation sub–parallel to the axial planes.

Geochronological data constrain deposition of sediments in the Yeneena Basin occurred between ~910 Ma, the age of the youngest detrital zircon in the basal Coolbro Formation (Bagas & Nelson 2007), and ~830 Ma, the age of intermediate to mafic rocks that intrude the lower part of the basin (D. Maidment, unpublished data). These constraints are compatible with a Pb–Pb isochron age for carbonate rocks of the Isdell Formation of ~860 Ma (R Maas & DL Huston, unpublished data), interpreted as a diagenetic age. The sample of Kintyre uraninite (ANSTO minerals number Kintyre-13) was collected from the mineralised zone of the deposit in 1997 by CRA Exploration Pty Ltd and analysed by ANSTO in the same year.

The EPMA chemical U–Th–Pb uraninite results from Kintyre were interpreted by Cross et al (2011) to have a crystallisation age of 837 +35/-31 Ma (figure 2). This result is similar to the ~845 Ma age suggested for mineralisation by R.Maas of the University of Melbourne in Huston et al (2009) and confirms that uranium mineralisation post dates the host rocks of the Paleoproterozoic Yandagooge Formation and is likely related to the ~840 to ~810 Ma Miles Orogeny. Importantly, the recognition of unconformity–related mineralisation of Neoproterozoic age in the Paterson Orogen has implications for similar uranium systems related to other Neoproterozoic regions in Australia.

Oasis deposit

The Oasis uranium deposit (latitude: 144.4461^{0}E, longitude: 18.8035^{0}S) is located 20 kilometres northwest of Lynd in the Georgetown Inlier, northeast Queensland. Uranium mineralisation in this region is predominantly volcanic-related and associated with calderas, ring-dykes and linear fracture-controlled intrusion systems (McKay and Miezitis 2001). The largest deposits in the region are Ben Lamond and Maureen and the mineralisation is thought to have occurred in two main episodes, the late Devonian to early Carboniferous and the late Carboniferous to early Permian (McKay and Miezitis 2001). The age of the Maureen deposit is inferred to be 330 ± 10 Ma based on a uranium–lead age of fluorite closely associated with mineralisation (Huston et al 2011a).

In contrast to the dominant volcanic–related uranium mineralisation in the Georgetown region, the Oasis deposit is hosted by a north-trending shear zone that cuts the Mesoproterozoic Mywyn Granite, which intrudes Paleo– to Mesoproterozoic metasedimentary rocks of the Etheridge province. The mineralised zone comprises a mylonitic, biotite–rich unit that is tabular in shape, ranges from less than 10 to 15 metres thick and extends for 300 metres along strike reaching a depth of 175 metres with grades between 0.12 to 0.17 per cent U_3O_8 (Huston et al 2011b). Uraninite is the dominant ore mineral which in some cases appears to have overgrown biotite (Huston et al 2011b).

The host Mywyn Granite is an S–type, strongly deformed foliated, feldspar porphyritc granite. Recent SHRIMP U–Pb zircon geochronology reported by Neumann and Kositcin (2011) has constrained the crystallisation age of this unit to 1559 ± 3 Ma, which provides a maximum age for uranium mineralisation. Analyses of muscovite and biotite from the mineralised mylonitic zone, using the argon^{40}/argon^{39} method (Ar–Ar) have ages between 439 to 429 Ma. The ~439 Ma age was interpreted by Huston et al (2011b) to represent a minimum age of mylonitic deformation, whereas the ~429 Ma age, a later period of muscovite growth.

The EPMA chemical U–Th–Pb analyses of uraninite from the mineralised mylonitic zone were interpreted by Huston et al (2011b) to have crystallised at 433 +3/-4 Ma. This result is

well within error of the 439 to 429 Ma mica ages determined from the same samples. Therefore, the period between ~440 to ~430 Ma is seen to be a good estimate for the timing of uranium mineralisation at the Oasis deposit. This result suggests that uranium mineralisation at the Oasis deposit was influenced by the mid–Silurian, Benambran deformational event which affected much of North Queensland including the Camel Creek, Hodgkinson and Charters Towers regions (Champion et al 2009). Additionally, this new age for the Oasis deposit demonstrates that uranium mineralisation in the Georgetown region has occurred in possibly three different time periods, the mid-Silurian, late Devonian to early Carboniferous and the late Carboniferous to early Permian.

Conclusions

The EPMA chemical ages for the Kintyre unconformity–related uranium deposit and the Oasis shear–hosted uranium deposit are considered relatively robust radiometric age determinations. In both cases, the EPMA chemical ages are supported by independent isotopic results. These results demonstrate that in some circumstances, EPMA chemical U–Th–Pb geochronology of uraninite can be used to directly date uranium mineralisation, providing relatively inexpensive, robust, reconnaissance-level radiometric age determinations.

Acknowledgements

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