National Argon Map: an AuScope initiative
Data Acquisition Project Proposal

This form should be completed and returned to Geoff Fraser (Geoff.Fraser@ga.gov.au) for consideration by the National Argon Map Oversight Panel

Project Proponent

Name: Solomon Jones
Affiliation and position: PhD Student in the Structure Tectonics Team (ANU)
Collaborators: Cees Swager (AngloGold Ashanti), Brendan Hardwick (AngloGold Ashanti)
Project Title: Thermochronological Constraints on Crustal-Scale Shear Zones
Geographic Region: North Queensland
Geological Province or Tectonic Unit: Hodgkinson Province\ Barnard Province

How will these samples benefit the National Argon Map?

Timing of extensive deformation and shearing within the Hodgkinson province of Queensland is inadequately constrained. Extant records of U-Pb zircon geochronology for the proposed samples either date the high temperature magmatic stage of granite emplacement, or in the case of the Barnard metamorphics, detrital grains. These provide only an estimate of the maximum age and do not constrain later metamorphism, exhumation, or deformation. The proposed method of Argon geochronology has the capacity to date recrystallisation events in shear zones and constrain the thermal evolution of K-feldspar bearing rock units. This project is focused on a geological province that currently has no $^{40}Ar/^{39}Ar$ sample entries in the NAM and will thus contribute to the objectives of the National Argon Map initiative.

