# K-Ar and $^{40}Ar/^{39}Ar$ Laboratory

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# Report Ar-ArCAMECO

## $^{40}Ar/^{39}Ar$ Age Determinations of

## 4 Muscovites: Sample Numbers
## MRD0103-0848
## MRD0101-1109
## MRD0104-1154
## NAND0207-1760


Analyses and report by

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# $^{40}Ar/^{39}Ar$ Dating of Muscovites Separated from Metamorphic Rocks

## 1. INTRODUCTION

This report documents $^{40}Ar/^{39}Ar$ dating results obtained from aggregates of muscovite crystals that were separated from metamorphic rocks by the staff at the Australian National Univerisity. The sampling location of the rocks is known by the client. The samples were supplied to the ANU as rock fragments or cores for dating purposes.

## 2. ANALYTICAL PROCEDURES

Approximately 10 mg of each muscovite sample was packed in aluminium foil and placed into an irradiation canister together with aliquots of the flux monitor GA1550 Biotite (Age = 98.5 Ma; Spell and McDougall, 2003). The canister was irradiated for 12 days in either X33 or X34 (as described by McDougall and Harrison, 1999) of the HIFAR reactor, NSW, Australia. After irradiation, the samples were removed from their packaging and an aliquot was loaded into a double-vacuum resistance furnace and heated to progressively higher temperatures, with temperatures maintained for twelve minutes per step (see enclosed data tables). $^{40}Ar/^{39}Ar$ step-heating analyses were carried out on an extraction line connected to a VG MM12 mass spectrometer using an electron multiplier detector. Mass discrimination was monitored by analyses of standard air volumes. Correction factors for interfering reactions are as follows: $(^{36}Ar/^{37}Ar)_{Ca} = 3.50 \times 10^{-4}$; $(^{39}Ar/^{37}Ar)_{Ca} = 7.86 \times 10^{-4}$; $(^{40}Ar/^{39}Ar)_{K} = 0.027$ (± 0.005). The reported data have been corrected for system backgrounds, mass discrimination, interfering nuclear reactions and radioactive decay since irradiation. The $^{40}Ar^{*}/^{39}Ar$ ratios and ages have also been corrected for fluence gradients and atmospheric contamination. Errors associated with the age determinations are one sigma uncertainties and exclude errors in the J-value estimates. Isochron analysis of the data set was not useful as the samples are extremely radiogenic (plotting near the x-axis in almost all cases).

Decay constants are those of Steiger and Jager (1977). The $^{40}Ar/^{39}Ar$ dating technique is described in detail by McDougall and Harrison (1999).

## 3. $^{40}Ar/^{39}Ar$ STEP-HEATING RESULTS

High purity (>99%) mineral separates were obtained for all four samples. Visual analysis of various size fractions did not suggest more than one phase of mica growth. Results of $^{40}Ar/^{39}Ar$ step heating experiments are summarized in Table 1 (Excel file). $^{40}Ar/^{39}Ar$ apparent age spectra are presented in Figure 1. K/Ca plots are supplied in Figure 2.

**Figure 1:** Age spectrum diagram as .pdf file, with x-axis as $\%^{39}Ar$ released, and y-axis as age in millions of years. The low temperature side of the diagrams is on the left (see also Table 1 for temperature listings). The experiments were finished at high temperature (about 1350 °C) on the right hand side of the diagrams.

**Figure 2:** K/Ca plotted as a function of $\%^{39}Ar$ released. Thus, the K/Ca of each step can be compared with the associated age of that step. Note that very high values of K/Ca indicate that $^{37}Ar$ was at or near background levels, thus the associated measurement of Ca was approaching unmeasureable, and the ratio K/Ca becomes very large by necessity.

Table 1: Analytical Data – Step Heating Measurement

Figure 1: Age Spectrum Diagrams

Figure 2: K/Ca Versus Released Ar

**Table 1:** Excel file of the analytical data for each step-heating measurement, including temperatures for each step. Heating duration was 12 min in all cases. The integrated ages in this data table correspond to the integrated ages shown in Figure A. These integrated ages are commonly referred to as total fusion ages or TFAs.

Note that Ar/Ar ages are only directly comparable to U/Pb ages if caution is applied. This is due partially to the fact that different standards are used in the two dating schemes, and partially to the fact that the decay constants for the two methods are not “intercalibrated”. Ar/Ar ages quoted today are generally about 1% younger than U/Pb ages, all other things being equal, due to this subtle problem with decay constants and standards. See Heath et al. (in press, Economic Geology). Thus, any U/Pb ages from this area are likely to be at least 18 million years older (or about 1% older) than these mica ages, just due to systematic uncertainty.

