



## **Program and abstracts of the 2017 Annual Australian TANG<sup>3</sup>O Meeting**

**TANG<sup>3</sup>O = Thermochronology and Noble Gas Geochemistry and Geochronology  
Organisation**



**The Research School of Earth Sciences, Australian National University,  
Canberra. 22<sup>nd</sup>-23<sup>rd</sup> November 2017**

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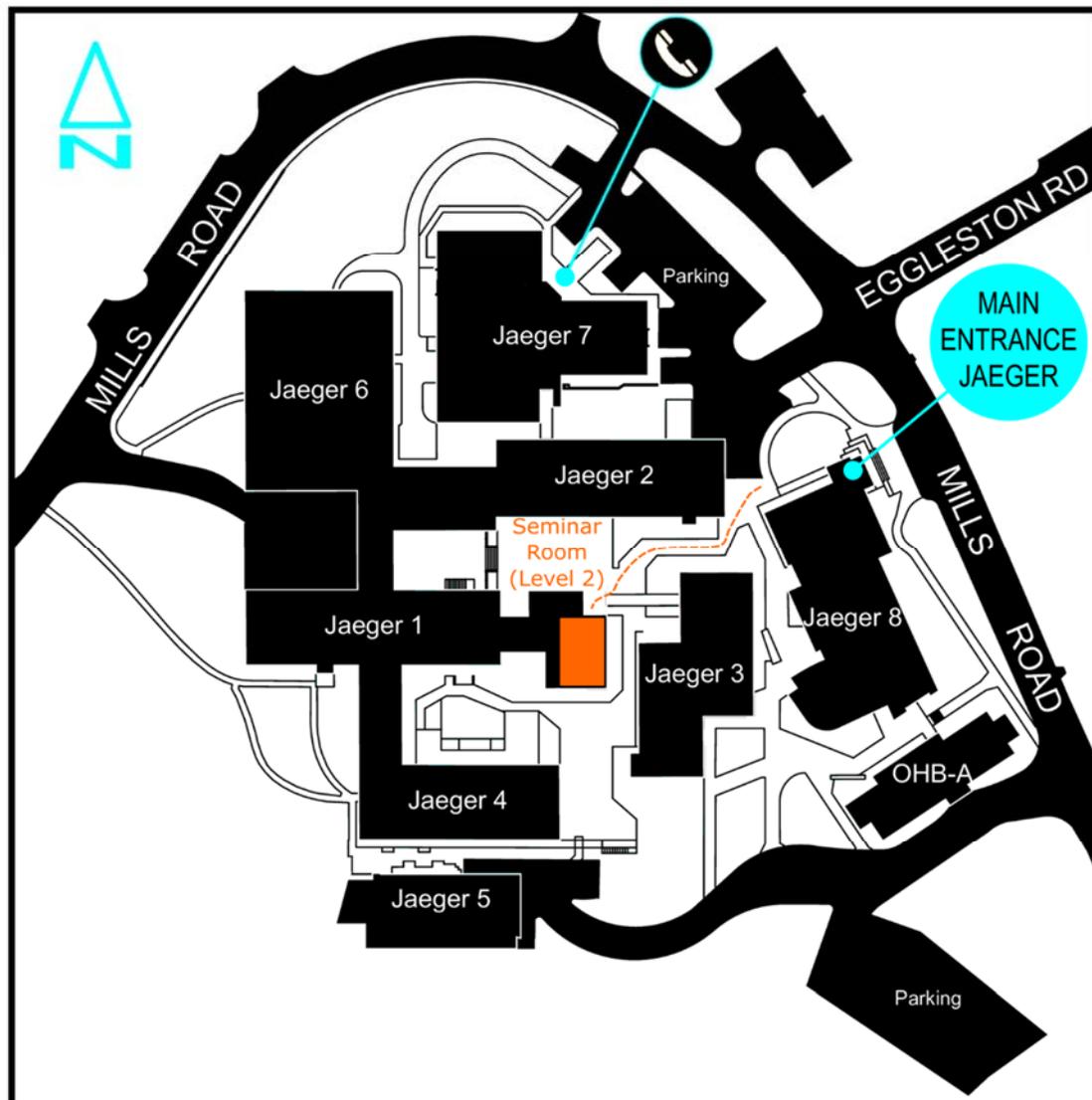
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## RSES location map

RSES Jaeger complex is situated at 142 Mills Rd., Acton, ACT 2601. All talks will be located in the J1 seminar room on the first floor (level 2) of the Jaeger 1 building. Coffee will be served in the J1 foyer on level 1.



Compiled by Mark A. Kendrick, RSES, ANU. 21st November 2017.

## Program – Day 1 – Wednesday 22<sup>nd</sup> November

0830	Coffee in the J1 foyer	
0900	Welcome	Mark Kendrick
	<i><b>U-Pb, Re-Os and Rb-Sr Geochronology</b></i>	<i>Chair Mark Kendrick</i>
0910	SPIDE <sup>2</sup> R is dating rocks	Yuri Amelin
0925	SPIDE <sup>2</sup> R is going to other (small) planets	Piers Koefoed
0940	Raman Spectroscopic imaging of zircon as a useful tool for the characterization of zircon prior to LA-ICP-MS analysis	Jay Thompson
0955	<i>In-situ</i> Rb-Sr Dating of Detrital Muscovites and Organic Rich Shales from Proterozoic Basins in NT, Australia	Alan Collins
1010	Use of Re-Os Isotopic Dating of Molybdenite to Constrain Ages and Fluid Sources of Mineralising Systems	Marc Norman
1025	Discussion	
1030-1100	School Coffee	
	<i><b>Diamonds, fluids and alteration</b></i>	<i>Chair Brent McInnes</i>
1105	<sup>40</sup> Ar/ <sup>39</sup> Ar Constraints on the Provenance History of Diamond Deposits, Namaqualand, South Africa	David Phillips
1120	Relation between fluid end-members and noble gases in South African diamonds	Suzette Timmerman
1135	Halogens and <sup>40</sup> Ar/ <sup>39</sup> Ar ages in international reference materials and Atlantis Bank IODP drill core, SW Indian Ridge	Mark Kendrick
1150	Serpentine in ultramafic rocks from the Isua Supracrustal Belt, a proxy for Archaean seawater chemistry	Joelle D'Andres
1205	Discussion	
1210-1330	Lunch	

	<b><i>Geo to Thermochronology</i></b>	<i>Chair David Phillips</i>
1330	Towards an Australian Ar geochronology map	Geoff Fraser
1345	Highly retentive <sup>39</sup> Ar diffusion parameters for a biotite from Sulawesi	Marnie Forster
1400	How hot the bottom of the orogenic lid of the European Alps?	Gordon Lister
1415	Cratonic reworking linked to far-field subduction systems: a Mesoproterozoic example from the western Gawler Craton	Anthony Reid
1430	What is the meaning of a fission track age?	Andrew Gleadow
1445	Evaluating a-radiation damage on zircon and baddeleyite (U-Th)/He systematics: A case study from Tasmanian dolerites	Barry Kohn
1500	Discussion	
1505-1530	Coffee in J1 foyer	
	<b><i>Surface processes</i></b>	<i>Chair Alan Collins</i>
1530	Flow mapping and <sup>40</sup> Ar/ <sup>39</sup> Ar dating of Melbourne basalt	Michael Heath
1545	Combined U-Th-disequilibrium and (U-Th)/He dating of zircon - a new geochronometer for Quaternary volcanic records	Martin Danišik
1600	Precise determination of cosmogenic Ne in CREU-1 quartz standard, using the Helix-MC Plus mass spectrometer	Masahiko Honda
1615	Routine <sup>40</sup> Ar/ <sup>39</sup> Ar Geochronology with a SFT	Paulo Vasconcelos
1630	Discussion - SA LIEF Bid	
1700	Beers and posters (J1 foyer)	
	The new University of Wollongong (UOW) cosmogenic isotope sample preparation and chemistry laboratories	Alexandru T. Codilean and Réka H. Fülöp
	The new ANSTO/UOW in-situ cosmogenic carbon-14 extraction system.	R-H. Fülöp
1930	<b>Conference Dinner</b> Lemon Grass Thai, Melbourne Building, London Circuit	

