National Argon Map: an AuScope initiative

Data Acquisition Project Proposal

Project Proponent

Name: Brendan Hardwick
Affiliation and position: Senior Geologist, AngloGold Ashanti (AGA)
Collaborators: Jack Muston (ANU), Sarah Dixon (AGA)
Project Title: $^{40}Ar/^{39}Ar$ thermochronology for Intrusion Related Gold Systems in NE Queensland
Geographic Region: Far North Queensland
Geological Province or Tectonic Unit: Charters Towers Terrane, Etheridge Terrane

How will these samples benefit the National Argon Map?

This proposal seeks to analyse K-feldspar – mica pairs from intrusions related gold (IRG) systems in northeast Queensland using $^{40}Ar/^{39}Ar$ radiometric dating method. The aim of this project is to gain further understanding of the timing and emplacement of mineralisation, crustal exhumation rates and magma emplacement paleodepths of the IRG systems. The proposed sample locations occur in the Charters Towers and Etheridge terranes of northeast Queensland where there is minimal $^{40}Ar/^{39}Ar$ geochronological data coverage in the National Argon Map database (Figure 1). It is proposed to attain 8 new $^{40}Ar/^{39}Ar$ samples from these mineral systems which will fill a significant geographic and knowledge gaps within this region, whilst also providing robust geochronological constraints on an important mineralisation style in northeast Queensland. It is envisioned this study will lead to further collection of samples in the Charters Towers and Etheridge terranes, further expanding the coverage of $^{40}Ar/^{39}Ar$ samples within those regions.

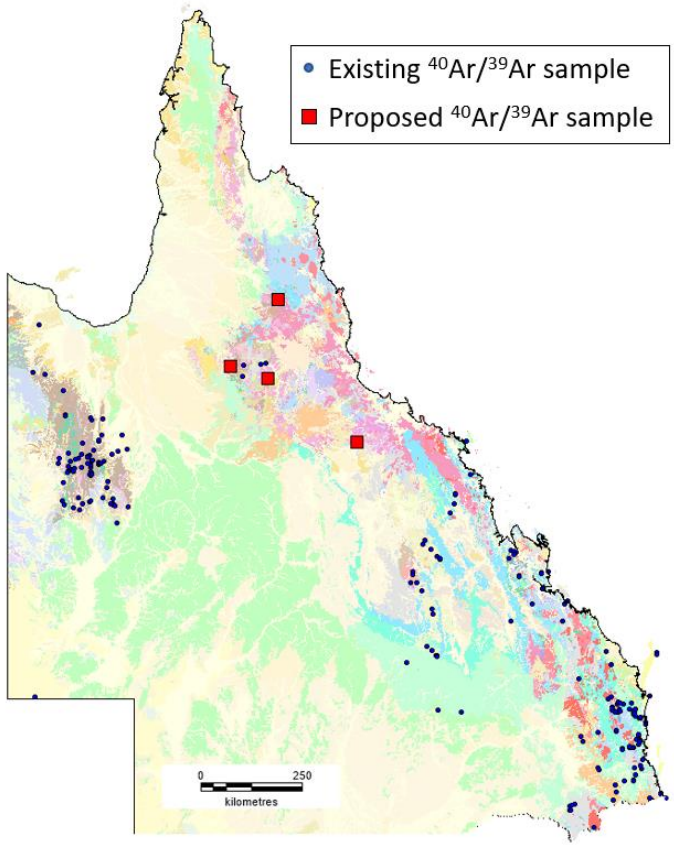

Figure 1. Proposed sample locations with existing $^{40}Ar/^{39}Ar$ samples.

Brief Project Description:

This project attempts to improve the understanding of IRG systems through $^{40}Ar/^{39}Ar$ isotope analysis of K-feldspar-mica pairs from the Kidston Gold Mine, Mt Leyshon Gold Mine, Mungana Gold Mine and the Mt Clark Gold Prospect in northeast Queensland. Mineralisation in these systems has formed by magmatic-hydrothermal processes and typically occurs within large breccia pipes (> 1km diameter) in the cupola to late Paleozoic felsic porphyritic intrusions (Morrison, 2017). The Mt Clark prospect is a large breccia complex that shares features to the IRG deposits (i.e. >1km^2 breccia complex, phyllic alteration, base metal mineralisation) however economic gold mineralisation has not yet been identified. This project will attempt to gain further understanding of these mineral systems by investigating the following:

