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

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Collaborators: Anthony Reid, Geological Survey of South Australia (GSSA)
Project Title: Ar-Ar thermochronology age constraints on mafic and felsic magmatism, and deformation in the Curnamona Province
Geographic Region: Mundi Mundi Plain, Olary Domain
Geological Province or Tectonic Unit: Curnamona Province

Brief Project Description:

The application of Ar-Ar for thermochronology and understanding deformation history in the Mundi National Drilling Initiative (NDI) area in NSW and the Olary Domain in SA will further our geological understanding of the Curnamona Province, the Adelaide Rift Complex and the Delamerian Orogeny – with implications for the geodynamic setting and mineral systems potential in western NSW, eastern South Australia and western Victoria.

The Curnamona Province is host to one of the world's largest mineral deposits at Broken Hill and has prospectivity for IOCG mineral systems as witnessed by deposits such as Kalkaroo and Portia. There is, however, very little argon geochronology from the Curnamona Province. Overview of sample information (Figure 1):

- New South Wales – a maximum of ten samples selected from drillholes and outcrop in rock units present in the MinEx CRC Mundi NDI area of the Curnamona Province
- South Australia – three samples selected from drillholes in the Olary Domain of the Curnamona Province

<u>Mafic magmatism</u>

The Mundi NDI area in NSW contains numerous mapped instances of mafic volcanic and intrusive rocks. These are mostly undercover and intersected by a handful of drillholes throughout the region. The main formal stratigraphic unit these have been assigned to is the Wilangee Basalt, although informal associations also exist (NSW Seamless Geology; Colquhoun et al. 2020). Little geochemical analyses and no geochronological data have been completed for mafic rocks assigned to this unit. Recent fieldwork and legacy sampling of drillcore (with thin sections made) as part of the MinEx CRC program in NSW has sampled mafic rock units (in outcrop in the Alberta Well region and in drillholes TD9207 and TD9203; Figure 1) – lithologies consists of massive basalt with epidote-chlorite alteration that has been weakly deformed with low-grade metamorphic features (lower greenschist facies). Thin sections will be examined to help select the best samples for Ar-Ar submission.

The main aim in submitting these basaltic rocks for geochronological analysis is to determine their associated tectono-magmatic event. Possibilities include: the break-up of the Rodinian Supercontinent (different pulses of Neoproterozoic Adelaidean rifting) from ~830-540 Ma;

volcanic-arc magmatism associated with the Delamerian Cycle from ~540-510 Ma; or another unknown magmatic event. The mafic composition of these rocks makes it difficult to apply U-Pb dating by ion microprobe techniques due to a lack of zircon crystals.

Pre-existing and/or possible geochronological constraints (see Table 1):

- Mafic magmatism attributed to the Willouran Basic Province (Crawford and Hilyard 1990), including the Little Broken Hill Gabbro and the Gairdner Dyke Swarm in South Australia (both ~827 Ma; Wingate et al. 1998), and the Wooltana Volcanics (e.g. Cooper and Tuckwell 1974) associated with the breakup of Rodinia (e.g. Li 2011)
- Mafic magmatism in the Delamerian Orogen (Koonenberry Belt) including the ~585 Ma Mount Arrowsmith Volcanics (Black 2007) and the ~510 Ma Bittles Tank Volcanics (Black 2005)
- Unknown dolerite and dacitic tuff from drillhole TD9206 (Tindara – Yella). SHRIMP U-Pb data suggest a minimum age is ~1100-1140 Ma (Fanning 1992)

Dating of thermal history of granitoids

Exposed outcrops and drilling intercepts of ~1590 Ma (Page et al. 2005) quartz–K feldspar–biotite–muscovite granite of the Mundi Mundi Suite (Table 1) occur in the Mundi NDI area. These granites can be dated by U-Pb analysis of zircon, although initial results using this method on similar samples has not produced definitive magmatic ages (Waltenberg pers. comm.). However, Ar-Ar thermo-geochronology of K-feldspar and mica can provide information on the post-crystallisation history of the granites, including thermal pulses and deformation events. Samples have already been collected (and thin sections made) from both exposure (outcrop) and drill core (Figure 1).

Samples have also been collected of equivalent granite from South Australia (Figure 1), the Honeymoon Granite in drill hole YAM 052C. This two-mica granite has been documented in two publications by GSSA (Fricke and Reid 2009; Jagodzinski and Fricke 2010). The SHRIMP zircon U-Pb emplacement age of 1541 ± 59 Ma is poorly defined and the majority of zircons recovered from the sample were inherited and discordant. Dating of muscovite, biotite and K-feldspar (orthoclase) form two samples of this granite will provide further constraints on the thermal evolution of this granite, and potentially on the timing of alteration in the granite. Fricke and Reid (2009) document a variety of alteration styles within this granite that may be related in some way to the nearby Honeymoon uranium deposit, located in overlying Cenozoic sandstones.