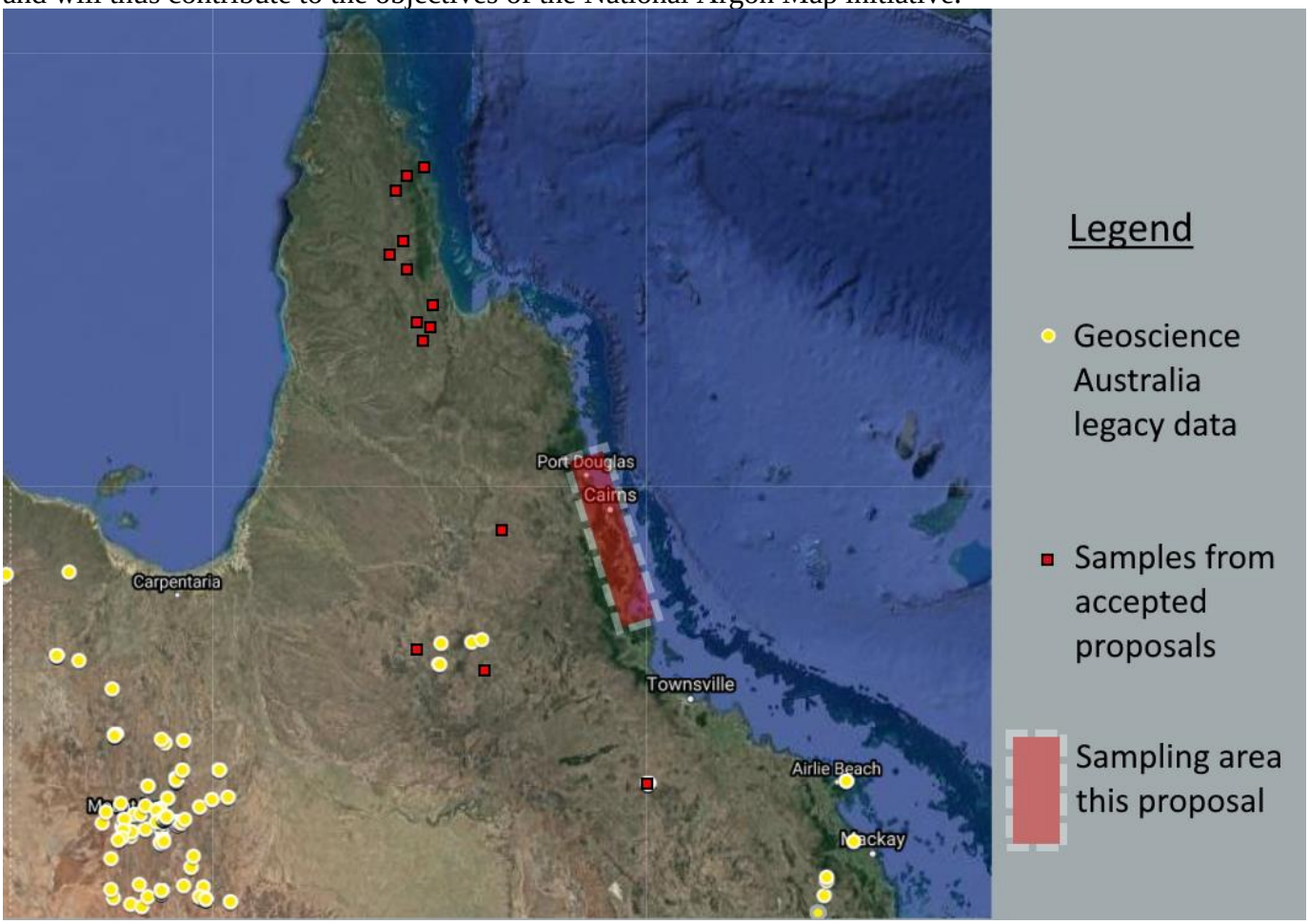


Figure 1: National Argon Map Coverage in North Queensland.
The proposed sampling area in the Hodgkinson and Barnard geological provinces is indicated by the transparent red rectangle. Intended sampling complements other approved AuScope sampling in the Charters Towers and Ethridge provinces, and Coen inlier by extending scope to the Late Paleozoic - Early Mesozoic deformation of the Hodgkinson province. See **Figure 2** for intended sample sites.

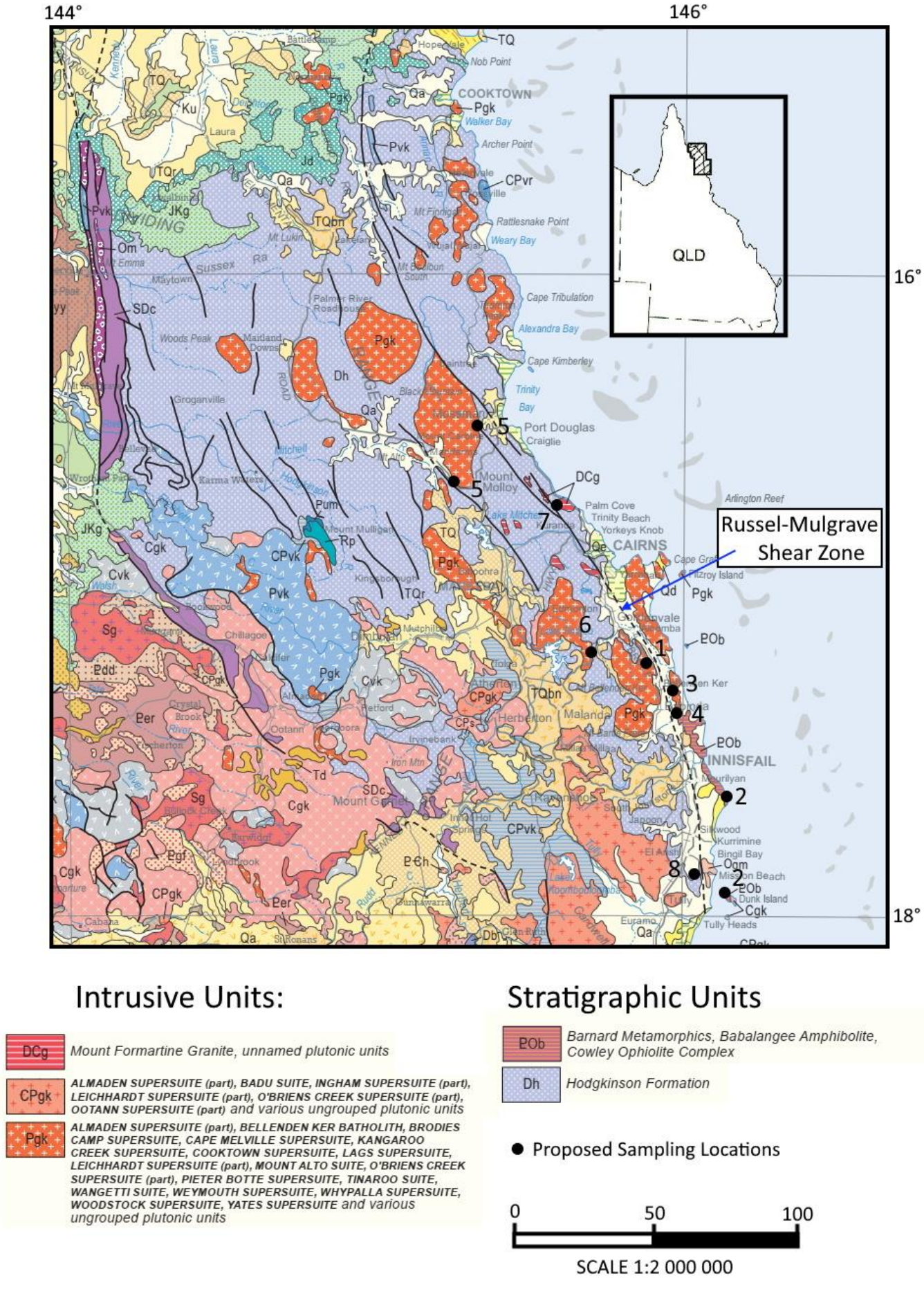
Brief Project Description:
This project would take place within a current PhD project involving the collaboration between the Australian National University (ANU) and AngloGold Ashanti (AGA) to investigate the tectonic architecture of northeast Queensland. The project aims to constrain movement on long lived crustal structures throughout the region, most of which have received little attention, and which are poorly constrained in time. This will be achieved by utilising $^{40}Ar/^{39}Ar$ geochronology and thermochronology on key fit for purpose minerals.
The proposed samples from the Hodgkinson province and Barnard metamorphics have been selected to constrain timing of province-scale shearing following the intrusion of the Kennedy Igneous Association at the late Palaeozoic - early Mesozoic margin of the Australian continental plate. East of the Palmerville fault, within the Hodgkinson province, northwest-southeast oriented en-echelon faults juxtapose or bound granitoids of the Kennedy Igneous Association. The geodynamic environment of these intrusions is not well understood, and further work is required to determine their provenance (Mackenzie and Wellman, 1997). Zircon U-Pb dating constrains the emplacement of these intrusions to the Carboniferous and Permian, however evidence exists for shearing, and potential exhumation and metasomatism at their margins (Champion and Bultitude, 2013).