1. Timing of emplacement and mineralisation

This study proposes to compliment the existing geochronological record for IRG systems in north Queensland (Table 1). Utilisation of $^{40}Ar/^{39}Ar$ thermochronology method on K-feldspar-mica pairs will provide a continuous temperature-time history that includes both high and low temperatures respectively. K-feldspar has been shown to retain argon at higher temperatures (~500-700°C) (Forster et al, 2015) and can therefore enable a detailed thermal history model of the igneous intrusions, starting from the time at which potassium feldspar grew or was recrystallised during metasomatic events. Using the K-feldspar-mica pairs will complement the existing geochronological database and allow distinction of any younger metasomatic events from magmatic crystallisation ages, thus building a comprehensive history for magma emplacement and subsequent mineralisation.

2. Crustal exhumation rates

The IRG systems occur within districts where high level rhyolite complexes are juxtaposed by contemporaneous, deep seated but thereafter exhumed granite batholiths (Withnell & Cranfield, 2013 and references therein). Juxtaposition of contrasting lithofacies can be explained by rapid crustal exhumation. Modelling the time-temperature pathway of the IRG systems will provide a quantitative measure to determine exhumation rates occurring in the crust at the time of mineralisation.

3. Magma emplacement paleodepth

The IRG systems have limited vertical extent and estimates on emplacement paleodepth are poorly constrained. Defining the vertical limits of emplacement and mineralisation is critical to selection of prospective districts to explore for economic mineralisation. Modelling the time-temperature thermal history of these mineral systems will provide a proxy for depth of emplacement in the upper crustal environment and will be used to determine vertical limits of extent.

Deposit	Rock	Mineral	Assemblage	Age	Method	Reference
Kidston	Median dyke	Zircon	Magmatic	334.7 ± 3.3 Ma	Pb/U	Perkins and Kennedy,1998
Kidston	K-rich andesite dyke	Zircon	Magmatic	332.4 ± 2.4 Ma	Pb/U	Perkins and Kennedy, 1998
Kidston	Cavity Infill	Sericite	Hydrothermal	332.5 ± 0.8 Ma	Ar-Ar	Perkins and Kennedy, 1998
Mt Leyshon	Phyllic alteration	Sericite	Hydrothermal	283 ± 4 Ma	K-Ar	Blevin and Morrison, 1997
Mt Leyshon	Granodiorite	Zircon	Magmatic	287.4 ± 3.6 Ma	Pb/U	Blevin and Morrison, 1997
Mt Leyshon	Mineralisation	Galena	Hydrothermal	280 Ma	Pb/PB	Carr et al., 1988
Mt Leyshon	Mineralisation	Sericite	Hydrothermal (?)	296 ± 2 Ma	Ar-Ar	Perkins and Kennedy, 1998
Mungana	Porphyry	Zircon	Magmatic	317.3 ± 2.3 Ma	Pb/U	Georgees, 2007
Mungana	Granite	Molybdenite	Magmatic	307.1 ± 2.5 Ma	Re-Os	Georgees, 2007
Mungana	Rhyolite Porphyry	Zircon	Magmatic	324 ± 2 Ma	Pb/U	Lehrmann, 2012
Mungana	Skarn	Molybdenite	Hydrothermal	335 ± 2 Ma	Re-Os	Lehrmann, 2012

Table 1. Existing geochronological data for intrusion related gold systems in Queensland.

A total of 8 samples will be taken from historic drill core from each of the mineralised systems. Diamond drill core for Kidston, Mt Leyshon and Mungana Gold Mines are currently stored at the Geological Survey of Queensland's Exploration Data Centre in Brisbane, while core for the Mt Clark prospect is currently stored at AGA's storage facility in Townsville. For each location, fit for purpose samples will be selected for separation of pristine K-feldspar and/or biotite from the magmatic assemblage and mica (white mica and/or biotite) from the hydrothermal assemblage. The age and temperature data provided by the proposed $^{40}Ar/^{39}Ar$ step-heating experiments will be used in conjunction with existing geochronological data where they exist. This has been shown to be an effective method in unravelling tectonothermal events in other regions of the world (Forster et al, 2015, 2019, 2020; Li et al, 2007).

References

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Li, Z. X., Wartho, J., Occhipinti, S., Zhang, C., Li, X., Wang, J., Bao, C., 2007. Early history of the eastern Sibao Orogen (South China) during the assembly of Rodinia: New mica $^{40}Ar/^{39}Ar$ dating and SHRIMP U–Pb detrital zircon provenance constraints. *Precambrian Research*. 159:1/2. 79-94.

