ROYALTIES FOR REGIONS
EXPLORATION INCENTIVE SCHEME

Enhanced geochronology and potential for understanding tectonics and mineralization

by

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Knowledge of the age of rocks and tectonic events is fundamental to understanding geological evolution and the timing of mineralizing events. The Geological Survey of Western Australia routinely determines the ages of rocks by measuring the ratios of uranium, thorium, and lead isotopes in crystals of zircon and other minerals using the Sensitive high resolution ion microprobe (SHRIMP). Additional funding from the Exploration Incentive Scheme (EIS) has enabled GSWA to build on its existing strengths and expertise in geochronology, with the addition of in situ dating of phosphate minerals, Sm–Nd isotope analysis of whole rocks, and Lu–Hf isotope analysis of individual zircon crystals. These data can greatly enhance the understanding of geology and mineral potential in underexplored parts of Western Australia. In concert with these developments, substantial changes aimed at making results easier to access and more rapidly available, are improving the delivery of geochronology and other isotope data.

U–Pb zircon and baddeleyite geochronology

Dating of zircon and baddeleyite continues to be an essential component of GSWA's geochronology program. In 2008–09, more than 100 rock samples were processed at GSWA's laboratory for dating, with more than 90 samples dated by ion microprobe. These samples were collected to support GSWA mapping programs in the west Musgrave Province, Murchison Domain, Eastern Goldfields, eastern Yilgarn Craton, and the Capricorn and Albany–Fraser Orogens, and have yielded significant results.

A new regional geochronology dataset for the eastern Albany–Fraser Orogen indicates that a 1690 to 1660 Ma magmatic and sedimentary terrane, the Biranup Zone, extends for at least 1200 km along the southern and southeastern margin of the Yilgarn Craton (Spaggiari et al., 2010, this volume). These data also show that the Biranup Zone underwent a previously unrecognized deformation event at c. 1680 Ma (Kirkland et al., 2010). Such regional age information is not only critical in placing mineralizing events — such as the one that formed the significant Tropicana gold deposit — in their geological context, but also helps to identify areas that may have been subjected to similar episodes of mineralization.

Although the majority of gold, nickel, and platinum group element (PGE) deposits in Western Australia are hosted within mafic igneous rocks found in greenstone belts, few of these rocks have been dated directly, and most age constraints are indirect, involving the dating of crosscutting granites or detrital zircons in associated sedimentary rocks. Recent baddeleyite and zircon dating of leucogabbros in the northern Murchison Domain (where mafic–ultramafic rocks in layered intrusions make up about 40% by volume of greenstones) have defined four late Archean mafic suites, which host both vanadium and nickel–copper–PGE mineralization. In addition, this magmatism was in part coeval with mafic–ultramafic magmatism in the Burtville Terrane of the Eastern Goldfields Superterrane, suggesting the possibility of a shared history. Another example of direct dating of mineralization comes from a copper-mineralized dyke in the western Musgrave Province, which yields a U–Pb zircon age of c. 1070 Ma. This constrains the age of mafic magmatism associated with significant orthomagmatic Ni–Cu–PGE mineralization in the province (e.g. Nebo–Babel deposit).

In situ phosphate geochronology

Techniques for in situ dating of minerals in polished thin sections enable textural relationships between rock fabrics (i.e. deformation) and mineral growth to be put in a temporal context. Supported by both EIS and an Australian Research Council (ARC) Linkage grant, GSWA is collaborating with Curtin University of Technology, to apply in situ dating (Fig. 1) of a range of minerals (mainly monazite and xenotime) to regional- and deposit-scale field mapping. Although the magmatic and high-temperature metamorphic history of the Capricorn Orogen is reasonably well-defined by zircon geochronology, little is known about low- to moderate-temperature events such as sediment deposition, early diagenesis, low-grade regional metamorphism, and hydrothermal fluid flow and mineralization. Initial results from metasedimentary rocks include a range of monazite ages between c. 1550 and 1000 Ma. Samples have also