The Russel-Mulgrave shear zone is a structure of interest because it represents a major discontinuity between the Barnard and Hodgkinson provinces (Bultitude and Champion, 2013). Little appears to be known about the timing or duration of shear zone activation, apart from the upper limit placed by the intrusive bodies that are sheared by the zone in the corridor between Tully and Port Douglas. Reported information on suggested samples 1,3,4,5, and 7 indicate localised evidence for recrystallisation and fluid alteration such as mylonitic fabrics or strong localised foliation. This indicates that temperature-time histories for shear zone activation may be recovered using $^{40}Ar/^{39}Ar$ geochronology. This is possible either through the analysis of relict domains in K-feldspar that has been partially recrystallised, or the selection of recrystallised mica grains from zones of foliation, to date major deformation events. This requires thin section analysis to identify microstructural evidence for recrystallization, which will be conducted as part of the PhD project. In the event that k-feldspar has not been recrystallized by metasomatic events or shearing, thermal histories of the granites will still be of significant interest, as they may provide information on paleodepth of magma emplacement and exhumation rates. This information will contribute to a better understanding of the provenance of the Kennedy Igneous Association.

The Barnard province metamorphics were selected due to their proximity to the Russel-Mulgrave shear zone. It has been previously proposed that these high temperature metamorphics are an uplifted basement assemblage (Withnall and Cranfield, 2013); are the result of in-place Buchan style metamorphism of the Hodgkinson formation (De Keyser, 1965); or that they have been transported from the Charters-Towers province (Henderson et al,. 2011). Current U-Pb Zircon geochronology lists an age of 427.1 ± 5.5 Ma (Kositcin et al., 2015a), approximately 18 km north of Innisfail that probably represents a population of detrital grains. Approximately 35 km south of Innisfail, a proposed metamorphic zircon age of 451.8 ± 2.6 Ma (Kositcin et al., 2015b) is reported. A metamorphic age older than detrital grains suggests that the sampled units cannot have the same depositional history. K-feldspar bearing gneiss has been reported as part of the Barnard province metamorphics. The cooling history of this unit may help resolve the issue of provenance. Timing the movement of the Russel-Mulgrave shear zone may also provide evidence for or against the proposed transportation of this unit from the Charters Towers Province. Evidence for the tectonic process that would allow this to happen is currently limited.