## Program – Day 2 - Thursday 23<sup>rd</sup> November

0830	Coffee in J1 foyer	
	<i>Technical Advances</i>	<i>Chair Trevor Ireland</i>
0900	Noble Gas Measurements of Ground and Surface Water: First Field-Samples and Application Developments	Alec Deslandes
0915	Characterisation of an ion source on the Helix MC <i>Plus</i> noble gas mass spectrometer - pressure dependent mass discrimination	Xiaodong Zhang
0930	Introducing the new Altona amplifier: redefining the dynamic range of the Faraday cup	Damian Tootell
0945	Noble Gas Mass Spectrometry with multicollection and high resolving power – a British perspective	John Saxton
1000	Noble Gas Mass Spectrometry – an update	Doug Hamilton
1015	Discussion	
1030-1100	School Coffee	
	<i>Data storage and Business Meeting</i>	<i>Chair Mark Kendrick</i>
1105	Creating an International Geochemistry Network to Connect Researchers, Data Repositories and Publishers	Lesley Wyborn
1120	A vision for a geochemistry open data ecosystem	Brent McInnes
1135	Ar Map, next Tang3o meeting + other business	
1230-1330	Lunch	
1330	THERMO FISHER USERS MEETING Hales Room	

## **SPIDE<sup>2</sup>R is dating rocks**

Yuri Amelin, Vickie Bennett and Sonja Zink

*Research School of Earth Sciences, The Australian National University*

The **SPIDE<sup>2</sup>R** (Sensitive and Precise Isotopic Dating of Earth's and Extraterrestrial Rocks) facility at RSES, operational since 2009, includes a clean chemistry lab suitable for ultra-low Pb blank sample preparation, and two thermal ionisation mass spectrometers (Triton Plus and modified/up-graded MAT 261). In this presentation, we will show the scope and examples of geochronological and isotope geochemical research at SPIDE<sup>2</sup>R. We are determined to refine the methods of isotopic dating, and to apply them to the most important geological problems.

A key activity of our lab is high precision single zircon ID-TIMS U-Pb dating using an in-house prepared <sup>233</sup>U-<sup>236</sup>U-<sup>202</sup>Pb-<sup>205</sup>Pb spike that allows isotope dilution measurements with in-situ fractionation correction for both parent and daughter elements, an in-house developed silica gel emitter with high ionisation efficiency (Huyskens et al. 2012), and our refined procedure for chemical abrasion of zircon (Huyskens et al. 2016). Among our recent and ongoing projects based on high precision U-Pb dating of zircon are the study of chronostratigraphy of Palaeozoic sedimentary basins (ongoing joint work with Geoscience Australia and Geological Survey of NSW), measuring rates of sediment accumulation (Ayaz et al. 2016), chronology of mafic magmatism and gold mineralisation in Yilgarn Craton (Hayman et al. 2015 AJES and Precambrian Research), dynamics of mineralisation development at Olympic Dam (ongoing project with the University of Tasmania), and determination of eruption volume dynamics of continental flood basalts (ongoing project with Peking University).

For dating rocks where zircon is absent or is unsuitable for age determination, we have developed methods involving analysis of other U- and/or Th-bearing minerals: apatite, baddeleyite, xenotime, rutile, and cassiterite. In addition to geochronology, Sm-Nd and Rb-Sr isotopic tracing studies including measurement of extinct nuclide compositions (e.g., high precision measurement of <sup>142</sup>Nd isotopic compositions) at SPIDE<sup>2</sup>R are aimed at understanding the evolution of the Earth's crust and oceanic and lithospheric mantle (McCoy-West et al. 2016, and ongoing research by V.C. Bennett).

## **SPIDE<sup>2</sup>R is going to other (small) planets**

Piers Koefoed and Yuri Amelin

*Research School of Earth Sciences, The Australian National University*

Measuring the precise time of formation of extraterrestrial rocks has been one of the primary goals of researchers at SPIDE<sup>2</sup>R (facility for Sensitive and Precise Isotopic Dating of Earth's and Extraterrestrial Rocks) since it was established (Amelin et al. 2010). We use precise in-situ fractionation corrected Pb-isotopic data to measure the ages of a wide variety of achondrites (extraterrestrial igneous rocks composed mostly of silicate minerals) that were derived from various small planetary bodies (asteroids). The studies of several achondrites from the same group (classified on the basis of similarities in mineralogy and elemental and oxygen isotope abundances that are interpreted as an indication of the same parent body) that formed at different time allow us to reconstruct the evolution of their parent asteroid.

Many achondrites found in the recent years have unique chemical and isotopic characteristics, and do not fit in to the established groups, and so are referred to as ungrouped achondrites. They are thought to sample a large number of different asteroids. Discovery of these meteorites, together with recent advancements of analytical techniques, allow us for the first time to go beyond the case studies of a small number of select asteroids to a representative picture of the accreting protosolar nebula based on the data from diverse asteroids that formed and partially melted in different domains, at different time, from different source materials, and under different conditions.

Isotopic dates with precision of 0.3-0.5 Ma or better are required to resolve the stages in the rapid and eventful protoplanetary and earliest planetary evolution that continued for less than 10 Ma (Iizuka et al. 2014 GCA, Koefoed et al. 2016 GCA, Amelin et al. 2017 submitted to GCA). In order to achieve the best possible precision, we use a combination of advanced partial dissolution methods to separate radiogenic and non-radiogenic Pb in the minerals with concentrations of U and radiogenic Pb of 3-10 parts per billion or less, sample preparation procedures with the lowest possible contamination level, and most sensitive methods of isotope analysis. To better constrain the time of formation and metamorphism of achondrites, we compare Pb-isotopic to the extinct radionuclide dates of the same rocks determined by our collaborators – leading cosmochemists in the United States and Europe.

### **Raman Spectroscopic imaging of zircon as a useful tool for the characterization of zircon prior to LA-ICP-MS analysis.**

Jay Thompson<sup>1</sup>, Thomas Rodemann<sup>2</sup>, Sebastien Meffre<sup>1</sup> and Leonid Danyushevsky<sup>1</sup>

<sup>1</sup>ARC Centre of Excellence in Ore Deposit Research, University of Tasmania; <sup>2</sup> Central Science Laboratory (CSL), University of Tasmania

*In-situ* analysis of the mineral zircon by SHRIMP or LA-ICP-MS has been a useful tool to geoscientists over the past several decades; greatly expanding our understanding of the timing of geological events in earth history. A single Zircon crystal can often record multiple crystallization events and *in-situ* analysis can target these specific age domains. To target specific domains in zircon, cathodoluminescence (CL) and backscattered electron (BSE) images have proven useful tools<sup>1</sup> to characterize zircon as they can reveal internal structures in the crystals that are not apparent in transmitted or reflected light and therefore allowing researchers to target specific domains for age analysis.

Raman spectroscopy uses monochromatic laser light to look at inelastic scatter of light on a sample, the wavelength (or wave number) of which is related to the vibrational mode of the covalent molecular bonds in the sample. Raman spectroscopy has previously been utilized to assess the degree of metamictisation in zircon<sup>2</sup> and more recently Raman spectroscopy was applied to zircon to help understand the zircon matrix effect in LA-ICP-MS analysis<sup>3</sup>. We present Raman spectroscopic images of zircon and age results from LA-ICP-MS analysis to show that Raman spectroscopy can reveal internal crystal structure similar to that seen in traditional CL images as well as give an indication of zircon crystallinity, the latter of which has been shown to strongly affect the accuracy of LA-ICP-MS ages<sup>3</sup>. Future use of Raman spectroscopy will compliment traditional tools like CL and BSE for characterization of zircon

prior to *in-situ* analysis and each Raman spectroscopic image can be acquired on the order of a few minutes depending on required resolution. Additionally, because Raman spectroscopy is hyperspectral, there can be other useful information about zircon chemistry / crystal structure recorded in the spectrum that may later prove useful in interpretation of age results.

1. J. M. Hanchar and R. L. Rudnick, *Lithos*, 1995, **36**, 289-303.; 2. L. Nasdala, M. Wenzel, G. Vavra, G. Irmer, T. Wenzel and B. Kober, *Contributions to Mineralogy and Petrology*, 2001, **141**, 125-144.; 3. E. Marillo-Sialer, J. Woodhead, J. M. Hanchar, S. M. Reddy, A. Greig, J. Hergt and B. Kohn, *Chemical Geology*, 2016, **438**, 11-24.

