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: Joshua Shea
Affiliation and position: Macquaire University, Ph.D. Student
Collaborators: Anthony Lanati, Stephen Foley, and Olivier Alard
Project Title: Geochronology of the eastern Australian leucitite suite
Geographic Region: Central NSW, and central Victoria
Geological Province or Tectonic Unit: Eastern Australian Leucitite suite

How will these samples benefit the National Argon Map?

Provide a succinct answer to this question, see the suggestions in the Guidelines and Criteria on the next page.

Previous $^{40}K/^{40}Ar$ ages of the eastern Australian leucitite suite in the National Argon Map have been shown to have suffered Ar loss due to extensive weathering, reducing the number of sites displaying preferred ages 38 from to 9 (Cohen *et al.*, 2008).

We want to combine the new $^{40}Ar/^{39}Ar$ ages with a new method of *in situ* Rb/Sr analysis of leucite, phlogopite and clinopyroxene. Since both Rb and Sr, unlike Ar, are constituents of the crystal lattice of leucite, phlogopite and clinopyroxene we can assess the extent of Ar loss on previous ages in the National Argon Map, while also assessing the precision and accuracy of the new Rb/Sr ages against the recognised $^{40}Ar/^{39}Ar$ method.

We have collected 12 samples with little to no weathering implying minimal to no Ar loss, from previously sampled and new locations that cover the entire eastern Australian leucitite suite. By comparing $^{40}Ar/^{39}Ar$ and Rb/Sr ages it could show if non-preferred ages stored in the National Argon Map have been significantly affected by Ar loss or have recorded significantly longer geological events than previously thought.

We have disaggregated groundmass and mineral separates appropriate for $^{40}Ar/^{39}Ar$ analysis, which require little work before sending them to a $^{40}Ar/^{39}Ar$ laboratory. This leaves irradiation and noble gas analysis, we have contacted the UMelb Ar Laboratory who have advised this can take up to 6-7 months, so this project can fit within the National Argon Map initiative timeframe.

Brief Project Description:

Approximately 500 word maximum. Include what geological process/problem will be addressed, and how new $^{40}Ar/^{39}Ar$ data from the specific samples to be dated will contribute. Please include reference to pre-existing geochronological constraints, if any exist. Please include a simple location map which showing the spatial distribution of samples in their geological context (with scale).

This project has three main objectives; first, we intend to date 12 new samples using both $^{40}Ar/^{39}Ar$ and Rb/Sr isotopic systems to assess if argon loss is significant, or if previously measured younger $^{40}K/^{40}Ar$ ages are recording younger volcanic events; second, compare the ages from the routine $^{40}Ar/^{39}Ar$ system and the optimised *in situ* Rb/Sr method using LA-ICP-MS/MS to test the accuracy of *in situ* Rb/Sr ages on young material; third, provide $^{40}Ar/^{39}Ar$ ages for all leucitite locations, including important but as yet undated areas, such as the northernmost locality of Bokhara River (Figure 1), which has never been dated or characterised, to assess the role of age progressive volcanism in eastern Australia.