The dates from this two-mica granite will complement the existing National Argon Map project that has dated similar granites from the western portion of the Curnamona Province, in the Bimbowrie area and in drill hole Frome 12 (Figure 1).

A second sample of as yet undated (grano)diorite is also selected for this project. Diorites in the Benagerie ridge region are known to intrude metasedimentary rocks and are typically either less altered or weakly altered than the adjacent albitite or albite-rich rocks. This suggests the diorites may be late in the alteration history or are part of a younger magmatic event. Geochemically the diorites are similar to other mafic rocks of the Ninnerie Supersuite and interpreted to therefore be part of the c. 1580 Ma magmatic event. The sample selected, 3704279, contains both hornblende and biotite that are amenable to argon dating. A previous attempt to date the diorite from a nearby drill hole was unsuccessful as no zircon grains were recovered (Jagodzinski and Fricke 2010).

Dating of deformation of Paragon Group (Willyama Supergroup) rocks

The Mundi NDI area in NSW contains outcrop and drillholes that have intersected numerous metasedimentary rocks (e.g. schist, slate) interpreted to belong to Paleoproterozoic basement units (i.e. the Paragon Group - Willyama Supergroup). The rock units show strong deformation fabrics with the growth of micaceous minerals that would be good targets to date using Ar-Ar methods. Some samples have been collected (and thin sections made) from outcrop and legacy drillcore (Figure 1).

There are few pre-existing geochronological dates/constraints on the proposed samples, although many exhibit one strong cleavage direction. If these samples are indeed from Willyama Supergroup basement rocks, then this would suggest the main deformation age would be the Olarian Orogeny at 1600-1580 Ma (Table 1).

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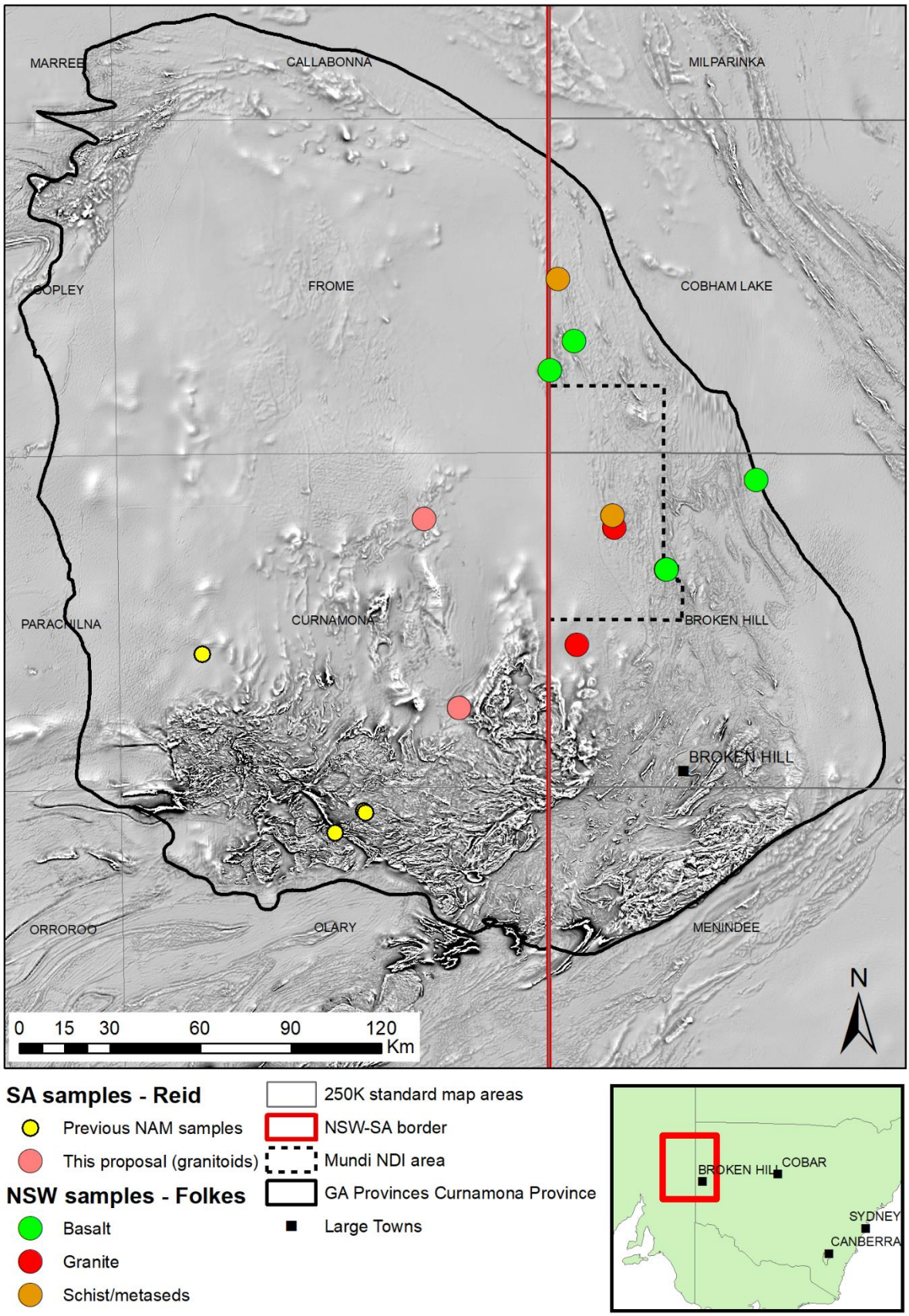