## **In-situ Rb-Sr Dating of Detrital Muscovites and Organic Rich Shales from Proterozoic Basins in NT, Australia**

Juraj Farkas<sup>1</sup>, Alan S Collins<sup>1</sup>, Grant Cox<sup>1</sup>, Stijn Glorie<sup>1</sup>, Ahmad Redaa<sup>1</sup>, Lise Jensen<sup>1</sup>, Sarah Gilbert<sup>1</sup>, Fred Fryer<sup>2</sup> and Thomas Zack<sup>3</sup>

<sup>1</sup>University of Adelaide; <sup>2</sup>Agilent Technologies; <sup>3</sup>University of Gothenburg

Reliable dating of igneous and sedimentary rocks are essential for the calibration of geological time scale and for the absolute age determination of major tectonic and depositional events throughout the Earth's history. Such geochronological constraints are particularly important for the studies and exploration of Proterozoic basins, which cannot rely on the biostratigraphy due to a lack of reliable macrofossil record. The intra-basin correlation and burial histories in Proterozoic basins, such as the McArthur and Amadeus Basins in Northern Territory (NT), can be constrained via Rb-Sr dating of selected authigenic minerals, which readily form either during the sediment depositions (i.e., glauconite), and/or the later stages of sediment diagenesis (i.e., illite). In addition, the *in-situ* Rb-Sr dating of detrital micas can help to constrain the 'maximum depositional age' and provenance of sedimentary sequences, in similar way as done routinely for the U-Pb system in detrital zircons.

Here we present the first available *in-situ* Rb-Sr dating of detrital muscovites from the Heavitree Quartzite, collected in the NE Amadeus Basin, which yielded an isochron age of  $\sim 1802 \pm 74$  Ma, which thus points to the source region of the Arunta. In addition, our pilot *in-situ* Rb-Sr dating of organic-rich shales (Velkerri Formation) from the central McArthur Basin yielded an age of  $\sim 1328 \pm 97$  Ma, which overlaps within the error with the published Re/Os depositional age for this sedimentary unit that range from  $1362 \pm 21$  to  $1417 \pm 29$  Ma, for the top and bottom parts of the formation, respectively. These data are exciting and support the proposal for a collision-cell split-stream facility to be developed to provide a new basin-focussed facility.

# Use of Re-Os Isotopic Dating of Molybdenite to Constrain Ages and Fluid Sources of Mineralising Systems

Marc Norman and Vickie C. Bennett

*Research School of Earth Sciences, The Australian National University.*

[marc.norman@anu.edu.au](mailto:marc.norman@anu.edu.au)

A continuing challenge is to better understand the evolution of mineralising systems by dating the formation of ore minerals directly. We have pursued this objective through  $^{187}\text{Re}$ - $^{187}\text{Os}$  dating of molybdenite ( $\text{MoS}_2$ ) using a novel technique in which  $\text{OsO}_4$  is introduced into a multi-collector ICPMS as a vapour phase, following high pressure Carius tube Re-Os spike equilibration and digestion. Molybdenite ( $\text{MoS}_2$ ) is well suited for Re-Os geochronology because it forms with high Re concentrations (typically 10's-100's ppm) and essentially no initial Os. It has a high closure temperature and is robust against subsequent thermal events and metamorphism. The relatively short half-life (comparable to  $^{87}\text{Rb}$ ) allows for dating young events with a long-term analytical reproducibility of  $\sim 0.5\%$  on the ages. The reliability of Re-Os molybdenite dating is now well established but care to ensure representative sampling is needed because small-scale decoupling of  $^{187}\text{Re}/^{187}\text{Os}$  within individual crystals has been inferred. Multiple episodes of molybdenite crystallization tend to form as discrete crystal populations rather than as overgrowths, so age distributions can sometimes be at least partially resolved through analysis of multiple aliquots or different grain size fractions. Age-correlated variations in Re contents can also be used as an indicator of multiple mineralizing events and/or sources. Sulfur isotopic compositions of molybdenite can potentially provide information about fluid sources although relatively few such studies have been published. For example, Raith and Stein (2000 Min. Dep.) found a narrow range of  $\delta^{34}\text{S}$  values (+3.6 to +4.5 per mil) in a set of W-Mo deposits from western Namaqualand, South Africa, and concluded that they formed via a large-scale, oxidized system related to a late-stage, I-type granites rather than in a sedimentary-exhalative setting. A reconnaissance application of integrated zircon, molybdenite, and cassiterite dating to the Mole granite, NSW, will be presented.

# **<sup>40</sup>Ar/<sup>39</sup>Ar Constraints on the Provenance History of Diamond Deposits, Namaqualand, South Africa**

David Phillips<sup>1</sup>, Jeff W. Harris<sup>2</sup>, Mike C.J. de Wit<sup>3</sup>, Erin Matchan<sup>1</sup>

<sup>1</sup>*The University of Melbourne, Parkville, Australia, [dphillip@unimelb.edu.au](mailto:dphillip@unimelb.edu.au).* <sup>2</sup>*University of Glasgow, Glasgow, Scotland, [Jeff.Harris@glasgow.ac.uk](mailto:Jeff.Harris@glasgow.ac.uk).* <sup>3</sup>*Tsodilo Resources Ltd, Toronto, Canada, [mdewit@tsodiloresources.com](mailto:mdewit@tsodiloresources.com).*

The West Coast of Namaqualand in South Africa hosts extensive detrital diamond deposits, but considerable debate exists as to the provenance of these diamonds. Some researchers have suggested that the diamonds were sourced from the erosion of >115 Ma orangeites located on the Kaapvaal craton. Others have argued that the Namaqualand diamonds originated from erosion of Permo-Carboniferous Dwyka glacial deposits (ca.300 Ma), with their ultimate source being pre-Karoo kimberlites on the Kaapvaal craton.

In this study, we analysed clinopyroxene inclusions extracted detrital diamonds from the Namaqualand coast using a new generation ARGUSVI mass spectrometer. Of the inclusions analysed, only six of 30 samples yielded (maximum) ages >300 Ma, with the majority (22 of 30) being <260 Ma. No inclusions produced ages <100 Ma. These results confirm that the majority of Namaqualand diamonds were sourced from post-Dwyka kimberlites/orangeites. None of the inclusions yielded ages typical of 80-90 Ma kimberlites, which suggest dominant diamond provenance from Cretaceous/Jurassic orangeites rather than Cretaceous Group I kimberlites. This conclusion accords with palaeo-drainage reconstructions in the area, which indicate a change in drainage in the mid-Cretaceous from a southwesterly directed palaeo-‘Karoo’ fluvial system to the current westerly directed Orange river drainage basin.

## **Relation between fluid end-members and noble gases in South African diamonds**

S. Timmerman, M. Honda, D. Phillips, A.L. Jaques, J. W. Harris

Fibrous diamond growth zones contain abundant high density fluid inclusions (HDFs). These fluid inclusions provide the most direct information on the source and composition of the diamond-forming fluids. There are four different fluid end-members (silicic, low-Mg, high-Mg carbonatitic, and saline) and their origin and evolution is poorly constrained. As noble gases are primarily concentrated in the high-density fluid inclusions, their noble gas composition can provide new information to further constrain the fluids. In this study, diamonds from the Finsch (n=3), DeBeersPool (n=7), and Koffiefontein (n=3) mines were investigated. Along core to rim traverses of polished plates, the  $\delta^{13}\text{C}$ , N concentrations, and fluid inclusion major element compositions were measured. Noble gas concentrations and isotopic compositions were subsequently determined by crushing. In this study we will show that the different fluid end-members, based on major elements, also have different  $^3\text{He}/^4\text{He}$  and  $^{40}\text{Ar}/^{36}\text{Ar}$  isotopic compositions and different helium concentrations. The combined fluid–noble gas results from this study provide important new insights into the origin of diamond-forming fluids.