This work complements existing approved proposals from Brendan Hardwick and Jack Muston which seek to constrain the timing and emplacement conditions of intrusive suites in the Charters Towers and Etheridge provinces, and the Coen inlier, respectively. This proposal would extend the scope of examination to the Hodgkinson province and allow for a wider regional synthesis of the tectonics of Late Palaeozoic – Early Mesozoic North Queensland. Proposed sample sites are indicated in **Fig. 2** below. Sample sites were selected using 1:100,000 scale maps available from the Queensland Government *GeoResGlobe* portal. Their approximate locations have been indicated on this larger scape map. Some sample numbers are listed twice, as several potential sampling sites are indicated. Sampling will take place as part of PhD field work scheduled for the first quarter of 2021, supported by AngloGold Ashanti. Current COVID-19 restrictions allow travel from the researcher's place of residence to Queensland.

Figure 2: Subset of GSQ 1:2000000 map with proposed sample locations. Only relevant units listed.



Intrusive Units:

DCg — *Mount Formartine Granite, unnamed plutonic units*

CPgk — ***ALMADEN SUPERSUITE (part), BADU SUITE, INGHAM SUPERSUITE (part), LEICHHARDT SUPERSUITE (part), O'BRIENS CREEK SUPERSUITE (part), OOTANN SUPERSUITE (part)*** *and various ungrouped plutonic units*

Pgk — ***ALMADEN SUPERSUITE (part), BELLENDEN KER BATHOLITH, BRODIES CAMP SUPERSUITE, CAPE MELVILLE SUPERSUITE, KANGAROO CREEK SUPERSUITE, COOKTOWN SUPERSUITE, LAGS SUPERSUITE, LEICHHARDT SUPERSUITE (part), MOUNT ALTO SUITE, O'BRIENS CREEK SUPERSUITE (part), PIETER BOTTE SUPERSUITE, TINAROO SUITE, WANGETTI SUITE, WEYMOUTH SUPERSUITE, WHYPALLA SUPERSUITE, WOODSTOCK SUPERSUITE, YATES SUPERSUITE*** *and various ungrouped plutonic units*

Stratigraphic Units

POb — *Barnard Metamorphics, Babalangee Amphibolite, Cowley Ophiolite Complex*

Dh — *Hodgkinson Formation*

● Proposed Sampling Locations

0 50 100

SCALE 1:2 000 000

This map is a subsection of 'Queensland Geology 1:2,000,000 scale map and structural framework 2012'
ISBN: 978-1-922067-03-6

Table 1: Proposed Samples

Nb. All geochronology listed from the Australian Stratigraphic Units Database unless otherwise noted.

Site #	Stratigraphic Unit	Current Geochronology	Lithology	Target Minerals	Sample Justification
1	Bellenden Ker Granite	280 ± 4 Ma * U-Pb Zircon	Porphyritic biotite granite	K-feldspar White Mica	Strongly sheared by the Russel-Mulgrave shear zone. Possibility for K-feldspar phenocrysts to preserve relict ages and recrystalised muscovite to date shear zone movement. Potential emplacement and deformation\exhumation history.
2	Barnard Metamorphics	427.1 ± 5.5 Ma 451.8 ± 2.6 Ma 484 ± 11 Ma U-Pb Zircon	Migmatitic biotite gneiss	K-feldspar White Mica	U-Pb ages likely date detrital zircons. Constraints on the timing of metamorphism and exhumation of this unit may indicate significantly younger tectonic events, or transport from another geological province. See main text.
3	Babalangee Amphibolite	642 Ma K-Ar 'extraneous argon' **	Amphibolite, locally altered with minor tourmaline	Tourmaline	Foliation and alteration in unit likely the result of the Russel-Mulgrave shear zone. A date for this unit will either provide a constraint on the Russel-Mulgrave shear zone or provide insight into the tectonic environment and record of accretion at this margin.
4	Mission Beach Granite Complex	463 ± 7 Ma 459 ± 8 Ma U-Pb Zircon	Biotite granite	White Mica or Biotite	Reported faulted contact with Hodgkinson formation, indicating localised deformation post emplacement. May be used to trace out the southern onshore extent of the Russel-Mulgrave shear zone.
5	Mount Carbine Granite	280 ± 7 Ma Rb-Sr	Porphyritic (muscovite-) biotite monzogranite	White Mica	Local deformation and shearing on the Eastern side of the unit likely to provide a constraint for the timing of the Daintree fault or associated shear zones further south.
6	Tinaroo Granite	~280 Ma Rb-Sr 'poorly constrained' 268 - 283 Ma K-Ar	Biotite granite	K-Feldspar White Mica	Tectonic contact with Hodgkinson low-grade metamorphics may indicate an exhumation via detachment faulting. Zones of well-developed foliation are reported at margin.
7	Mount Formartine Granite	357 ± 7 Ma U-Pb Zircon 247 ± 2 Ma K-Ar From analogous unit nearby believed to be a metamorphic age	Muscovite-biotite granite, localised mylonitic shearing	K-Feldspar White Mica	Mylonitic fabric believed to be significantly younger than Zircon U-Pb age. Analogous rocks dated in 1988 using K-Ar method suggest Jurassic deformation and metamorphism. Confirmation of this and use of modern thermochronology desirable to substantiate the extent and timing of ~SE-NW left lateral transpression in Hodgkinson region.
8	Cowley Ophiolite Complex	Unknown Post-Devonian emplacement suggested	Serpentinite, altered gabbro, carbonate-talc rock; minor chlorite-magnetite. basaltic or andesitic dykes	Biotite(?)	This small unit is considered part of the Barnard province, but little is known about it. It is included as a speculative possibility, as it is adjacent to the Barnard metamorphics, to the south of Innisfail. Geochronology may contribute a better understanding of the timing of accretion events.

