K-Ca dating in biotite

C. Storey[1], J. Darling[1] & K. Papapavlou[1]

[1]School of Earth and Environmental Sciences, University of Portsmouth, Portsmouth PO1 3QL, UK

Background and aims

A 1-day pilot ion microprobe study was undertaken in April 2016 to assess the viability of dating biotite mica using the K-Ca decay system. This followed submission of a full proposal titled "Dating mid-crustal shear zones using K-Ca on mica and the development of a new mineral exploration tool", which was considered by the steering committee to require pilot work prior to resubmission of the proposal.

The absolute age dating of ductile deformation has been achieved convincingly using Ar-Ar, Rb-Sr, and U-Pb isotope systematics. There are two approaches that can provide evidence that radioisotope systems are recording the age of deformation. The first is to prove quantitatively that crystal-plastic deformation induced isotopic disturbance of the micro-analytical volume and modified parent/daughter isotopic ratios. The second is to prove texturally that the chosen mineral chronometer defines a penetrative recrystallization fabric or a shear sense indicator. A common problem of the decay systems with volatile radiogenic daughter products (e.g. Ar-Ar) is that deformation-induced diffusional resetting may yield significantly complex age patterns. For that reason, decay systems with more retentive daughter products are preferred (e.g. U-Pb, Rb-Sr). An underutilised isotope system for the age dating of deformation and metamorphic events is the K-Ca system. In more detail, ^{40}K undergoes a branched decay to ^{40}Ar (10%) and ^{40}Ca (90%) giving rise to K-Ar and K-Ca decay schemes. So far, the K-Ca isotope system has been applied successfully as a geochronometer of high K/Ca igneous, metamorphic, and authigenic minerals and in one study isotopic microanalysis using ion microprobe has been used [1].

The main aim of this study was to test if the in-situ K-Ca age dating of fabric-forming and syn-kinematic potassic micas can be used to directly date deformation in mid-crustal environments. This will be tested on well-characterized samples from greenschist to amphibolite facies, biotite-rich mylonitic zones, which are spatially related with globally significant Ni-Cu-PGE sulphide ore bodies in the highly deformed South Range of the Sudbury impact structure (Sudbury, ON, Canada).

Samples

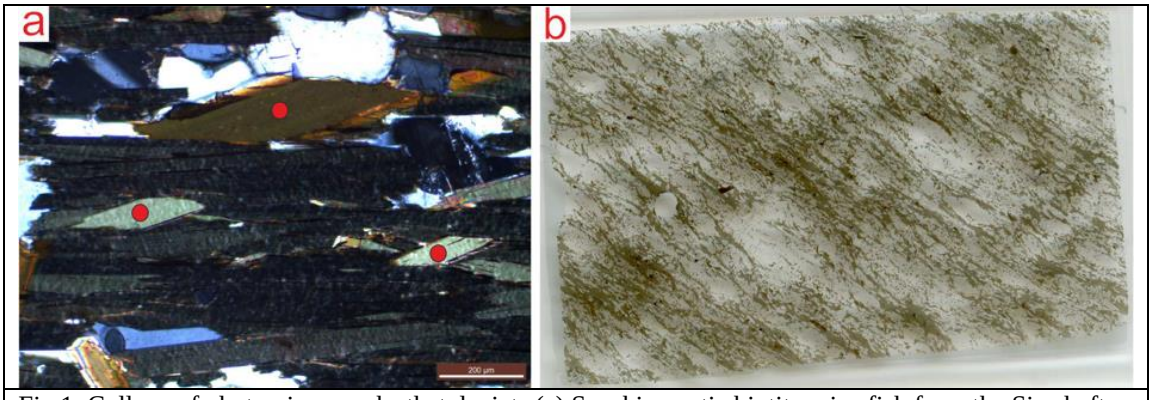

Fig 1. Collage of photomicrographs that depicts (a) Syn-kinematic biotite mica fish from the Six shaft shear zone, with red spots indicating spots for ion microprobe analysis, (b) scanned thin section from a Biotite-rich mylonite from the RAR shear zone. In this scale is evident a strong shape preferred orientation of the biotite flakes that define the mylonitic fabric.

The two structures under investigation are the Six Shaft and RAR shear zones that crop out in Creighton Mine (southern part of the Sudbury impact structure). The Six shaft shear is a km- scale, biotite-rich mylonitic zone that exhibits a strain gradient from proto-mylonites up to the local

development of ultra-mylonitic bands. The RAR shear is a steeply dipping structure with a penetrative mylonitic fabric defined by calcic amphibole (ferro-hornblende) and biotite grains. Microstructural observations show that both structures contain potassic micas with consistent synkinematic relationships, including mica fish, and biotite grains with strong shape preferred orientation that define the mylonitic fabrics (Fig. 1). Previous work on the samples provides independently constrained age data with which to compare the K-Ca results. Preliminary U-Pb isochron age data from titanites with strong shape preferred orientation, which we interpret to record syndeformational growth, yield ages of 1672 ± 53 Ma and 1663 ± 66 Ma in the Six Shaft and RAR shears respectively.