## **Halogens and $^{40}\text{Ar}$ - $^{39}\text{Ar}$ ages in international reference materials and IODP drill core from the SW Indian Ridge**

Mark A. Kendrick, Joëlle D'Andres, Pete Holden, Trevor Ireland

*RSES, ANU, ACT 2601, Australia. Corresponding: [mark.kendrick@anu.edu.au](mailto:mark.kendrick@anu.edu.au)*

A suite of international rock standards (BHVO-2, BCR-2, BIR-1a, AGV-2, GSP-2, JB-2 and JR-1) were investigated for halogens using SHRIMP-II and  $^{40}\text{Ar}$ - $^{39}\text{Ar}$  methodology. The rock powders and calibration standards were prepared as Li-metaborate flux glasses for SHRIMP analysis and gave F concentrations within 10% of previous analyses, demonstrating that reliable whole rock F analyses can be obtained together with mineral analyses in a single SHRIMP session. Sample powders were vacuum encapsulated for analysis of Cl, Br and I by the noble gas method, to prevent recoil loss of  $^{39}\text{Ar}_\text{K}$  and  $^{37}\text{Ar}_\text{Ca}$  and thermal loss of other noble gas isotopes. Cl and Br concentrations determined this way are mostly within 10% of reference values. Iodine concentrations agree with some previous analyses but have higher reproducibility than previous studies suggesting our analyses are the most accurate yet available. The majority of samples analysed are less than 1 Myr old, however, total fusion  $^{40}\text{Ar}$ - $^{39}\text{Ar}$  ages were obtained for BCR-2 ( $13.6 \pm 0.6$  Ma), AGV-2 ( $18.2 \pm 0.4$  Ma) and GSP-2 ( $968 \pm 9$  Ma). These ages are mostly younger than the source rocks reflecting the low retentivity of  $^{40}\text{Ar}$  in feldspar bearing whole rocks.

The results suggest this technique has great promise for investigation of halogens and  $^{40}\text{Ar}$ -loss during seafloor alteration, and we present preliminary results for IODP drill core U1473A recovered from the Atlantis Bank on the SW Indian Ridge during Expedition 360.

## **Serpentine in ultramafic rocks from the Isua Supracrustal Belt, a proxy for Archaean seawater chemistry**

Joëlle D'Andres<sup>1</sup>, Mark A. Kendrick<sup>1</sup>, Vickie C. Bennett<sup>1</sup>, Allen P. Nutman<sup>2</sup>

<sup>1</sup> *RSES, Australian National University* <sup>2</sup> *University of Wollongong, Australia*

Ancient alteration minerals formed by reaction between Archaean seawater and the oceanic lithosphere represent a potentially valuable proxy for constraining the composition of Earth's early hydrosphere. Serpentinized ultramafic rocks from the Isua Supracrustal Belt (ISB) are suggested to record the D/H and  $^{16}\text{O}/^{18}\text{O}$  ratios of Eoarchaean seawater ( $\sim 3.7$  Ga; Pope et al., 2012) and ancient atmospheric noble gases have been reported in fluid inclusions hosted by hydrothermal quartz from the North Pole locality of the Pilbara Block ( $\sim 3.5$  Ga; Pujol et al., 2013). Recent work has revealed that serpentinites can incorporate high concentrations of atmospheric noble gases and halogens (Kendrick et al., 2011). Therefore, new samples of the Eoarchaean serpentinites were collected from the ISB locality best preserving an Archaean seawater signature (Pope et al., 2012). A variety of techniques were employed to fully characterize the serpentinites and samples were irradiated and analyzed for noble gases to enable determination of heavy halogens, K and Ca (extended  $^{40}\text{Ar}$ - $^{39}\text{Ar}$  methodology), and to thoroughly test if an Eoarchaean  $^{40}\text{Ar}/^{36}\text{Ar}$  signature could be detected.

A few magmatic zircons with SHRIMP U-Pb ages of  $3699 \pm 15$  Ma ( $n=4$ ) attest to the ancient character of the most hydrated and carbonated sample. Major and trace element geochemistry, petrography and field relationships suggest that the serpentinites originated from ultramafic cumulates formed at the base of a picritic lava flow rather than a mantle section. Excess  $^{40}\text{Ar}$  is present in all the samples investigated, meaning an Archaean paleo atmospheric component could not be isolated. However, the best preserved antigorite schists yielded halogen signatures strikingly similar to modern serpentinites. The spread in noble gas and halogen concentrations and isotopic and elemental ratios can be explained by variably overprinting an original seawater signature related to hydration and serpentinization of an ultramafic cumulate by a secondary  $\text{CO}_2$  bearing metamorphic fluids. The low I/Cl ratio of the original serpentinite implies that biomass was playing a similar role in moderating the seawater halogen composition in the Eoarchaean as it is today, this finding has significant implications for the prevalence of life on the Early Earth.

Kendrick et al. (2011). *Nature Geoscience*, 4(11), 807-812. Pope et al. (2012). *PNAS*, 109(12), 4371-4376; Pujol et al., (2013). *Nature*, 498(7452), 87-90.

## **Towards an Australian Ar geochronology map**

Geoff Fraser<sup>1</sup>, Marnie Forster<sup>2</sup>, Davood Vasegh<sup>2</sup>

*1 Geoscience Australia, 2 Research School of Earth Sciences, Australian National University*

At the previous TANG<sup>3</sup>O meeting, in Adelaide, we presented the idea of developing an Ar geochronology map of Australia. In recent months we have developed a prototype of such a map. Much work remains to be done; (i) to further populate the map with existing data, (ii) to develop a range of appropriate visualization tools, and (iii) to fill major data gaps with new data. The prototype map does, however, provide an example of a systematic way to compile Ar geochronology data and then view it in map form.

In this presentation we will:

- describe the motivation for this work, emphasising the value of map views of isotopic data to reveal geological evolution, and to facilitate integration of these data with independent geological and geophysical datasets.
- illustrate the data structure and the prototype Ar map.
- seek feedback on the approach used, the data structure, and the availability of existing data for inclusion in the compilation.

## Highly retentive $^{39}\text{Ar}$ diffusion parameters for a biotite from Sulawesi

Marnie Forster<sup>1</sup>, Gordon Lister<sup>1</sup> and Juliane Hennig<sup>2</sup>

<sup>1</sup>Argon Geochronology and Structural Geology, Earth Dynamics Group, RSES, ANU,  
<sup>2</sup>SouthEast Asia Research Group (SEARG), Department of Earth Sciences, Royal Holloway  
University of London, Egham, TW20 0EX, UK

The interpretation of results from biotite  $^{40}\text{Ar}/^{39}\text{Ar}$  geochronology relies on relatively few direct measurements of the diffusion parameters at relevant conditions of pressure and temperature. However, whereas it is difficult to conduct experiments that ensure mineral stability at pressure and temperature, it is readily possible to conduct  $^{39}\text{Ar}$  diffusion experiments under conditions experienced in ultra-high-vacuum (UHV) conditions, at the same time as undertaking furnace step-heating temperature-controlled  $^{40}\text{Ar}/^{39}\text{Ar}$  geochronology. The caveat applied must be that the mineral remains metastable under the conditions of the experiment, which appears possible if all traces of water and extraneous  $^{40}\text{Ar}$  are removed by virtue of a prolonged episode of cleaning made possible by warming the mineral under UHV conditions for a protracted period prior to the experiment.

No direct observation of irradiated material has been undertaken, so the observation of a well-behaved Arrhenius plot is used as a proxy to suggest whether or not the diffusion experiment succeeded. A new design of furnace has been employed that will allow future experiments with non-irradiated material. Samples would have to be extracted (and replaced) during such experiments, which introduces possible effects related to the incursion of air and water once more into the sample. The new experiments will also be extremely time consuming, since once the furnace has been exposed to the atmosphere, it must be rigorously cleaned before UHV conditions can once again be attained.

We have modelled Arrhenius data from two biotite samples from a young rapidly cooled Pliocene pluton in northern Sulawesi, using the Wunderkind inversion routines in the *eArgon* computer program to obtain estimates of the diffusion parameters. Visual inspection of the Arrhenius plots allows estimates of the activation energy that vary from 55 kcal/mol for the least retentive domain, and up to 110 kcal/mol for the retentive domain. The lower estimate is compatible with previous experimental results, where the estimated activation energy was 47 kcal/mol in one experiment and 50 kcal/mol in another experiment, for two biotite with different Fe/Mg ratios. The automated inversion process using the *eArgon Wunderkind* routines produces an estimate of ~51 kcal/mol for the least retentive domain, which is within error of the result obtained using hydrothermal experiments measuring bulk loss of  $^{40}\text{Ar}$  from Fe-rich biotite.

