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Using zircon geochemistry to map alteration in the Gawler Craton, South Australia

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SUMMARY

Zircon is a refractory mineral that is able to crystallize within hydrothermal, igneous and metamorphic environments, resulting in extreme variability in its external morphology, internal textures and chemistry. The chemistry of zircon is sensitive to its source rock type and crystallisation environment. Zircon has a tendency to incorporate a range of minor and trace elements, largely determined by its crystal structure and changes in temperature, pressure and composition. Internal textures of zircon can be used to indicate the type of crystallisation environment, as well as the environment(s) to which it was subjected following crystallisation. Given the complexity of zircon textures and the uncertainty associated with interpreting isotopic ages, trace element analysis is becoming widely applied as another line of evidence for more confident petrogenic interpretation.

Here we present geochemical and morphological data from zircon from the Gawler Craton, South Australia. This area preserves a complex geological history dating back to the late Archean and preserves multiple igneous units that each have their own unique geochemical characteristics and are associated with iron oxide-copper-gold mineralisation. We show that zircon will preserve chemistry reflective of its host rock, and possibly of alteration associated with mineralisation.

Key words: Zircon, Geochemistry, Gawler Craton

INTRODUCTION

Zircon is often used to study petrogenesis and evolution of rocks, due to its robustness during surficial, metamorphic and igneous processes, as well as its affinity for REE, U and Th. More recently research has shifted towards understanding and characterising the geochemical composition of zircon as it has a large impact on trace and rare earth element budget seen in whole rock geochemical data (Hoskin & Schaltegger 2003). This has been met with many challenges as REE and trace element compositions can be highly variable in zircon from within the same lithological unit. On a smaller scale, zircon composition can vary within a single grain, which is often attributed to micro inclusions, metamictisation, strong differences in compositional zoning and recrystallisation of zircon. Despite this, zircon has successfully been used to discriminate between igneous, metamorphic and sedimentary source rocks, although zircon from granitoids in general are often more difficult to distinguish from each other (Belousova *et al.* 2002).

The Gawler Craton, South Australia preserves multiple igneous events that each have their own unique geochemical signatures. Within the region, zircon is commonly used for dating or isotopic purposes however limited research has focused the geochemistry of zircon and how it may vary across different stratigraphic units. In this study, new zircon geochemical data has been collected from samples from the Sleaford Complex, Donington Suite, St Peter Suite, Gawler Range Volcanics and Hiltaba Suite. The morphology and geochemical composition of zircon from each suite has then been assessed and used to discriminate between igneous units.

GEOLOGCAL SETTING

Figure 1. Simplified geological map of the Gawler Craton displaying the distribution of the Sleaford Complex, Donington Suite, St Peter Suite, Gawler Range Volcanics and Hiltaba Suite, sample locations and key mineral deposits within the region.

The Gawler Craton preserves a complex geological history spanning from the Archean to the early Mesoproterozoic, and preserves evidence of multiple deformation, magmatism and mineralisation events (e.g. Hand *et al.* 2007; Reid *et al.* 2008). Mesoarchean granitoids of the Cooyerdoo Granite emplaced between ca. 3200-3150 Ma are the oldest rock units within the Gawler Craton (Fraser *et al*. 2010; Reid & Hand 2012), and are overlain by Neoarchean to early Paleoproterozoic units, known as the Sleaford Complex and Mulgathing Complex (Fraser *et al.* 2010; Reid & Hand, 2012). These complexes formed during a period of basin development, bimodal magmatism and sedimentation and are exposed in two belts in the southern and central western Gawler Craton. Basin development in the region was terminated during the ca 2480-2420 Ma Sleafordian Orogeny that resulted in deformation and metamorphism of the Archean part of the Gawler Craton (Daly & Fanning, 1993; Daly *et al.* 1998; Reid & Hand, 2012). Localised magmatism and widespread sedimentation occurred until the onset of rift-basin formation (Szpunar *et al.* 2011). This was interrupted by the emplacement of the ca. 1850 Ma Donington Suite in the eastern Gawler Craton, during compressional deformation associated with the Cornian Orogeny (Reid *et al.* 2008) Subsequent bimodal magmatsim and widespread sedimentation, which included the 1760-1740 Ma Wallaroo Group (Cowley *et al.* 2003), was terminated by ca. 1730-1690 Ma Kimban Orogeny, that resulted in low- to high-grade metamorphism together with magmatism (Dutch *et al.* 2008; Ferris *et al.* 2002; Hand *et al.* 2007; Hoek & Schaefer, 1998). This was followed by period of widespread crustal melting and intense magmatism as a result of juvenile mantle input, and includes the ca. 1640-1608 Ma St Peter Suite, ca. 1592 Ma Gawler Range Volcanics and the ca. 1595-1575 Ma Hiltaba Suite (Creaser & Cooper, 1993; Daly *et al.* 1998; Fanning *et al.* 1988; Reid & Hand 2012; Swain *et al.* 2008; Symington *et al.* 2014; Teasdale, 1997). Further deformation across the Gawler Craton occurred during the ca 1570-1540 Ma Kararan Orogeny and ca 1470–1450 Coorabie Orogeny (Hand *et al.* 2007).