Results and outlook

K-Ca isochrons with at least six analyses were measured, and ages calculated from four samples: two from the Six shaft shear zone, and two from the RAR shear zone (Fig 2). In all cases, the isochrons give precisions of c.1%, which demonstrates analytically that the method produces good quality and reproducible data. In terms of accuracy, the ages are all much younger than the titanite U-Pb ages. This was an unexpected result and demonstrates that the closure temperature for Ca in biotite must be low. The area is ca.7km north of the Grenville Front and hitherto there had been no recorded thermal overprint of the area. These new data imply that this is not the case and so low T Grenvillian overprinting should be taken into consideration in future studies of the southern part of the Sudbury impact melt sheet and its mineralisation. Further work on white mica, which will have a higher closure temperature for Ca, is likely to be the best way forward for dating ductile shear zones that are above greenschist facies or have been subjected to later thermal overprinting. Biotite K-Ca dating could be a useful addition to low temperature geochronometry.

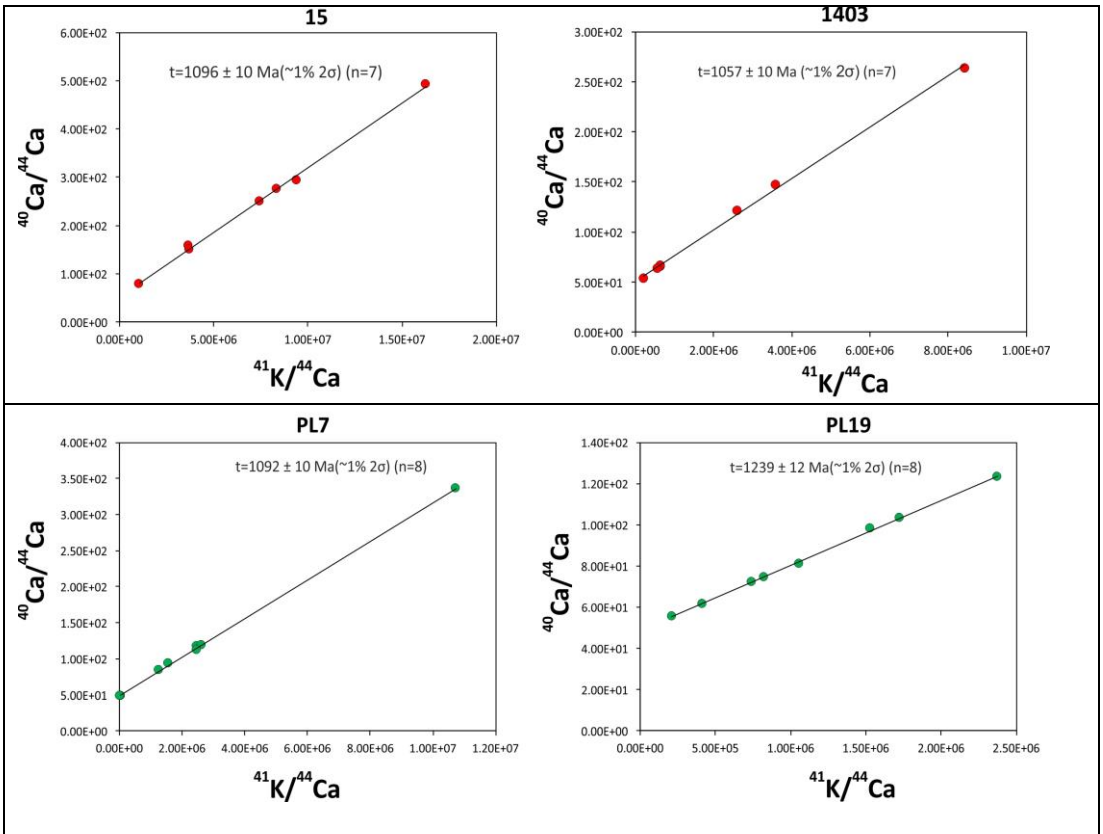

Fig 2. K-Ca isochrons from biotites within the Six shaft shear zone (samples 15 and 1403 – red spots) and RAR shear zone (samples PL7 and PL19 – green spots)

References

[1] T.M. Harrison, M.T. Heizler, K.D. McKeegan, A.K. Schmitt., 2010, In situ ^{40}K-^{40}Ca 'double-plus' SIMS dating resolves Klokken feldspar ^{40}K-^{40}Ar paradox. *EPSL* 299, 426 – 433.