Biotite can range in its composition over a wide range, and incorporate fluorine for example. In the latter case, since fluorine is electron hungry, we speculate that such biotite would have very high retentivity in respect to argon diffusion. Very high cooling rates have been inferred for the Palu Metamorphic Complex in northwest Sulawesi, based on the coincidence or near coincidence of U–Pb ages from zircon and from  $^{40}\text{Ar}/^{39}\text{Ar}$  geochronology. Similarly extreme rates of cooling (~1150°C/Ma) can be inferred from the near coincidence of the  $3.24 \pm 0.05$  Ma cooling age, determined from the least retentive domain of this biotite, with the  $3.36 \pm 0.08$  Ma maximum age that derives from the retentive domains. Closure temperatures for the two domains are 358°C and 494°C, respectively, for a cooling rate of 1150°C/Ma, at 200 MPa ambient pressure.

## How hot the bottom of the orogenic lid of the European Alps?

Gordon Lister, Marnie Forster, Jack Muston

*Earth Dynamics Group, RSES, Australian National University, Australia*

When mountain belts form, the orogenic lid rarely survives. Uplift and erosion make short work of its degradation. Yet what happens to it is diagnostic of the processes that were taking place in the hot rocks of the orogen core. When fragments do survive, the key question is how thick these fragments were at the time that the metamorphic rocks beneath were exhumed. Here we illustrate calculations designed to answer this question, based on data obtained from samples from the base of the orogenic lid of the European Alps, in Eastern Switzerland. We ascertain their maximum temperature immediately prior to the initiation of detachment faulting.

The calculation is made possible because the variation of temperature with time can be constrained by inversion, using the results of: i)  $^{40}\text{Ar}/^{39}\text{Ar}$  geochronology during a sequence of temperature-controlled furnace-step-heating experiments; and ii) modelling the development of age spectra using diffusion parameters derived from  $^{39}\text{Ar}$  diffusion experiments during the same sequence of experiments. The time of juxtaposition has been determined by dating the mylonites beneath, with the maximum temperature reached in the early stages of mylonitisation inferred from the minerals that have grown during this deformation. Since biotite developed in microdilution sites in mylonites immediately below the detachment, this temperature is inferred to be  $\sim 400^\circ\text{C}$ . Since: i) the inversion can be shown to sensitively determine the upper envelope of temperature at the time of juxtaposition; and ii) the conductivity equations ensure that there is immediate (*i.e.*, on a very short time scale) relaxation of the step in the geotherm caused by a major detachment fault, at least when it comes to temperature variation in samples taken within a short distance of it, therefore the maximum temperature at the base of the orogenic lid immediately prior to juxtaposition can also be inferred.

The nature of the orogenic lid of the European Alps has long been disputed, with the currently prevailing theory that it was cold and thick, floating above northward extruding hot metamorphic rocks now exposed in the Lepontine and Tauern culminations. The alternative hypothesis is that the cold upper levels of the orogen are preserved as relatively thin disrupted sheets, exposed above extensional low-angle normal detachment faults associated with extensional ductile shear zones. According to this view, the Lepontine and Tauern culminations are metamorphic core complexes formed by extreme extension. They were horizontally stretched, at a low-angle to the trend of the mountain belt, during westward roll back of the lithosphere of the PalaeoPo basin. In the first case the orogenic lid is supposed to be 20-30 km thick. In the second case, it may be much thinner. We test the two models by inverting Arrhenius data from two potassium feldspar diffusion experiments, to determine diffusion parameters, and thereafter, by establishing admissible pressure-temperature-time (P-T-t) paths for rocks at the base of the orogenic lid. The results support the core complex model. The base of the orogenic lid was  $<150^\circ\text{C}$  at the time that the underlying hot metamorphic rocks were drawn from beneath it and exhumed. The orogenic lid was no more than 5-6 km thick at the time of its juxtaposition against the underlying metamorphic rocks. Deeper slices of the Dent Blanche nappe, such as host the iconic Matterhorn in central Switzerland, were drawn from beneath thicker exposures of these rocks in Austria, some 100 km to the east.

# **Cratonic reworking linked to far-field subduction systems: a Mesoproterozoic example from the western Gawler Craton**

Anthony J. Reid<sup>1,2</sup>, Fred Jourdan<sup>3</sup>

<sup>1</sup>*Geological Survey of South Australia, Adelaide, SA 5001* <sup>2</sup>*Department of Earth Sciences, University of Adelaide, Adelaide, SA 5005* <sup>3</sup> *Department of Applied Geology, Curtin University, Perth WA 6845*

The interiors of continents can respond to far-field tectonic forcing and thermochronological data on the movement history of major structures is required in order to understand how potential far-field subduction systems may have affected the craton. We have undertaken a thermochronological transect across ~300km from the central Gawler Craton to its western edge in order to understand the cooling and exhumation history of this region.

Previous thermochronology from the western Gawler Craton has highlighted that several major shear zones were active over the interval c. 1530 – 1500 Ma and again at c. 1450 Ma (Fraser, 2006). New laser ablation <sup>40</sup>Ar/<sup>39</sup>Ar analyses from igneous and metamorphic biotite give ages that young towards the edge of the craton, from c. 1580 Ma to c. 1470 – 1450 Ma. K-feldspar gives age spectra with ages as old as c. 1400 Ma to as young as c. 1100 Ma.

Recently rocks with subduction affinities recovered in government drilling programs have been interpreted to reflect east-dipping magmatic arcs that operated between the Yilgan and Gawler cratons at c. 1620 Ma, c. 1510 - 1490 Ma and c. 1400 Ma (Spaggiari and Smithies, 2015).

Cooling and/or shear zone movement ages in the Gawler Craton do not appear to directly correlate in timing with the subduction-related magmatic events preserved to the west. A possible interpretation of this is that the episodic nature of the magmatism and cooling of the inboard craton could reflect periods of steep versus flat subduction during the Mesoproterozoic. Further work is underway to better constrain the cooling history of the western Gawler Craton.

Spaggiari, C., Smithies, R.H., 2015. Eucla basement stratigraphic drilling results release workshop: extended abstracts. Geological Survey of Western Australia, Record 2015/10.

## **What is the meaning of a fission track age?**

Andrew Gleadow<sup>1</sup>, Barry Kohn<sup>1</sup> and Christan Seiler<sup>2</sup>

<sup>1</sup> *Earth Sciences, University of Melbourne, Vic 3010;* <sup>2</sup> *Geoscience Australia, Jerrabomberra Ave, Symonston ACT 2609*

Fission track dating differs from other radiometric dating systems in that the *effect* of the radioactive decay, as represented by fission tracks, is measured rather than the *amount* of the decay product. When the fission track age equation was first derived in the early 1960s it was recognised that the relationship between the number of tracks recorded on an etched surface and the volume density of parent <sup>238</sup>U atoms, depended on the length of the tracks. Until recently the practical procedures used have used neutron-induced <sup>235</sup>U fission tracks to estimate

the  $^{238}\text{U}$  parent abundance via their known isotopic ratio. Because  $^{238}\text{U}$  and  $^{235}\text{U}$  fission tracks are essentially identical in their properties (at least initially), it was assumed that their respective track length terms would cancel in the age equation, and could be therefore be ignored. However, it has also been known for over 30 years that the length distributions of spontaneous and induced fission tracks can actually be very different. Moreover, now that increasingly the  $^{238}\text{U}$  concentration is being measured directly using laser-ablation ICP-MS, there is no justification for ignoring the spontaneous track length term in the fission track age equation. For a complex spontaneous track length distribution, containing many shortened tracks, the effect of including the lengths will be to significantly increase the apparent fission track age. This could change the apparent ‘inversion’ in the sequence of apatite fission track and (U-Th)/He ages sometimes observed in studies from slowly-cooled terrains. The all-important question then needs to be asked, as to what exactly is the significance of a fission track age as conventionally calculated without reference to the track lengths. This conventional age can be considered a model age that assumes the track length distribution to be the same as that for the rapidly-cooled age standards used to calibrate the fission track dating system.