METHODS AND RESULTS

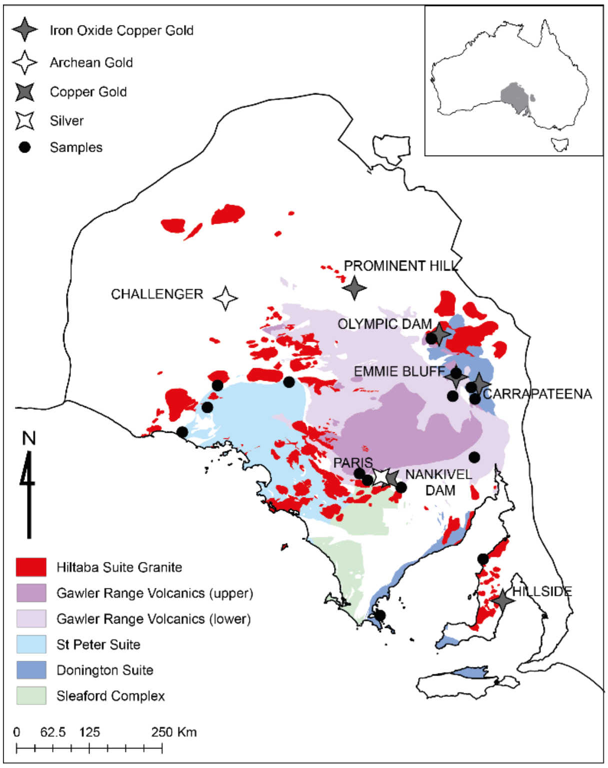
Sample Selection & Preparation

Where possible, mounted zircon samples from the Geological Survey of South Australia (GSSA) that have been used for dating and Lu-Hf isotopes were used in this study. These were complemented by new samples collected from open file drill cores held at the South Australia Drill Core Reference Library, Tonsley. Zircon were extracted from drill core samples using panning and magnetic separation techniques at the University of South Australia. Representative grains were handpicked under a microscope and mounted in epoxy resin discs, then polished to approximately half-grain thickness and coated with carbon.

Whole-rock geochemical data was collected for all samples. Where possible, whole-rock geochemical data of was taken from the online South Australian Resources Information Geoserver (SARIG) for the representative zircon mount sample obtained from the drill cores. For the remaining samples, whole rock geochemical analysis was undertaken at Bureau Veritas, Wingfield using standard preparation methods (https://www.bureauveritas.com.au/).

Zircon Morphology

Internal structures of zircon were imaged under cathodoluminescence (CL) on the MLA Quanta SEM 600 at Adelaide Microscopy. Zircon morphology is reflective of the chemical variation of the evolving residual melt, where the



zoning is representative of growth rates and compositional variation of Zr, Si, Hf, P, Y, U, Th and rare earth elements (e.g. Corfu *et al.* 2003; Rayner *et al.* 2005; Samperton *et al.* 2017). Zircon from igneous units display a variation in zoning. The Sleaford Complex, Donington Suite and Gawler Range Volcanics are typically oscillatory to broadly zoned with little disruption. The St Peter Suite and Hiltaba suite preserve more complex textures and have recrystallised hotter rims, thought to be the result of magma injection post crystallisation.

Zircon Geochemistry

Laser Ablation Inductively Coupled Mass Spectrometer (LA–ICP-MS) data was collected at Adelaide microscopy, the University of Adelaide using the Agilent 7900 ICP-MS with attached RESOluton LR Excimer Laser. Two shots were fired prior to each analysis in order to remove surface contamination. The analytical parameters include a spot size of 19 µm, and a 2.1 J/cm2 influence. Mass bias and instrumental drift were corrected using the standard sample-standard bracketing procedure, including a block of international glass (NIST 610) and GJ-1 zircon standards run every 20 unknown analyses. Data processing was conducted using the Trace_Element_IS data reduction scheme in the Iolite software (Paton *et al.* 2011), with Zr as an internal standard and NIST 610 glass standard used to calculate elemental concentrations. Zr was used over Si as the internal standard as there is less fractionation/bias however, it was assumed that samples contained 49.7 wt% Zr. The resulting compositions are within 15 % accuracy of the published trace element data for GJ-1 zircon standard, with the exceptions of La and Pb. The CPS signal and geochemistry of each grains was further analysed to remove grains with potential inclusions. Grains with a disrupted CPS signals representing inclusions were removed along with samples with anomalously high Al, Cu, Fe and Au (in the thousands cps). Few samples with moderately-high Al, Cu and Fe contents, however, have been left in the sample set as there is no disruption in the Zirconium, Silicon, Thorium and Uranium CPS signals, and it is believed these elements are enriched/substituted within the zircon lattice.

Zircon geochemistry can vary as a result of compositional zoning, micro inclusions, metamictisation and alteration. Trace and rare earth elements are used to discriminate between igneous units, and samples that vary in alteration. The Sleaford Complex is enriched in REE (Ce, Pr, Nd, Sm, Gd, Tb), Mn, U, Hf, and depleted in Ho, Er, Tm, Yb, Lu, Th, Nb and Ta relative to other igneous units. The Donington Suite is characteristically enriched in P, and depleted in Nb, Ta, Ce, Pr, Nd, Sm, Gd, Tb. The St Peter Suite and Gawler Range Volcanics do not have many characteristic geochemical signatures, however, the Hiltaba Suite is characterised by enrichment of Nb, Ta, Th, U, and depletion in P.

CONCLUSIONS

Despite the difficulties in discriminating between igneous units, zircon from igneous units in the Gawler Craton display characteristic trace and REE chemistry, as a result of different fluid/magma chemistry, crystallisation environment and temperature. Further work into how the geochemistry changes in different types of alteration associated to mineralisation needs to be undertaken to be able to use this information to aid in provenance studies and exploration.

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