Thermochronological history of the northern Olympic Domain of the Gawler Craton; correlations between cooling ages and mineralising systems

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SUMMARY

The Olympic Domain of the Gawler Craton is home to the world class Olympic Dam Iron Oxide Copper Gold (IOCG) mineral deposit in addition to numerous other IOCG mineral deposits. The Olympic Domain preserves a complex geological history that began in the Palaeoproterozoic. However, most published work conducted on these IOCG deposits have focused on their initial formation, with only a few studies investigating the post-formation thermal history of the Olympic Domain. This study uses multi-method thermochronology by combining apatite U/Pb, muscovite and potassium feldspar $^{40}Ar/^{39}Ar$, zircon and apatite (U-Th-Sm)/He, and apatite fission track (AFT) dating to provide insights into the thermal history of the northern Olympic Domain between ~550°C and surface temperatures. Apatite U/Pb and muscovite $^{40}Ar/^{39}Ar$ record post magmatic cooling of the ~1850 Ma Donington Suite, and ~1590 Ma Hiltaba Suite. Potassium feldspar $^{40}Ar/^{39}Ar$ analyses record a cooling signal that is likely related to rifting in the Neoproterozoic Adelaide Rift Complex. A combination of AFT, and zircon and apatite (U-Th-Sm)/He dating preserves three thermal periods, at ~1000 Ma, ~430-400 Ma and ~200 Ma. The older two thermal periods are interpreted to be regional cooling. However, the youngest ages are preserved closest to known IOCG deposits suggesting that they reflect cooling of this elevated geothermal-gradient crust in the Mesozoic. These results have been modelled to produce a thermal history map of the northern Olympic Domain.

Key words: Olympic Dam, apatite fission track, Olympic Domain, Gawler Craton, apatite U/Pb, thermochronology.

INTRODUCTION

The Olympic Domain is home to the world class Iron-Oxide-Copper-Gold (IOCG) mineral deposit Olympic Dam, in addition to numerous other IOCG mineral deposits (indicated by stars in Fig 1). The Olympic Domain preserves a complex geological history that began in the Palaeoproterozoic (Hand, et al. 2007). The ~1590 Ma Hiltaba Event is the most notable event within the Olympic Domain (Daly, et al. 1998, Hand, et al. 2007), which produced the host rocks for the IOCG deposits. Published work conducted on these IOCG deposits have investigated the various aspects of their formation (Belperio, et al. 2007, Davidson, et al. 2007, Direen and Lyons 2007, Jagodzinski 2014, Kamenetsky, et al. 2016, Kirchenbaur, et al. 2016, Macmillan, et al. 2016, McPhie, et al. 2011, Skirrow, et al. 2007). However, few studies have ventured into the post-Hiltaba thermal history of the Olympic Domain (Reid et al., 2017). Additionally, recent studies have highlighted that Ordovician hydrothermal activity remobilised uranium within the Olympic Dam deposit (Kamenetsky, et al. 2016, Maas, et al. 2011, McPhie, et al. 2011), therefore, greater understanding of the thermal history of the Olympic Domain is imperative to understand and potentially explore for IOCG deposits.

This study combines multiple thermochronological methods (apatite U/Pb, muscovite and potassium feldspar $^{40}Ar/^{39}Ar$, zircon and apatite (U-Th-Sm)/He, and apatite fission track dating) to determine the thermal history of the northern Olympic Domain between ~550 °C and surface temperatures. Apatite U/Pb and muscovite $^{40}Ar/^{39}Ar$ record post magmatic cooling of the Donington and Hiltaba suites. Feldspar $^{40}Ar/^{39}Ar$ data preserves heating during the deposition of the Neoproterozoic Adelaide Rift Complex. Apatite fission track and (U-Th-Sm)/He dating preserves three thermal periods, at ~1000 Ma, ~430 – 400 Ma and ~200 Ma.