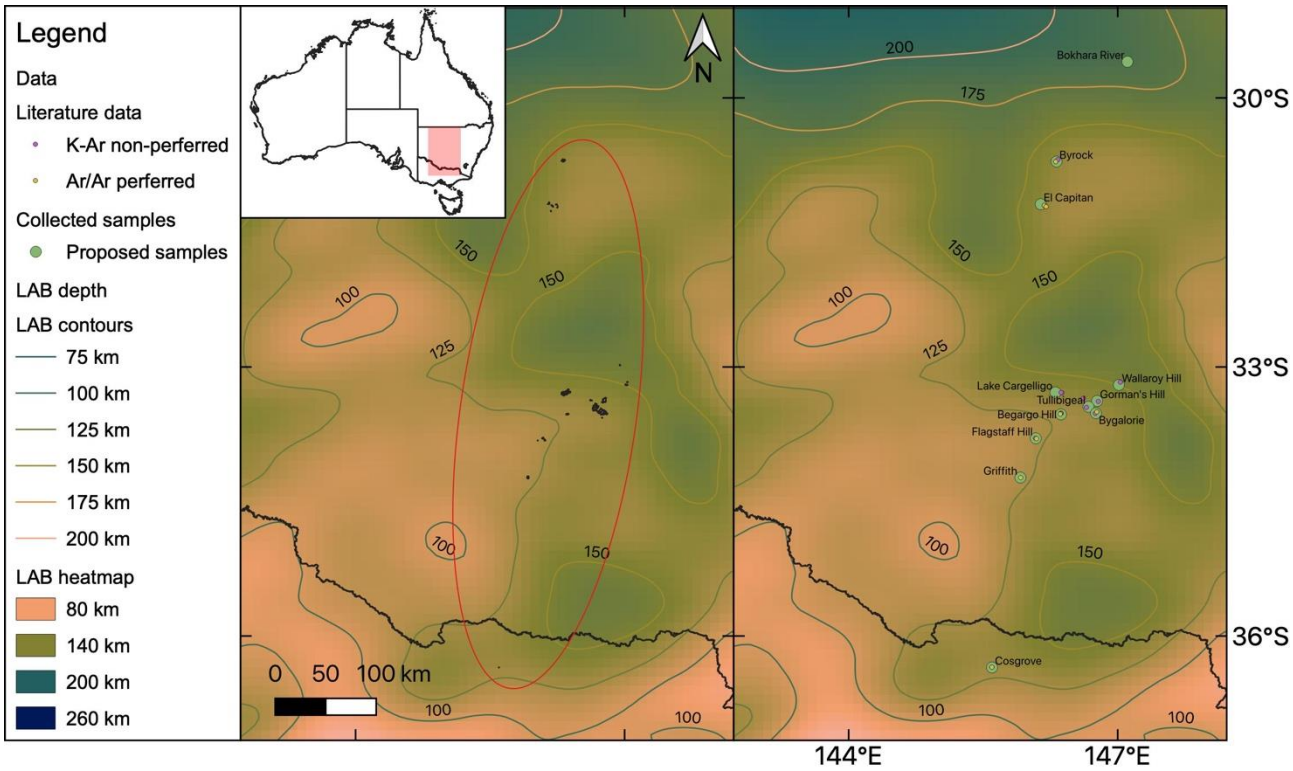

Figure 1. Maps showing the location of the leucitite suite outcrops Australia, along with location of ages from the National Argon Map and proposed locations for $^{40}Ar/^{39}Ar$ dating. The red insert on the small map of Australia shows the location of the two larger maps. The large map on the left shows the leucitite outcrops, which all fall within the red ellipse. The large map on the right shows the distribution of preferred $^{40}Ar/^{39}Ar$ ages (small yellow circles) and non-preferred $^{40}K/^{40}Ar$ ages (small purple circles) from the National Argon Map with locations of proposed samples (large green circles), with location names. The heatmap and contours on the larger maps show the lithosphere-aesthenosphere boundary (LAB) depth (LAB data from Rawlinson et al. (2017)); steps in this boundary, from thick to thin, have been argued to drive edge-driven convection that may have provided a mechanism for melting the source for the leucitite melts.

The eastern Australian leucitite suite is a part of eastern Australia's late Mesozoic-Cenozoic intraplate mafic volcanism. Volumetrically they are a minor component, however they make up two-thirds of the world's longest continental hotspot track – the Cosgrove hotspot track (Davies et al., 2015). This age progression in the leucitites, younging from north to south, is based on 9 preferred $^{40}Ar/^{39}Ar$ ages, because previous $^{40}K/^{40}Ar$ ages have been mostly discarded due to speculations of significant Ar loss (Cohen et al., 2008).

Recently, edge driven convection has been put forward as a mechanism for melt generation for eastern Australia's Cenozoic intraplate volcanism, including the leucitite suite (Rawlinson et al., 2017). This

brings into question the role of a mantle plume in eastern Australia, and the age progressive nature of the leucitites. This is especially relevant since Sr-Nd-Hf and Pb isotopic signatures suggest lithospheric sources for the entire leucitite suite, and separate Cosgrove apart from the NSW leucitites (Figure 1; Paul et al., 2005, Hergt et al., 2006).

Recent optimisations in the laser ablation-inductively couple plasma-tandem mass spectrometry (LA-ICP-MS/MS) method for *in situ* Rb/Sr analysis at Macquarie University allow for younger ages to be obtained due to improved accuracy and precision (Gorojovsky and Alard, 2020). Since this method will be applied to material this young for the first time, we will be testing the accuracy of its ages by comparing them to $^{40}Ar/^{39}Ar$ ages from the same samples. However, not all samples can be dated using the *in situ* Rb/Sr method due to fine grained groundmass smaller than the laser ablation diameter and a lack of appropriate phases for analysis.

Bokhara River in Northern NSW (Figure 1), has not been previously dated and is only suitable for $^{40}Ar/^{39}Ar$ dating due to plagioclase dominating its groundmass and a lack of leucite and phlogopite for Rb/Sr dating. Bokhara River lies along the Cosgrove hotspot track, and has been speculated to be related to the leucitites, but this depends on its age. This makes Bokhara River the most valuable addition to the National Argon Map on this proposal, since it could minimise a 640 km geochronological gap in the Cosgrove hotspot track between Buckland (a basaltic field to the north) and Byrock (Figure 1), reducing it to a 500 km gap.