## **Evaluating a-radiation damage on zircon and baddeleyite (U-Th)/He systematics: A case study from Tasmanian dolerites**

BP Kohn<sup>1</sup>, L Chung<sup>1</sup>, VS Kamenetsky<sup>2</sup>, AJW Gleadow<sup>1</sup>

<sup>1</sup>*Earth Sciences, University of Melbourne, Melbourne 3010;* <sup>2</sup>*School of Earth Sciences, University of Tasmania, Hobart 7001*

Since the advent of modern zircon (U-Th)/He (ZHe) thermochronology, several studies have demonstrated the potential of this mineral for broad application in geo-thermochronology. Recent ZHe studies have centred on the effect of accumulated a-radiation damage on He diffusion. A first order approximation for estimating this damage is derived by calculating the effective uranium concentration [eU]. Plots of ZHe age versus [eU] may be positive or negative depending on the degree of radiation damage and thermal history. We present results of a study from the well dated Early Jurassic Tasmanian dolerites demonstrating how ZHe ages from granophyric phases, with a surprisingly wide range of [eU], yield unexpected relationships. In this case ranging from the age of dolerite emplacement in low radiation damage zircon to mid Cretaceous ages in high radiation damage zircons. The latter are concordant with apatite fission track and (U-Th-Sm)/He ages on the dolerites, which have been related to a regional cooling episode associated with East Gondwana rifting tectonics. These findings indicate that (U-Th)/He data from highly radiation-damaged zircons may in some circumstances act as ultra-low temperature thermochronometers. This finding underscores the complexity of the radiation damage-He diffusion relationship. We also report results of the first attempt to carry out (U-Th)/He dating of baddeleyite, which in this case coexists with zircon in the dolerites studied.

## **Flow mapping and $^{40}\text{Ar}/^{39}\text{Ar}$ dating of Melbourne basalt**

Michael Heath, David Phillips & Erin Matchan

Previous K-Ar dating of Melbourne area basalts has suggested an age range that spans almost the entire history of the province (4.5 – 0.7 Ma), and a complex flow history has been inferred from borehole data. This seemingly complex history has been unravelled in the current study. Here, a combination of petrographic analysis, major- and trace-element geochemistry and high-precision  $^{40}\text{Ar}/^{39}\text{Ar}$  step-heating data were utilised to generate a detailed lava flow map. A geological history was then constructed to evaluate how each volcanic event has contributed to the evolution of the Melbourne landscape.

Between 8 and 4.6 Ma, volcanic activity in the Melbourne area was limited to small volume basanites and alkali basalts, forming low cones and causing occasional minor diversions of drainage channels. At 4.6 Ma, the first in a series of large volume transitional basalt flows filled a valley to the north-west. This was followed by flows at 3.0, 2.3 and 0.8 Ma, each completely filling river systems and drastically altering drainage channels. The present-day surface of Melbourne is the result of uninterrupted erosion and valley formation over the last 800 thousand years.

## **Combined U-Th-disequilibrium and (U-Th)/He dating of zircon - a new geochronometer for Quaternary volcanic records**

Martin Danišik

*John de Laeter Centre, Curtin University*

Accurate dating of Quaternary geological events is difficult because the application of traditional dating tools (e.g., radiocarbon, argon, cosmogenic nuclides or luminescence) is often limited by the lack of datable materials. Hence there is a critical need for new dating methods appropriate to Quaternary timescales. (U-Th)/He dating of zircon, when combined with  $^{238}\text{U}/^{230}\text{Th}$  disequilibrium dating, is a novel approach for dating young (<1 Ma) volcanic rocks that helps overcome these limitations. The approach, hereafter referred to as ZDD (zircon double-dating), is based on 'dependent' determination of crystallization and eruption ages for single zircon crystals by U-Th-disequilibrium and (U-Th)/He methods by using secondary ion mass spectrometry (SIMS) and conventional noble gas mass spectrometry, respectively. It is essential that both methods are applied in tandem in order to correct the (U-Th)/He based eruption ages for disequilibrium in the U and Th decay chains that is to be expected in grains younger than 1 Ma. The ZDD method has enormous potential for Quaternary Earth Science globally. Perhaps the major two advantages of the method are the following: (i) it is one of the few dating methods applicable to young (~3 ka-1 Ma) volcanic rocks; and (ii) zircon is ubiquitous in silicic rocks that are often difficult to date by argon methods due to lack of K-rich minerals. In this presentation I will describe the analytical protocols for the ZDD methodology currently employed at Curtin University and present some case studies where the ZDD method was successfully applied to date important Quaternary volcanic deposits in New Zealand and Indonesia.

## Precise determination of cosmogenic Ne in CREU-1 quartz standard, using the Helix-MC *Plus* mass spectrometer

M Honda, X Zhang, D Phillips, E Matchan, D Hamilton

The Helix-MC *Plus* multi-collector noble gas mass spectrometer at the Australian National University is uniquely equipped with three high mass resolution collectors on H2, Axial and L2 positions. Their mass resolution and mass resolving power are as high as 1,800 and 8,000, respectively. The Helix-MC *Plus* can totally separate  $^{20}\text{Ne}^+$  from  $^{40}\text{Ar}^{++}$  isobaric interference and also partially separate  $^{21}\text{Ne}^+$  from  $^{20}\text{NeH}^+$  and  $^{22}\text{Ne}^+$  from  $^{12}\text{C}^{16}\text{O}_2^{++}$ . By adjusting collector positions, we are able to measure interference-free Ne isotope intensities and have re-determined the  $^{21}\text{Ne}$  abundance in air. Analyses by Honda et al. (2016) demonstrated that  $^{20}\text{Ne}^1\text{H}$  contributes approximately 2% to previously determined atmospheric  $^{21}\text{Ne}$  values, and a new atmospheric  $^{21}\text{Ne}/^{20}\text{Ne}$  ratio of 0.002906 was calculated.

Using the Helix-MC *Plus* mass spectrometer, we measured Ne abundances in the CREU-1 quartz standard and determined cosmogenic concentrations by subtraction of atmospheric Ne with the new atmospheric  $^{21}\text{Ne}/^{20}\text{Ne}$  value. The average concentration of cosmogenic  $^{21}\text{Ne}$  determined from four repeated analyses is  $338 \pm 12 \times 10^6$  atom/g ( $2\sigma$ ). This compares with the average concentration of  $348 \pm 10 \times 10^6$  atom/g ( $2\sigma$ ) from 45 analyses determined by several laboratories, where Ne isotope analyses were undertaken by conventional low resolution mass spectrometers and atmospheric Ne was subtracted using the conventional atmospheric  $^{21}\text{Ne}/^{20}\text{Ne}$ . On this basis, for a sample with abundant cosmogenic Ne, like CREU-1 quartz, previously measured by low mass resolution mass spectrometers are likely valid and their geological implications are unaffected. However, for low  $^{21}\text{Ne}$  concentration samples, combining new generation of mass spectrometers as well as the new atmospheric ratio may have significance for cosmogenic  $^{21}\text{Ne}$  surface exposure dating.

## Routine $^{40}\text{Ar}/^{39}\text{Ar}$ Geochronology with the Helix-SFT

Paulo Vasconcelos

*University of Queensland, Brisbane, Australia,*

Something to do with surface processes but it's basically a surprise.....!

## **Noble Gas Measurements of Ground and Surface Water: First Field-Samples and Application Developments**

Deslandes, A.<sup>1</sup>, Suckow, A.<sup>1</sup>, Smith, S.<sup>2</sup>, Gerber, C.<sup>1</sup>

<sup>1</sup>*CSIRO Land and Water, Gate 5, Waite Rd., Urrbrae, SA 5064, [alec.deslandes@csiro.au](mailto:alec.deslandes@csiro.au)*

<sup>2</sup>*Utah Geological Survey, Salt Lake City, UT, USA*

The noble gas facility at CSIRO's Waite site is the only laboratory in Australia and on the southern hemisphere dedicated to measure the concentrations of all noble gases (He, Ne, Ar, Kr, Xe) and the activities of the radioactive noble gas isotopes <sup>222</sup>Rn, <sup>85</sup>Kr, <sup>39</sup>Ar and <sup>81</sup>Kr in water samples.

A fully-automated measurement system that is supported by an offline extraction system has been under development from 2014-2016 for the measurement of He, Ne, Ar, Kr, and Xe. Since January 2017 we have advanced to measuring samples from groundwater and surface water field projects, together with series of gas standards and internally produced temperature-controlled water standards. This talk will feature results that highlight performance characteristics of the measurement system during this commissioning phase and how that translates into the quality of results in the application in the field.

