Metasomatism in the Mesoproterozoic – evidence for a regional fluid event in the central Aileron Province

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Introduction

At AGES 2012, the preliminary findings of a study into high-heat producing granites of the Palaeoproterozoic Aileron Province in central Australia was presented by the Northern Territory Geological Survey (Beyer et al. 2012). The primary aim of the project was to better understand the nature and prospectivity of two of these granites – the Wangala and Ennugan Mountains granites – which outcrop in the central Aileron Province (Figure 1). These two granites were targeted because they are strongly uraniferous and host zones of biotite schist anomalously enriched in a range of elements, including U, Th, P, F, high field strength elements (HFSE) and the rare earth elements (REE). What follows is a summary of the outcomes from the project and an updated perspective on the nature of the schists and their role in identifying a regional fluid event during the Mesoproterozoic.

Wangala and Ennugan Mountains granites

The Wangala and Ennugan Mountains granites occur approximately 75 km apart in NAPPERBY. The Wangala Granite is an S-type muscovite-biotite monzogranite comprised of five main phases that are distinguished on the basis of texture and mineralogy (Beyer in prep). It is dominated by porphyritic to equigranular biotite-muscovite granite with localised tourmaline ± garnet leucogranite. Primary muscovite (± garnet) is present in four of the five main phases suggesting that the intrusion, as a whole, is peraluminous. LA–ICP–MS U–Pb dating of zircon cores from the Wangala Granite indicates an emplacement age of 1777 ± 11 Ma; U-rich zircon overgrowths on cores indicate an isotopic resetting event at 1571 ± 28 Ma (Beyer et al. 2015).

In contrast, the Ennugan Mountains Granite is an I-type biotite ± hornblende monzogranite that contains a number of distinct phases, the dominant one being a porphyritic biotite-bearing granite with abundant felsic microgranular enclaves. Although hornblende is only developed locally, its presence reflects the overall metaluminous composition of the granite, distinguishing it from the Wangala Granite. SHRIMP U–Pb zircon dating of Ennugan Mountains Granite indicates that it was emplaced at ca 1621 ± 5 Ma with no clear evidence in the zircon data for a later overprinting event (Kositcin et al. 2013).

Biotite schists

The southern outcrops of the Wangala Granite are distinguished by the presence of discrete, mesoscale lensoidal bodies of biotite-apatite schist (Figures 1, 2a). The schists contain up to 70% biotite and 25% apatite, with minor muscovite and quartz. The contact between schist

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Figure 1. Generalised geology map of the central Aileron Province.

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and granite is gradational at the centimetre scale and is marked by the presence of topaz and fluorite. Relative to the enclosing granite, the schists display elevated abundances of elements such as P, U, F, Li, Co, Ni, Zn, Ag, Sn, W and REE. Zircons from the schist have a dominant age population at 1762 ± 16 Ma that is within uncertainty of the magmatic crystallisation age of the host granite (Beyer et al. 2015). U-rich rims on zircons are variably developed and are characterised by inclusions of monazite, thorite and barite (Figure 3). Dating of these rims yielded an age of 1569 ± 25 Ma, providing a close match to the rim age for the host granite (Beyer et al. 2015). SHRIMP U–Pb dating of monazite from the schist gave an age of 1574 ± 2 Ma, better constraining the timing of isotopic resetting (Kositcin et al. 2013). These results indicate that both the granite and schist were affected by a later thermal event at ca 1575 Ma.

Outcropping in the central part of the Ennugan Mountains Granite are several zones of biotite schist up to 2 m wide (Figures 1, 2b). Unlike the biotite-apatite schists of the Wangala Granite, these are composed primarily of abundant, strongly foliated biotite, large strained muscovite ‘fish’ and fine-grained polygonal quartz. However, like the Wangala schists, they are variably enriched in numerous trace elements and metals such as U, Th, P, F and REE, as well as Rb, Cs, Hf, Zr, Ta, Nb, Bi, Sn, W and Zn. Zircons from biotite schist have a dominant age population at 1615 ± 5 Ma that is within uncertainty of the age for the host granite (Kositcin et al. 2013). In situ monazite U–Pb dating of the schist yielded two distinct age populations: 1606 ± 2 Ma that is consistent with the age of the schist determined by zircon dating, and 1574 ± 7 Ma interpreted to date a metamorphic fluid event (Kositcin et al. 2013).