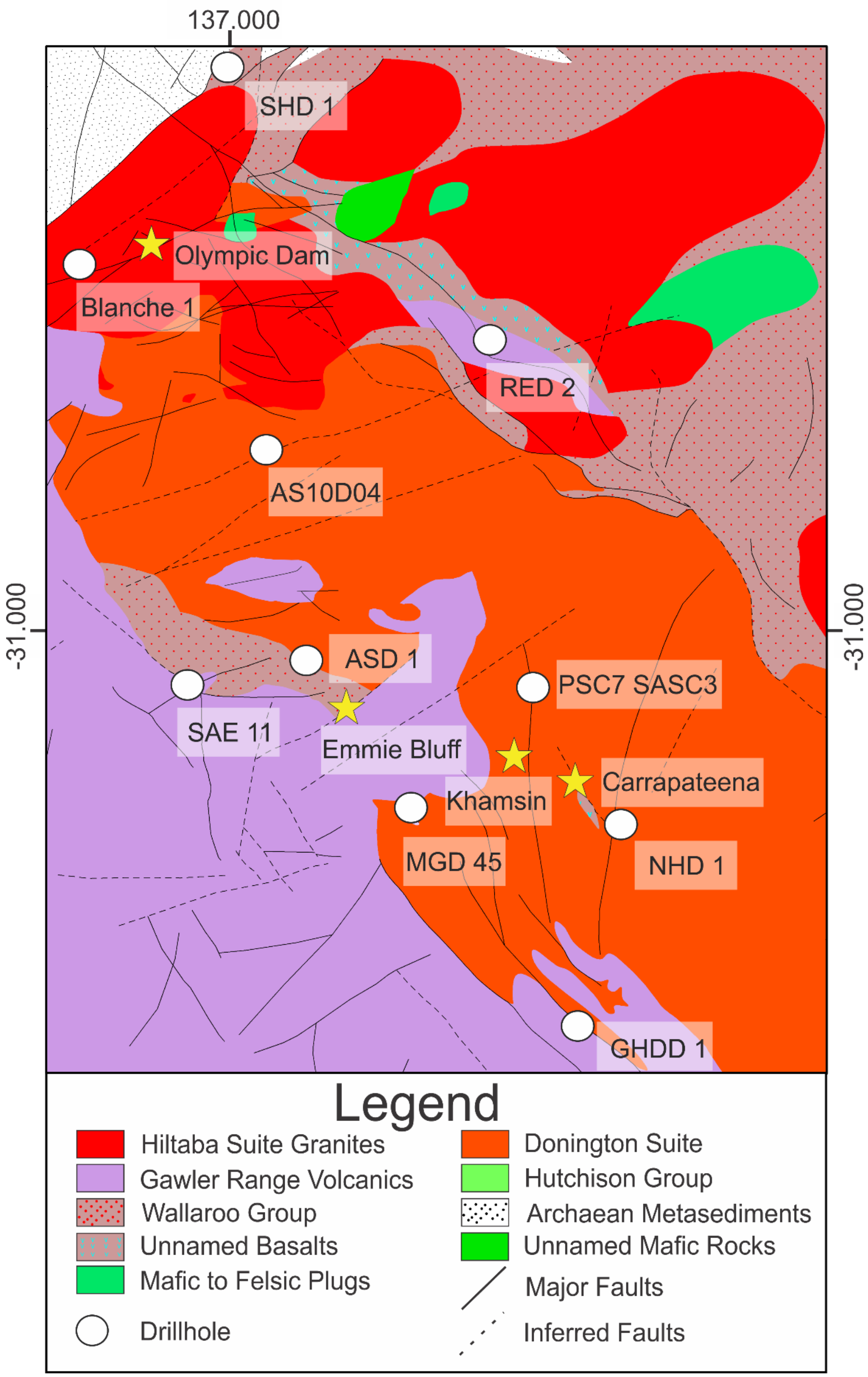

Figure 1: Interpreted solid geology map of the northern Olympic Domain indicating the locations of major IOCG deposits, and sampled drill holes. Adapted from Wise, et al. (2015).

METHODS

Apatite U/Pb and apatite fission track dating

Samples were crushed and the apatites were separated and mounted using conventional methods. the apatite mounts were etched in a 5M HNO^3 solution for 20 seconds at 20 ⁰ C to reveal the spontaneous fission tracks. Uranium, lead, thorium, and chlorine, concentrations were collected using a Laser-Ablation Inductively-Coupled-Plasma Mass-Spectrometer (LA-ICP-MS) at Adelaide Microscopy. Data reduction was conducted using *Iolite* (Paton, et al. 2011). Apatite fission track imaging and automatic counting was performed using *Track Works* and *Fast Tracks* on a *Zeiss AX10* microscope (Gleadow, et al. 2009). Data reduction was carried out following Glorie, et al. (2017). NIST glasses (Pearce, et al. 1997) and Madagascar apatite (Thomson, et al. 2012) were used as primary standards, and Durango (McDowell, et al. 2005) and Mount McClure (Thomson, et al. 2012) apatites were used as secondary standards. Further details on the applied data reduction can be found in Chew, et al. (2014), Gillespie, et al. (2017) and Glorie, et al. (2017).

$^{40}Ar/^{39}Ar$ dating

Potassium feldspar and muscovite separates were analysed at Curtin University. Full methods for both potassium feldspar and muscovite $^{40}Ar/^{39}Ar$ are reported in Schmieder, et al. (2014) and McGee, et al. (2015). Mineral separates were irradiated and analysed on a 110 W Spectron Laser System, with a continuous-wave Nd-YAG laser. Data processing was conducted using the *ArArCALC* software (Koppers 2002).

(U-Th-Sm)/He analysis

Four zircon separates and one apatite separate were selected and analysed at the John De Laeter Centre at Curtin University. The full analytical procedure is reported by Danišík, et al. (2012). Individual grains were separated into Pt (for apatite) and Nb (for zircon) tubes, and degassed at ~960°C (for apatite) and ~1250 °C (for zircon). Each sample was digested in acid before the concentrations of ^4He, U, Th and Sm were recorded by a mass spectrometer.