Ongoing optimisation of the measurement process includes investigation of the adsorption and desorption kinetics of the noble gases during the cryogenic gas separation, which is of particular importance for our types of samples given the ranges of gas amounts that are analysed. Results will be presented that show differing behaviours of the separation system as we move through monolayer and multilayer adsorption regimes.

## **Characterisation of an ion source on the Helix MC *Plus* noble gas mass spectrometer - pressure dependent mass discrimination**

Xiaodong Zhang and Masahiko Honda

*Research School of Earth Sciences, The Australian National University, Canberra, Australia*

To obtain reliable measurements of noble gas elemental and isotopic abundances in a geological sample it is essential that the mass discrimination (instrument-induced isotope fractionation) of the mass spectrometer remains constant over the working range of noble gas partial pressures. It is known, however, that there are pressure-dependent variations in sensitivity and mass discrimination in conventional noble gas mass spectrometers. In this study, we discuss a practical approach to ensuring that the pressure effect in the Helix MC *Plus* noble gas high resolution, multi-collector mass spectrometer is minimised.

The isotopic composition of atmospheric Ar was measured under a range of operating conditions to test the effects of different parameters on Ar mass discrimination. It was found that the optimised ion source conditions for pressure independent mass discrimination for Ar were different from those for maximised Ar sensitivity. The optimisation can be achieved by mainly adjusting the repeller voltage. It is likely that different ion source settings will be required to minimise pressure-dependent mass discrimination for different noble gases. A

recommended procedure for tuning an ion source to reduce pressure dependent mass discrimination will be presented.

## **Introducing the new Altona amplifier: redefining the dynamic range of the Faraday cup**

Damian Tootell

*Isotopx, Middlewich, Cheshire, UK [damian.tootell@isotopx.com](mailto:damian.tootell@isotopx.com)*

The precision of isotope ratio mass spectrometry has always been limited by the ability to precisely measure ion beam currents, especially in the applications of static vacuum noble gas MS and Thermal Ionisation MS where there is an increasing trend to analyse smaller amounts of sample. The limit of precision becomes defined as the ion beam signal approaches the noise floor of the system where the signal/noise ratio falls and precision suffers.

Pulse counting techniques can be used with electron multiplier devices but are severely limited by dynamic range and can be susceptible to gain instabilities and non-linearities.

In contrast, the traditional Faraday cup detector has well characterised linearity, can be gain calibrated electronically and offers the ultimate dynamic range. Efforts to reduce noise have focussed on higher ohmic resistors, but this results in a compromise in dynamic range and time response.

In response to these limitations, we have developed a new Faraday amplifier ATONA (aA to nA) which offers unique performance displaying an extended dynamic range with an extremely low noise floor.

At 100sec integration time we can achieve  $1.5 \times 10^{-18}$ A (<10 cps) amplifier noise which exhibits the equivalent performance of a  $10^{14}\Omega$  (100T $\Omega$ ) resistor amplifier. Ion beams in excess of 1nA can be measured which is equivalent to 100 volts on a  $10^{11}\Omega$  (100G $\Omega$ ) resistor amplifier.

Data loss due to tau delays are reduced by two orders of magnitude compared to conventional amplifiers, the signal settles to <1ppm within 100ms.

## **Noble Gas Mass Spectrometry with multicollection and high resolving power – a British perspective**

John Saxton

*Nu Instruments*

Over the last few years, we have gathered extensive data to explore the measurement capabilities of Noblesse, our multicollector noble gas mass spectrometer. Noblesse now features a source with adjustable resolving power, and a multicollector with 5 channels, each switchable between a Faraday and an ETP multiplier.

High mass resolving power (MRP) allows measurement of noble gas species, free of interferences. This can be done either by true resolution (when the mass scan shows a valley between the peak and interference) or by edge resolution. There are advantages and

disadvantages to each method. We find edge resolution to be useful in many cases (the main exception being  $^3\text{He-HD}$ ).

We prefer to measure  $^{20}\text{Ne}$  edge resolved, as opposed to true resolved, from  $^{40}\text{Ar}^{++}$ . Edge resolution provides more peak flat (for a given MRP), or permits use of a lower MRP (than would be required for true resolution), giving greater sensitivity. Although the  $^{20}\text{Ne}$  measurement position then includes  $\text{HF}+\text{H}_2\text{O}$ , this contribution can be easily determined at the foot of the peak in a separate, brief, step. We have also determined the  $^{20}\text{NeH}$  contribution to the mass 21 peak; for air Ne this is 0.1 to 0.2%.

We can edge resolve  $^{36}\text{Ar}$  from  $\text{H}^{35}\text{Cl}$  (and hence also  $^{12}\text{C}_3$ ), but have demonstrated it is important to consider the effects of measuring  $^{36}\text{Ar}$  at the extreme edge of the peak. Mass setting is critical, and we have developed a method to verify this during the actual  $^{36}\text{Ar}$  measurement.

Multicollection permits a greater fraction of ions to be counted, which should yield greater precision for a given sample. This is clearly demonstrated by repeat measurements of small Xe samples.

## **Noble Gas Mass Spectrometry – an update.**

Doug Hamilton – Product Manager Noble Gas Mass Spectrometry<sup>1</sup>

<sup>1</sup>*Thermo Fisher Scientific, Bremen, Germany.* [Doug.Hamilton@ThermoFisher.com](mailto:Doug.Hamilton@ThermoFisher.com)

In the last decade there has been a revolution in static vacuum mass spectrometry. The emergence of a variety of new instruments with advances in ion optics, electronic design and materials development have resulted in a range of high performance instruments that have enabled the scientific community to resolve a number of long standing analytical issues.

The first of these systems, the *ARGUS VI*, is a low volume, therefore high sensitivity system, designed predominantly for the argon community. Its internal volume of less than 700cc's makes it extremely sensitive and its electronically cross calibrated flexible multicollector array make it very precise. The second system is the *HELIX SFT*. This system is designed as a high resolution multicollector platform for the analysis of helium 3 & 4 and as a high resolution peak jumping system. Given the *HELIX SFT's* large dispersion of 35cm's the system has a resolution of >700 at 5% valley. The final instrument in this product portfolio is a high resolution variable multicollector mass spectrometer for the Noble gas community. The *HELIX MC Plus* is a 35cm 120 degree extended geometry platform that has been developed with both multicollector and high resolution in mind. The collector array contains a number of exciting new developments including ultra stable CDD detectors and high gain faraday technology not seen before in a variable array static vacuum system. The design goal with regard to resolution was to enable the end user to deal with certain isotopic interferences that historically hampered the scientific community.

In my talk I will outline the status of these systems and present some new developments for 2017 applicable to these three platforms.

# Creating an International Geochemistry Network to Connect Researchers, Data Repositories and Publishers

Lesley Wyborn<sup>1</sup>, Shelley Stall<sup>2</sup>, Kerstin Lehnert<sup>3</sup>

<sup>1</sup>*National Computational Research Infrastructure, Canberra, Australia, [Lesley.wyborn@anu.edu.au](mailto:Lesley.wyborn@anu.edu.au)*; <sup>2</sup>*American Geophysical Union, Washington, USA, [sstall@agu.org](mailto:sstall@agu.org)*; <sup>3</sup>*Lamont-Doherty Earth Observatory of Columbia University, New York, USA, [lehnert@ldeo.columbia.edu](mailto:lehnert@ldeo.columbia.edu)*

Open, accessible high-quality data, as well as related data products and software, are critical to the integrity of published research: they are key to ensure transparency of research and to support reproducibility and repeatability. To accelerate this process, the American Geophysical Union (AGU) and a set of partners representing International Earth Sciences, have been awarded a grant from the Laura and John Arnold Foundation [1] to develop a collaborative solution across researchers, repositories and journals (including Science, Nature, Wiley and Elsevier) that will evolve the Earth science publication process to include not just the publication, but all research inputs into that publication (datasets, physical samples, images, video, software, etc.) to help develop a unified process that is efficient and standardised for researchers, and supports their work from grant application through to publishing. The project will be based around the FAIR guidelines [2], which seek to ensure that research artifacts that are input to and/or support the publication process will be Findable, Accessible, Interoperable, and Reusable (FAIR). Partners in this initiative from Australia are AuScope [3], the National Computational Infrastructure (NCI) [4] and the Australian National Data Service (ANDS) [5].