***** A possible date for shearing of this unit is 246 - 233 Ma, using K-Ar is attributed to Richards (1980), although this text is not available online and methodology has not yet been confirmed.

****** Date attributed to Richards et al. (1966). This date is not believed to be the true age of the unit, but a consequence of dating methodology. Intended furnace step heating schedule should avoid the issue of excess argon.

Reference List:

Bultitude, R.J., Champion, D.C., 2013, Chapter 3.6 Barnard Province. In Jell, P. A., (ed) Geology of Queensland, Geological Survey of Queensland, pp159-163

Champion, D.C., Bultitude, R.J., 2013, Chapter 6. Kennedy Igneous Association. In Jell, P. A., (ed) Geology of Queensland, Geological Survey of Queensland, pp473-513

De Keyser, F. (1963). The Palmerville fault — a "fundamental" structure in north Queensland. *Journal of the Geological Society of Australia*, *10*(2), 273–278. https://doi.org/10.1080/00167616308728545

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Geoscience Australia and Australian Stratigraphy Commission. (2017). Australian Stratigraphic Units Database.

Henderson, R. A., Innes, B. M., Fergusson, C. L., Crawford, A. J., & Withnall, I. W. (2011). Collisional accretion of a Late Ordovician oceanic island arc, northern Tasman Orogenic Zone, Australia. Australian Journal of Earth Sciences, 58(1), 1–19. https://doi.org/10.1080/08120099.2010.535564

Kositcin, N., Bultitude, R. J., Purdy, D. J., Brown, D. D., Carr, P. A., & Lisitsin, V. (2015a). Queensland Geological Record 2015 / 03 Summary of results — Joint GSQ – GA geochronology project : Kennedy Igneous Association, Mossman Orogen, Thomson Orogen and Iron Range Province, 2013–2014.

Kositcin, N., Purdy, D. J., Brown, D. D., Bultitude, R. J., Carr, P. A. (2015b). Queensland Geological Record 2015 / 02 Summary of results — Joint GSQ – GA geochronology project : Thomson Orogen and Hodgkinson Province, 2012–2013.

Mackenzie, D.E. and Wellman, P., 1997. Kennedy Province. North Queensland Geology: Australian Geological Survey Organisation Bulletin, 240, pp.488-500.

Withnall, I.W. and Cranfield, L.C., 2013. Geological Framework of Queensland. Queensland Minerals, 13.

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

Eight sample locations are proposed. Of these, four have the capacity for a paired study of white mica and K-Feldspar, necessitating two samples to be analysed from the location. Twelve samples in total would allow for this analysis to occur as proposed. If a sufficiently well preserved sample cannot be recovered from the Cowley ophiolite complex, a greenschist facies sample of the Hodgkinson formation, sometimes referred to as the (now obsolete) 'Barron River Metamorphics' may be substituted, as it is of sufficient scientific interest.

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

See **Table 1**, above.

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 proximity to PhD studies 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)