We have preliminary Rb/Sr ages that suggest previously dated samples in the National Argon Map may have not have experienced significant Ar loss, but may have recorded significantly longer volcanic events than suggested (Figure 2). The Rb/Sr age obtained for Byrock is particularly interesting at 14.33 ± 0.51 Ma which suggests activity at Byrock occurred at the same time, or earlier than Griffith ~400 km south (Figure 2).

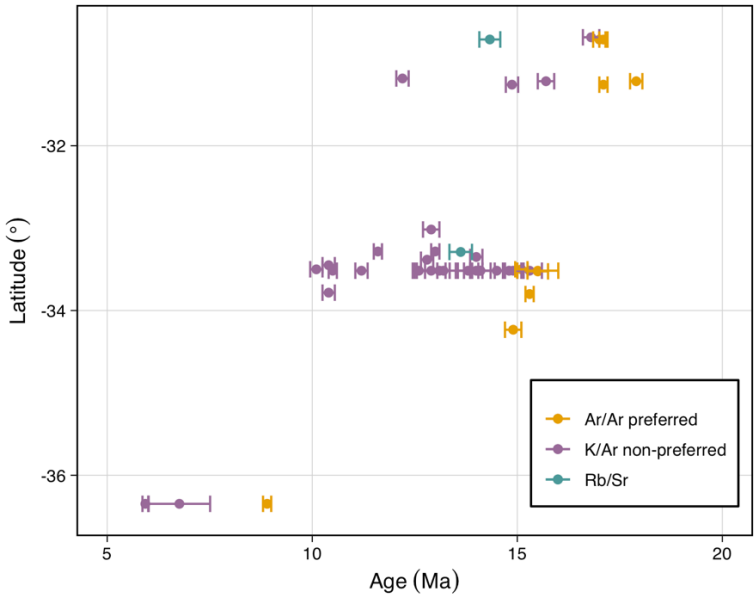

Figure 2. All recorded ages of the leucitite suite collated from the National Argon Map and from a collated list from Cohen et al. (2008). Preferred $^{40}Ar/^{39}Ar$ represent some of the oldest ages from the leucitite suite, while $^{40}K/^{40}Ar$ ages are up to > 5 Ma younger at some localities. However, Rb/Sr ages are also much younger, with Byrock ~4 Ma younger than preferred $^{40}Ar/^{39}Ar$ ages, while the Rb/Sr age at Lake Cargelligo lies within the non-preferred $^{40}K/^{40}Ar$ ages. This casts doubt on significant Ar loss in the $^{40}K/^{40}Ar$ ages, suggesting much longer events may have occurred than previously thought and volcanoes hundreds of kilometres apart may have been active concurrently.

The results from this proposal will form a part of the PhD projects for Joshua Shea and Anthony Lanati, which will be subsequently published in peer-review journals, with all ages being submitted to the National Argon Map.

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

Lithologies and minerals proposed for $^{40}Ar/^{39}Ar$ analyses:
Groundmass, phlogopite, leucite

Do you have a preferred ^{40}Ar-^{39}Ar laboratory? (ANU, Curtin, UQ, UMelb):
If so, why you prefer this laboratory (e.g. student affiliation, ongoing relationship, sample type etc):

UMelb, due to an ongoing relationship with their Argon lab.

References

COHEN, B. E., KNESEL, K. M., VASCONCELOS, P. M., THIEDE, D. S. & HERGT, J. M. 2008. 40Ar/39Ar constraints on the timing and origin of Miocene leucitite volcanism in southeastern Australia. *Australian Journal of Earth Sciences,* 55**,** 407-418.

DAVIES, D. R., RAWLINSON, N., IAFFALDANO, G. & CAMPBELL, I. H. 2015. Lithospheric controls on magma composition along Earth's longest continental hotspot track. *Nature,* 525**,** 511-514.

GOROJOVSKY, L. & ALARD, O. 2020. Optimisation of laser and mass spectrometer parameters for the in situ analysis of Rb/Sr ratios by LA-ICP-MS/MS. *Journal of Analytical Atomic Spectrometry,* 35**,** 2322-2336.

HERGT, J. M., DE LEON, A. & WOODHEAD, J. D. 2006. The NSW leucitites: lithospheric melts or hot-spot magmas? *Geochimica et Cosmochimica Acta,* 70**,** A247-A247.

PAUL, B., HERGT, J. M. & WOODHEAD, J. D. 2005. Mantle heterogeneity beneath the Cenozoic volcanic provinces of central Victoria inferred from trace-element and Sr, Nd, Pb and Hf isotope data. *Australian Journal of Earth Sciences,* 52**,** 243-260.

RAWLINSON, N., DAVIES, D. R. & PILIA, S. 2017. The mechanisms underpinning Cenozoic intraplate volcanism in eastern Australia: Insights from seismic tomography and geodynamic modeling. *Geophysical Research Letters,* 44**,** 9681-9690.

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)