These new requirements will be a challenge for geochemical and isotopic data. Unlike other geoscience ‘Big Data’ sets (e.g., airborne geophysics, remote sensing) where the data is typically standardized, and relatively well managed and curated in funded community data facilities, geochemistry is a part of the ‘Long Tail’ of science. Typical data sets are very small in size, and particularly where individual investigators acquire the data, these small datasets can be poorly shared and integrated: most are stored by researchers on their own or departmental private systems.

The pressure from funding agencies and publishers for greater accessibility to data acquired (especially that acquired with public funding) is leading to new challenges for data curation and archiving of geochemical and isotopic data. A key thing missing is internationally agreed, machine-readable standards for attributes/data models to describe geochemical and isotopic data and analytical methods. Such standards would lead to improved discoverability and reusability of high-value samples and datasets. There are groups in the US and in Europe who want to collaboratively develop these standards: participation from the Australian geochemical and isotopic community would be most welcome.

1. American Geophysical Union Coalition Receives Grant to Advance Open and FAIR Data Standards in the Earth and Space Sciences. Available from <http://news.agu.org/press-release/agu-coalition-receives-grant-to-advance-open-and-fair-data-standards/> Accessed 30 August 2017. 2. The Force 11 FAIR data principles. Available from <https://www.force11.org/group/fairgroup/fairprinciples>, accessed 30 August 2017. 3. AuScope. Available from <http://auscope.org.au/>, accessed on 30 August, 2017. 4. National

Computational Infrastructure. Available from <http://nci.org.au/>, accessed on 30 August, 2017.  
5. Australian National Data Service (ANDS). Available from <http://www.ands.org.au/>, accessed on 30 August, 2017.

## **A vision for a geochemistry open data ecosystem**

Brent McInnes<sup>1,2</sup>, Tim Rawling<sup>2,3</sup>, Ryan Fraser<sup>4</sup>, Lesley Wyborn<sup>5</sup>, Jens Klump<sup>4</sup>, Adam Brown<sup>4</sup>, Victor Tey<sup>4</sup> and Warick Brown<sup>1</sup>

*1. John de Laeter Centre, Curtin University, Perth WA; 2. AuScope Ltd; 3. University of Melbourne, Melbourne VIC; 4. CSIRO Mineral Resources/Data61, Perth WA ; 5. ANDS/NCI*

Geochemistry laboratories in public research institutions are producing unprecedented volumes of high-value data useful in understanding the composition and evolution of the Australian continent. AuScope is collaborating with other national and international research infrastructure bodies interested in supporting the Australian geoscience community to develop “open data” environments. Discussions at the 2016 TANG<sup>3</sup>O meeting indicated community interest in creating open data repositories for “high-value” geochronometry (e.g., U-Pb, Ar-Ar, U-He and fission track) and isotope geochemistry (e.g., Hf, Nd and Pb) data sets. These repositories would serve as a community resource where researchers could submit datasets that relate to publications and also meet ARC data management requirements.

The development of a national geochemical data repository has two critical dependencies: (1) a persistent identifier system for physical samples to eliminate confusion around replicate sample IDs, and (2) agreed standards for registering, contributing, accessing and sharing geochemical data. Regarding item (1), it is anticipated that Australian researchers will be able to register their research collections via a modified International GeoSample Number (IGSN) web service by mid-2018. Regarding item (2), AuScope is keen to address this issue by supporting Australian expert groups to work in partnership with US and European counterparts and in collaboration with the International Geochemical Society, to begin discussions on how to progress the development of the required technical standards for data reporting and governance. The AuScope Discovery Portal could be adapted to host the repositories, and create a greater awareness of the existence of primary materials and derivative datasets.

## The new University of Wollongong (UOW) cosmogenic isotope sample preparation and chemistry laboratories

Alexandru T. Codilean<sup>1</sup> and Réka H. Fülöp<sup>1,2</sup>

(1) *School of Earth and Environmental Sciences, University of Wollongong*

(2) *Australian Nuclear Science and Technology Organisation (ANSTO)*

In November 2016, the School of Earth and Environmental Sciences took possession of a series of new sample preparation and wet-chemistry laboratories, including a metal-free clean laboratory. From January 2017, all UOW cosmogenic nuclide sample preparation and chemistry work moved to these new labs, with over 250 samples processed to date. Initial sample handling (e.g., washing, sieving, magnetic separation) is performed in a dedicated 'dirty' lab and quartz purification is performed in a wet-chemistry laboratory equipped with two fume cupboards, an ELIX water purification system, a froth-floatation system, and hot-dog rollers for hydrofluoric acid leaching. The laboratory also has numerous ovens for sample drying and a setup for performing heavy-liquid separation. Beryllium and Aluminium chemistry is carried out in a clean laboratory that is equipped with two custom-built high-capacity fume cupboards suitable for the fuming of multi-litre volumes of hydrofluoric acid and perchloric acid, and two custom-built evaporation stations, each with six independent evaporation chambers. The laboratory is also equipped with two ductless fume cupboards and four ductless vertical laminar flow cabinets used for column chromatography work. The setup means that the new clean laboratory is unique in Australia in terms of versatility and quality of services.

Earth surface landscapes evolve because of complex interactions of both exogenic and endogenic processes. Understanding dimensions and timescales over which these processes operate is important considering potential feedbacks between tectonic activity, structural inheritance, climate change and human impacts. Cosmogenic <sup>10</sup>Be has proven to be the best suited technique for studying the erosion of Earth's continental topography over millennial timescales. Indeed, <sup>10</sup>Be-based denudation rates have now been determined in more than 3000 river catchments providing us with a large inventory of erosion rate estimates. However, we still know very little about the controls on denudation rates and mass fluxes in the low-gradient regions that cover ~90% of the planet's land surface. And likewise, we have much more to do in the steepest landscapes where episodic erosion processes such as landsliding dominate, making erosion rate estimates heavily dependent on the timescales over which they are computed. At UOW, we study the spatial and temporal dynamics of denudation at the extremes of the denudation-rate and topography spectrums, with projects in Australia, Japan, the Himalayas, and elsewhere.

**The new ANSTO/UOW in-situ cosmogenic carbon-14 extraction system.**

R-H. Fülöp<sup>1,2</sup>

*1. Australian Nuclear Science and Technology Organisation (ANSTO), Lucas Heights NSW 2234, Australia 2. School of Earth and Environmental Sciences, University of Wollongong, 2522, Wollongong, Australia*

We present results of in situ cosmogenic  $^{14}\text{C}$  system blank and calibration sample measurements obtained with the recently established ANSTO – University of Wollongong in situ  $^{14}\text{C}$  extraction system. The  $^{14}\text{C}$  extraction scheme follows the design of the University of Cologne (Fülöp et al., 2015), which exploits the phase transformation of quartz to cristobalite to quantitatively extract the carbon as  $\text{CO}_2$ . Offline high-temperature furnace extraction allows a relative rapid sample throughput and can accommodate samples ranging between 0.5 to 4 grams of clean quartz. Following extraction and isolation, the  $\text{CO}_2$  gas is graphitised using a micro-furnace and then measured using AMS similarly to routine small radiocarbon samples.

The relatively short half-life of  $^{14}\text{C}$ , namely, 5730 years, means that, compared to the other cosmogenic nuclides, it is substantially more sensitive to short term variations in process rates. Both the erosion of steep mountains and the dynamics of sediment transport, storage and recycling occur over timescales that are too short to be detectable by the cosmogenic nuclides that are currently used routinely, namely  $^{10}\text{Be}$  and  $^{26}\text{Al}$ . In situ  $^{14}\text{C}$  on the other hand is ideally suited for these short timescales, and used in combination with  $^{26}\text{Al}$  and  $^{10}\text{Be}$ , it will allow for rapid fluctuations in process rates and/or the relatively short timescales that characterise sediment transfer and storage to be measured accurately. The above make in situ  $^{14}\text{C}$  an important addition to the cosmogenic radionuclide toolkit.

Reference: Fülöp et al. (2015) Progress report on a novel *in situ*  $^{14}\text{C}$  extraction scheme at the University of Cologne, Nuclear Instruments and Methods in Physics Research Section B: Beam Interactions with Materials and Atoms Volume 361, Pages 20-24

Collaborators: A.T. Codilean, D. Fink, B. Yang, A. Smith, T.J. Dunai, L. Wacker