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Perkins, C. & Kennedy, A.K. 1998. Permo-Carboniferous gold epoch of northeast Queensland. Australian Journal of northeast Queensland. Vol 45, pp 185-200.

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Approximate number of samples proposed for $^{40}Ar/^{39}Ar$ analyses:

We propose 8 fit for purpose samples from the Kidston Gold Mine, Mt Leyshon Gold Mine, Mungana Gold Mine and the Mt Clark Gold Prospect in northeast Queensland (2 samples from each work area). Each location will have a K-feldspar - mica pair to constrain timing and model exhumation rates. Sample collection will depend on travel from Western Australia to Queensland which is currently the subject of border restrictions due to Covid-19.

Lithologies and minerals proposed for $^{40}Ar/^{39}Ar$ analyses:

It is proposed to sample pristine magmatic K-feldspar from magmatic suites regarded to be the causative intrusion to mineralisation. This will be supplemented by collection of mica (either white mica or biotite) from the hydrothermal alteration assemblage which hosts mineralisation.

Do you have a preferred $^{40}Ar/^{39}Ar$ laboratory? (ANU, Curtin, UQ, UMelb):

ANU is required for $^{40}Ar/^{39}Ar$ laboratory due to the ongoing relationship and the detailed nature of the step-heating analysis needed for temperature-time forward modelling.

Guidelines and Criteria

Project Proposals for funding support as part of the AuScope National Argon Map initiative will be assessed on the following criteria.

Australian: Samples must come from Australia (this may include Australian offshore regions)
Non-confidential: $^{40}Ar/^{39}Ar$ data must be made publicly-available (ie non-confidential)
Impact: to what extent new $^{40}Ar/^{39}Ar$ data from the proposed samples will contribute to geographic data coverage, or address key geological questions
Feasibility: whether the nature of the work is tractable via $^{40}Ar/^{39}Ar$ geochronology and the scale of the proposal is realistic within the time frame of the National Argon Map initiative (January 2020 – June 2021)?
Appropriate sample material: whether the proposed samples are (i) appropriate for $^{40}Ar/^{39}Ar$ analyses, and (ii) available within the time-frames of the National Argon Map initiative?

Oversight Panel

Dr Geoff Fraser, Geoscience Australia
Professor Zheng-Xiang Li,
Dr Anthony Reid, Geological Survey of South Australia
Peter Rea, MIM/Glencore
Dr Catherine Spaggiari, Geological Survey of Western Australia
Dr David Giles, MinEx CRC
Dr Marnie Forster (observer role as Project Coordinator)

Expectations

AuScope funding will cover the costs of sample irradiation and isotopic analyses.

Project Proponents will be responsible for:

- Provision of appropriate sample material. This includes mineral separation, which can be arranged at the relevant $^{40}Ar/^{39}Ar$ laboratories (in many cases this is preferred), but costs of mineral separation will be borne by the project proponent. The relevant laboratory reserves the right not to analyse material if it is deemed unsuitable for $^{40}Ar/^{39}Ar$ analysis.
- Provision of appropriate sample information. A sample submission template will be provided. Information in these sample submission sheets will form the basis of data delivery/publication, and the oversight committee or relevant laboratory reserves the right not to proceed with analyses unless and until appropriate sample details are provided. This includes description and geological context for each sample.
- Leading the preparation of reports and/or publications to deliver $^{40}Ar/^{39}Ar$ results into the public domain within the duration of the National Argon Map initiative (January 2020 – June 2021).
- Project Proponents will be expected to communicate directly with the relevant $^{40}Ar/^{39}Ar$ laboratory once a project has been accepted by the Oversight Committee, in order to clarify project expectations, arrange sample delivery, discuss results, collaborate on reporting and data delivery etc.

Participating Ar Laboratories will be responsible for:

- Providing advice to project proponents regarding suitable sample material and feasibility of proposed work
- Irradiation of sample material
- $^{40}Ar/^{39}Ar$ isotopic analyses
- Delivery of data tables, and analytical metadata to project proponents

Queries regarding possible projects as part of the National Argon Map initiative can be directed to Marnie Forster (Marnie.Forster@anu.edu.au) or Geoff Fraser (Geoff.Fraser@ga.gov.au)