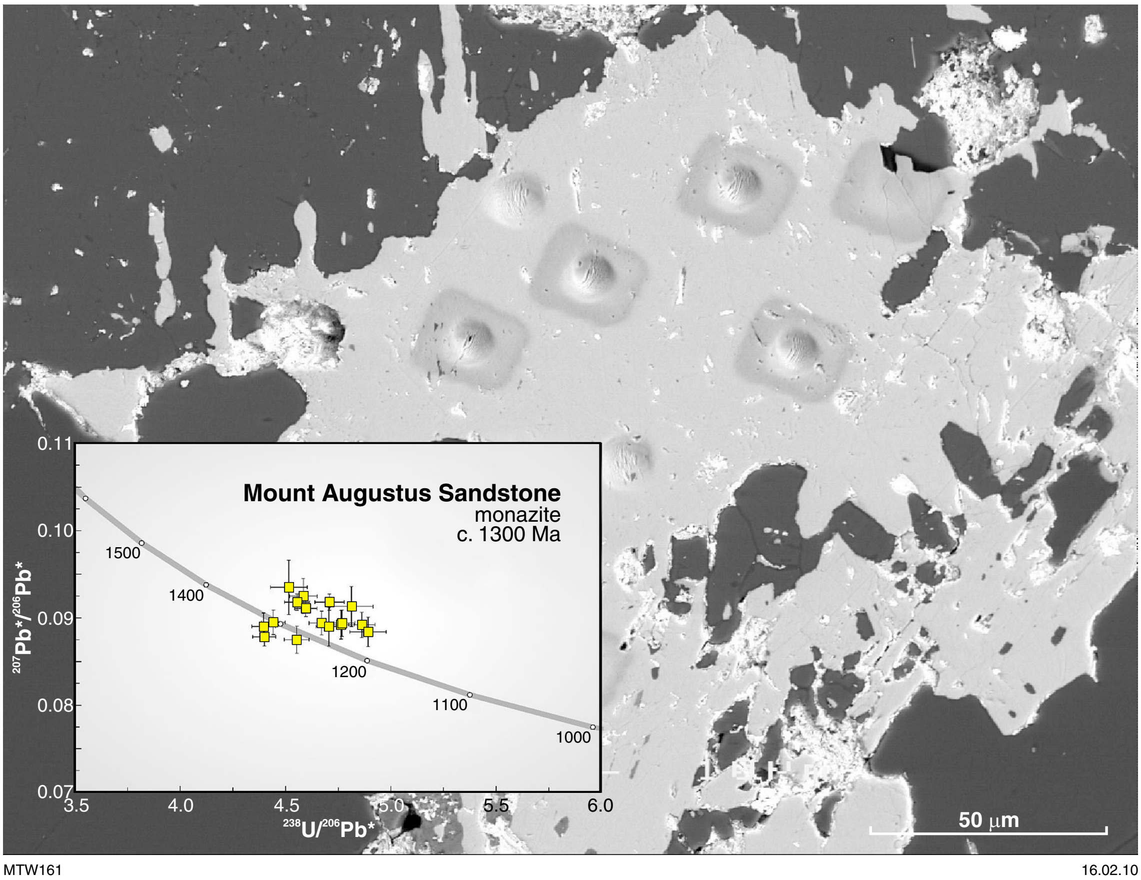

Figure 1. Backscattered electron (BSE) image of ion microprobe (SHRIMP) analysis craters in metamorphic monazite within a thin section of Mount Augustus Sandstone. Note the small size (<10 microns) of the analysis sites. The inset shows preliminary analytical results that indicate an age of about 1300 Ma. These and other analyses are helping to define a regional hydrothermal event at about 1300–1250 Ma that may have been responsible for widespread base metal mineralization in the Capricorn Orogen. Photomicrograph from Birger Rasmussen, Curtin University of Technology.

been collected to date rare earth element (REE)-bearing pegmatites using monazite and columbite–tantalite. In situ phosphate geochronology is expected to lead to a new understanding of tectonic events in the Gascoyne Province and Bangemall Supergroup, and will enable more effective exploration targeting.

Whole-rock Sm–Nd analyses

Insights into the nature of tectonics and crust–mantle interaction can be gained by studying Sm–Nd isotopes. To understand crustal evolution, knowledge of not only the age distribution of magmatic rocks but also of their sources (e.g. mantle-related or recycled older crust) is needed. Measurement of whole-rock $^{143}Nd/^{144}Nd$ can provide an estimate of when a melt was separated from a mantle source (or in complicated crustal source regions, an average mantle extraction age of all source components). In the Yilgarn Craton, Sm–Nd results have demonstrated a close spatial association between source domains of differing isotopic composition, age, and mineralizing events (Champion and Cassidy, 2007). Reconnaissance data available for parts of the Yilgarn Craton show that areas of different Nd model ages correspond to tectonic subdivisions, indicating that Sm–Nd isotope measurements can be used to map crustal age domains. Some younger 'juvenile' domains in the Youanmi and Kurnalpi Terranes are spatially related to known VHMS deposits, such as Golden Grove and the Teutonic Bore and Jaguar deposits. Under EIS, about 130 samples will be analysed each year for four years, mainly from mafic and intermediate rocks for which there are no U–Pb zircon data.

Zircon Lu–Hf analyses

In addition to providing crystallization ages, isotopic analysis of zircons can also elucidate the composition of the magma from which the zircons crystallized. Lu–Hf isotopes in zircon can be used in a similar manner to Sm–Nd, but with several key advantages. Owing to its extreme durability, zircon can survive geological recycling and retain information from early Earth history. The Lu–Hf system in zircon is also more resistant to disturbance than the Sm–Nd or U–Pb systems, and therefore has the potential to accurately retain information on the geological evolution of highly metamorphosed terranes. Lu–Hf analyses will include detrital zircons in sedimentary rocks, as well as zircons with multiple growth stages, which allow complex histories in both igneous and metamorphic rocks to be examined. About 1500 zircons, representing a large number of samples, can be analysed each year during EIS. The Lu–Hf analyses are conducted by the Centre for Geochemical Evolution and Metallogeny of Continents (GEMOC) at Macquarie University. The project is adding considerable value to the existing GSWA geochronology dataset, and will promote understanding of geological evolution at a regional scale.

For example, Lu–Hf analyses have been employed to evaluate the tectonic evolution of part of the Arunta Orogen. Based on the apparent absence of inherited zircons of appropriate age, the Warumpi Complex of the Arunta Orogen has been interpreted as exotic to the North Australian Craton (NAC), and the c. 1690 to 1670 Ma Argilke magmatic event has been attributed to an outboard magmatic arc. However, new Hf isotopic data indicate that crustal residence ages of Argilke intrusions are similar to those in the Aileron Province of the NAC, and also extend to more juvenile values. This may be more compatible with northward subduction along the southern Aileron Province margin or the incorporation of Aileron sediments in Argilke magmas. The absence of zircon inheritance can be explained by zirconium undersaturation, thermal reworking, or sampling bias.

Acknowledgement

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