Figure 1. Location of proposed samples from the Curnamona Province. The MinEx CRC Mundi NDI area is shown. The background image shows the 2019 Geoscience Australia greyscale national total magnetic image (TMI) first vertical derivative (1VD). Previous samples submitted for the National Argon Map from the Curnamona Province in South Australia are also shown.

Table 1 – Simplified time chart with major geologic events in the greater Curnamona Province (Gilmore and Hill 2019). Important events related to possible geochronological dates for these rocks are highlighted in yellow.

Period / Era (Ma)	Approximate age (Ma)	Stop	Geological feature
Cenozoic (66–present)	<2	4a	Alluvial, colluvial, aeolian and playa lake sediments.
	?30–?10	4b	Formation of silcrete horizons.
	60–45		Deposition of Eyre Formation.
Mesozoic (252–66)	?160–?100		Sediment deposited in the Eromanga Basin (part of the Great Australian Basin).
Palaeozoic (541–252)	350		Kanimblan Orogeny, open folding of Devonian rocks.
	415–360		Deposition of sand that is now cliffs at Mutawintji National Park.
	430–420		Magmatism along eastern margin (e.g. Tibooburra Granite).
	510–490		Delamerian Orogeny.
	541–510		Deposition of passive margin sedimentary rocks with calc-alkaline subduction-related (Mount Wright Volcanics) and MORB magmatism (e.g. Koonenberry Belt).
Neoproterozoic (1000–541)	635–541		Ediacaran period (first multicellular life forms appeared). Deposition of passive continental margin sediments. Rifting ~580 Ma with eruption of alkali basalts (e.g. Mount Arrowsmith Volcanics).
	645–630		Extensive Marinoan (Elatina) glaciation and ice sheets.
	700–660	1, 2,	Sturtian glaciation.
	720–635		Development of Rodinian epicontinental rift basin.
	850–810		Deposition of first 'Adelaidean' sedimentary and volcanic rocks from rifting and mafic volcanism / extension (e.g. Little Broken Hill Gabbro ~830 Ma, Wilangee Basalt).
	1560–1550		Moolawatana Suite felsic intrusions
Mesoproterozoic (1600–1000)	1590–1580	3a, b	Magmatism including Ninnerie Supersuite felsic intrusions and volcanism, including S-type Bimbowrie and Mundi Mundi Granites. Deposition of Radium Creek Group.
Paleoproterozoic (2500–1600)	1600–1580		Olarian Orogeny. Basin inversion, metamorphism of the Broken Hill sequence, anataxis and magmatism. Deformation.
	1642		Deposition of youngest rocks in Broken Hill sequence.
	1685–1680		Volcanic eruptions (Hores Gneiss protolith) and magma intrusions. Broken Hill ore body forms.
	1720-1695		Deposition of the first rocks in the Curnamona Province (in South Australia) and then also in NSW in an epicontinental rift basin.

*Ages in millions of years, not to scale.

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

- Basalt (magmatic) – five samples
- Schist (deformation) – three samples
- Granite (thermal history) – four samples
- Granodiorite (thermal history) – one sample

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

- Whole rock – basalt
- Micas – schist
- Biotite, muscovite, K-feldspar – granite
- Hornblende, biotite – granodiorite

Do you have a preferred ^{40}Ar-^{39}Ar laboratory? (ANU, Curtin, UQ, UMelb):
ANU for deformation and thermal history work (micas and K-feldspar). No preference for mafic rocks.

If so, why you prefer this laboratory (e.g. student affiliation, ongoing relationship, sample type etc):
Dr Foster has experience working on Mundi Mundi Suite granites. GSNSW and GSSA has worked with Dr Foster previously with excellent results unravelling complex deformation histories using Ar-Ar on mica.

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)