For age spectrum diagrams, such as in Figure A, “preferred” or “plateau” ages or “plateau-like” ages can be calculated from a subsection of the diagram. There are many reasons for and against doing such a calculation, but the primary reason for making the calculation is to exclude portions of the diagram that may contain strong age gradients. For example, the first 3-5 steps in sample 0848 Musc are much younger than the subsequent steps in the experiment. In addition the last one or two steps could be excluded if disirable. The integrated age (or TFA) for sample 0848 including all steps is 1807 ± 7 Ma, whereas when the first five steps and the final two steps are ***excluded*** the integrated age for the remaining steps is 1814.5 ± 7.2 Ma, and we have called this the “preferred age”. The calculation of such ages is generally considered as arbitrary, as the formalization of the calculation has never been agreed upon by workers in the field. Nevertheless, if you would like ages to be calculated from subsections of the diagrams I am please to do so.

## 4. SUMMARY

Muscovite concentrates extracted from metamorphic rock samples have been dated by the $^{40}Ar/^{39}Ar$ method. The data suggest a similar history for these rocks, wherein they have remained below greenschist facies temperatures (~350 °C) since about 1815 Ma. Micas are sensitive to thermal resetting and it is remarkable that these samples give such similar ages.

Sample 1760 is the exception. Given that sample 1760 was extracted, as a xenollith, from a dolerite dyke it seems likely that dyke intrusion occurred at or subsequent to about 1700 Ma. This hypothesis is consistent with Pb/Pb data indicating vein mineralization at a much younger time. It is concluded that the white mica in this sample grew prior to ~1700 Ma, and that dyke intrusion has resulted in partial resetting of the argon system.

For these Proterozoic muscovites an alternative interpretation of the data is that they are crystallization ages, provided that any thermal disturbance subsequent to about 1815 Ma was below about 300 °C. However, given the possibility of later dolerite intrusion, the data might best be interpreted as “cooling ages”. A decision to follow this interpretation would have to be based on the geological history of the region.

It is noted that there is evidence of “massive” or “total replacement” of original textures by growth of white micas. XRD data is yet to be determined, but will be available shortly. Concerning the replacement theory, there is no evidence in the argon data to indicate more than one stage of white mica growth. Further consideration of this theory could be made on textural grounds if necessary, but at this stage we strongly discount the possibility of multiple white mica forming events. If the micas in these samples are related to fluid influx then they are not likely to be contaminated by earlier mica generations.

## SELECTED REFERENCES:

McDougall, I. and Harrison, T.M., 1999. Geochronology and thermochronology by the $^{40}Ar/^{39}Ar$ method. Second Edition. Oxford Univ. Press, New York.

Spell, T. and McDougall, I., (2003). Characterization and calibration of $^{40}Ar/^{39}Ar$ dating standards: Chemical Geology, v. 198, p. 189-211.

Steiger, R.H. and Jager, E. (1977). Subcommission on geochronology: Convention on the use of decay constants in geo- and cosmochronology. Earth and Planetary Science Letters, 36, 359-362.

Table A. Summary of $^{40}Ar/^{39}Ar$ ***integrated ages*** (includes all measured steps) and ***preferred ages*** for muscovite samples. Ages quoted include a one sigma uncertainty, without including the error in J. Min = mineral dated (M for muscovite); Pur (%) = sample purity. “na” means not available. Size in mesh.

| Sample number | Min | Locality | Rock Type | Size (#) | Pur (%) | Integrated Age Preferred Age (Ma) ± 1σ |
|---|---|---|---|---|---|---|
| 0848 | M | unknown | Schist/gneiss | 60-85 | 99 | 1807 ± 7 |
| | | | Schist/gneiss | 60-85 | 99 | 1814.5 ± 7.2 |
| 1109 | M | unknown | Schist/gneiss | 60-85 | 99 | 1818 ± 7 |
| | | | Schist/gneiss | 60-85 | 99 | 1822.1 ± 6.9 |
| 1154 | M | unknown | Schist/gneiss | 60-85 | 99 | 1813 ± 9 |
| | | | Schist/gneiss | 60-85 | 99 | 1816.0 ± 9.3 |
| 1760 | M | unknown | Schist/gneiss | 60-85 | 99 | 1685 |
| | | | Schist/gneiss | 60-85 | 99 | na |