RESULTS

The apatite U/Pb ages record cooling from two igneous suites, the older ~1850 Ma Donington Suite in the south and the younger ~1590 Ma Hiltaba Suite and Gawler Range Volcanics (GRV) in the north. Samples from the Donington Suite record two different times for cooling, at around 1850 – 1800 Ma and ~1640 Ma. The Hiltaba Suite/GRV samples record cooling at ~1560 – 1520 Ma. Three samples yielded $^{40}Ar/^{39}Ar$ data, the muscovite $^{40}Ar/^{39}Ar$ age recorded an age plateau at 1533 ± 8 Ma. All potassium feldspar $^{40}Ar/^{39}Ar$ ages are recorded between 1000 – 650 Ma. Four apatite fission track age populations were recorded in the study region; ~1000 Ma, ~440 Ma, ~250 Ma, and ~150 Ma. The ~1020 Ma population is only recorded in two samples. All samples preserve Palaeozoic cooling, with 76% of the data falling within the two Palaeozoic age populations of 438.9 ± 9.8 Ma and 272.6 ± 8.9 Ma. The youngest age population is recorded at ~150 Ma and is dominated by high U analyses and analyses from a sample located in close proximity to Olympic Dam.

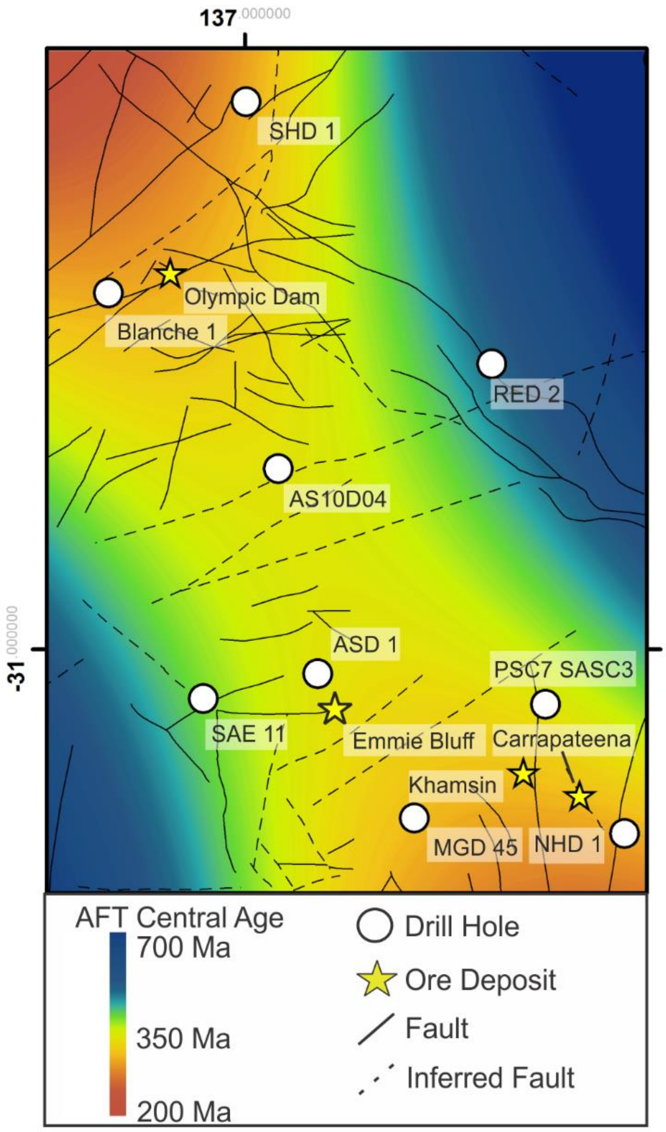

Figure 2: A modelled interpretation of the apatite fission track central ages. Where blue indicates older ages and red indicates younger ages. Drill holes and IOCG deposit locations are indicated in addition to major interpreted faults.

CONCLUSIONS

Multi-method thermochronology applied to samples from the Olympic Domain reveal multiple thermal events. Apatite U/Pb and muscovite $^{40}Ar/^{39}Ar$ thermochronology records post magmatic cooling of the Donington and Hiltaba suites, and the Gawler Range Volcanics. Apatite fission track and potassium feldspar $^{40}Ar/^{39}Ar$ data record Neoproterozoic ages, interpreted as a ~1000 Ma cooling event, and thermal activity relating to deposition of the Adelaide Rift Complex. Cooling relating to the Alice Springs Orogeny is preserved at around 430 – 400 Ma and 350 – 330 Ma. Regional Jurassic thermal activity cooled the region to near surface temperatures. A sample located near Olympic Dam preserves a Cretaceous thermal event, which is interpreted to be a result of localised hydrothermal activity in the Olympic Dam region.

ACKNOWLEDGMENTS

Christopher Trenouth is thanked for his assistance in apatite fission track data collection. Bradley McDonald (John De Laeter Center at Curtin University) and Ben Wade (Adelaide Microscopy) are thanked for their assistance with the U–Th–Sm/He methods and the use of the LA-ICP-MS respectively.

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