

Supplementary information

Detailed appraisal of biotite petrography

In order to evaluate the integrity of biotite Rb-Sr ages, it is important to conduct further petrographic assessment of these samples, as biotite ages may be adversely affected by chloritization.

SW12-03 (biotite Rb-Sr age: 440.4±1.3 Ma)

Biotite in this sample is extremely fresh, with no chlorite observed in thin section (Supplementary Figure 1. A-B). It is therefore extremely improbable that the age is affected by the effect of chloritization.

Further, the biotite within the sample is the most radiogenic of all samples analysed, with $^{87}\text{Sr}/^{86}\text{Sr}_{\text{biotite}}$ of 2.662, indicating that minimal chlorite can be present. We therefore propose that the biotite Rb-Sr age determined on this sample is robust.

SW12-06 (biotite Rb-Sr age: 417.1±1.2 Ma)

We consider that the age determined on the biotite from this sample is not robust. Firstly, the $^{87}\text{Sr}/^{86}\text{Sr}$ of the biotite is only slightly more radiogenic than the muscovite (0.913525 ± 12 compared with 0.900985 ± 13). There is also up to 30% chloritization in some, although not all, of the biotite grains (cf. Supp. Fig. 1.C-E). Whilst every care was taken when picking grains for isotopic analyses, it is impossible to state with certainty that no chlorite was incorporated into the analysed fraction. The integrity of the biotite Rb-Sr age determined on this sample therefore cannot be verified.

SW12-10 (biotite Rb-Sr age: 419.0±1.1 Ma)

The biotite in this sample is extremely coarse, up to 1cm in length. The majority of the large crystals are chlorite-free, however within several of the biotite grains, severe chloritization has occurred with one observed to have been >50% replaced by chlorite (Supp. Fig. 2 A&B). Although every care was taken during picking; it is difficult to say definitively that no chlorite was contained in the analysed fraction.

Therefore, despite the very high $^{87}\text{Sr}/^{86}\text{Sr}_{\text{biotite}}$ (2.143), that suggests the picked sample was not affected by severe chloritization, it is impossible to definitively state that the biotite Rb-Sr age has not been affected by the presence of chlorite.

SW12-11 (biotite Rb-Sr age: 410.4±1.1 Ma)

Biotite in this sample is very fine grained, typically <1mm in length, which may be the cause of the relatively low $^{87}\text{Sr}/^{86}\text{Sr}_{\text{biotite}}$: 1.305 compared to the $^{87}\text{Sr}/^{86}\text{Sr}_{\text{muscovite}} = 0.9543$. There is however, no evidence of chloritization within the biotite grains (Supp. Fig. 2 E&F), and no chlorite was observed during petrographic analysis. We therefore consider that chloritization has not affected the biotite age determined on this sample.

SW12-14 (biotite Rb-Sr age: 444.0±1.0 Ma)

Chlorite and biotite are both observed within this sample, but chlorite appears to be primary rather than a retrogressive feature caused by the chloritization of biotite (Supp. Fig 3). This, combined with the high $^{87}\text{Sr}/^{86}\text{Sr}_{\text{biotite}}$ (1.3706) compared to the $^{87}\text{Sr}/^{86}\text{Sr}_{\text{muscovite}}$ (0.7572) suggests that this age is not affected by chloritization.

Supplementary information – figure captions

Fig 1.

A – SW12-03 ppl; B – SW12-03 xpl; C – SW12-06 ppl; D – SW12-06 xpl; E – SW12-06 ppl chloritised biotite. All mineral abbreviations from Kretz 1983.

Fig 2.

A – SW12-10 ppl; B - SW12-10 xpl; C – SW12-10 2 ppl; D – SW12-10 2 xpl; E – SW12-11 ppl; SW12-11 xpl. All mineral abbreviations from Kretz 1983.

Fig 3.

A – SW12-14 ppl; B – SW12-14 xpl; C – SW12-14 2 ppl; D – SW12-14 2 xpl. All mineral abbreviations from Kretz 1983.