Regional metasomatism during the Chewings Orogeny (1590–1560 Ma)

Previous studies (eg Davies 1979) suggest that the biotite schists represent altered rafts of metamorphosed country rock; however, their age and chemistry suggest otherwise. The preferred interpretation is that they represent zones of their respective host granite that were hydrothermally altered during a post-magmatic metasomatic event. This interpretation is based on a number of lines of evidence including: the corresponding ages between schist and host

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**Figure 2.** (a) Field photo of biotite-apatite schist enclosed in porphyritic Wangala Granite. (b) Biotite schist in porphyritic Ennugan Mountains Granite. Hammer used for scale is 32 cm long.

**Figure 3.** Back scattered electron images of zircons from biotite-apatite schist from the Wangala Granite (provided courtesy of D Huston, Geoscience Australia). zr = zircon, mz = monazite, th = thorite, ba = barite.
granite; the gradational and altered nature of the contact between the rock types; and the presence of the metals, HFSE and REE enrichment seen in the schists. The timing of this event is constrained by zircon and monazite U–Pb isotopic data which strongly support an episode of accessory phase growth at ca 1575 Ma, coincident with the regionally significant ca 1590–1560 Ma Chewings Orogeny. Whole-rock and mineral geochemistry of samples of the schists and accessory phase inclusions in zircon indicate the metasomatic fluid was enrichment in U, Th, P, F and REE, plus a host of metals. This is strong evidence that the zircon rims precipitated from a fluid that was high in all these elements.

Although, the timing of the metasomatic event seems clear, the source of the fluid is less obvious. The Chewings Orogeny is a tectonothermal event of fundamental importance throughout the central and southern Aileron Province. At present, there is little reported magmatism associated with the event, however fluid flow during this time period is evident from metamorphic zircons rims from a number of stratigraphic units across these areas (some examples are presented in Rubatto et al 2001, Claué-Long and Hoatson 2005, Donnellan 2008, Bodorkos et al 2013). Furthermore, recent work carried out at the Nolans REE-P-U fluoroapatite vein-hosted deposit points to a significant metasomatic and mineralising event in the central Aileron Province between 1550–1525 Ma (Huston et al 2016). Isotopic and chemical data for Nolans indicate that the fluid that metasomatised the host Boothby Orthogneiss (ca 1805 Ma) and produced massive fluoroapatite and associated mineralisation, was derived from alkaline, possibly phosphatic, low degree partial melts (Huston et al 2016, Huston et al 2017). Thus it is plausible that the metasomatic fluids that produced the schists in the Wangala and Ennugan Mountains granites had the same, or similar, origin. It is also worth noting that the Boothby Orthogneiss does not classify as high-heat producing; this indicates that the fluid event affected more than just that compositional type of host rock. A regional scale alkaline metasomatic fluid source is supported by the alkaline composition of the biotite schists within the Wangala Granite, and by an isolated occurrence of monzonite intruding the southern outcrops of the Wangala Granite (Figure 1). The monzonite is allanite-bearing and has a strongly alkaline composition; it also displays some enrichment compared to the Wangala Granite, in particular P and REE, though not to the degree seen for the schists. The age of the monzonite is presently unknown but is hypothesised to be ca 1575 Ma. If so, this would confirm the first known alkaline magmatism of this age in the Aileron Province.

Conclusions

The key finding of this study is that a regionally significant U-P-F-REE-rich fluid flow event affected Palaeoproterozoic granites of the central Aileron Province during the Chewings Orogeny (1590–1560 Ma). This implies there is significant potential for basement-hosted uranium and/or REE deposits in the region, particularly in areas where the thermal and/or chemical conditions were suitable to localise mineralisation.

References


