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The problem of 37Ar & 39Ar recoil redistribution in dating Ca-rich groundmass-like samples

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The 40Ar/39Ar dating technique requires the transformation of 39K in 39Ar by neutron activation. Neutron activation has undesirable secondary effects such as interfering isotope production and recoil of 39Ar and 37Ar atoms from their (dominant) targets of K and Ca. Previous studies [e.g., 1] have highlighted the influence of 39Ar and 37Ar loss on 40Ar/39Ar ages of fine-grained minerals. 39Ar loss directly increases the 40Ar*/39ArK ratio and therefore the apparent age. 37Ar loss, in the case of Ca-rich minerals, affects the apparent 40Ar/39Ar age via interference corrections on 36Ar (and to a lesser extent 39Ar), yielding lower 40Ar*/39ArK and thus, an age spuriously too young. Recoil is harmless for most applications of the 40Ar/39Ar technique, but the increasing needs to date fine-grained rocks (e.g., aphyric basalt or impact melt rocks [2]) render this effect more obvious.

The grains produced by mechanical crushing during sample preparation have typical sizes of 200-1000 μm, much larger than the size of individual crystals contained in the groundmass (few μm to tens of μm). As a result, the low surface/volume ratio of the grains prevents any 39Ar and 37Ar loss out of the system during irradiation. On the other hand, 39Ar and 37Ar recoil might affect the shape of the step-heating age spectrum by reallocating the 39ArK to domains with low K/Ca ratio and the 37ArCa to domains with high K/Ca ratio. Traditionally, the low-temperature hump in the age spectrum is interpreted as 39Ar recoil loss from these sites, whereas the high-temperature pseudo-plateau is suggested to represent the true emplacement age of rock.

In this study, we present five 40Ar/39Ar step-heating experiment results carried out on crypto-crystalline pseudotachylitic breccias from the Gravberg-1 drill core, Siljan impact structure. The five samples produced variably tilde-shaped age spectra suggesting that they are unevenly affected by recoil redistribution. The high-temperature steps of the five experiments define five tiny "plateaus" with ages ranging from 377.2 $\pm$ 1.7 (including 26% of the 39Ar gas) to 379.4 $\pm$ 1.6 (47% of 39Ar) Ma and are positively correlated with the respective amounts of gas included in the plateaus. Integrated (total fusion) ages of the five samples yielded five concordant ages with a weighted mean of 382.1 $\pm$ 0.6 Ma (P=0.53, calculated with the latest decay constants of [3]). The Ca-rich high-temperature phases of the melt rock yielded variably perturbed age spectra with, as a general observation, the shorter the plateau, the younger the age. We interpret this result as an indication that the 37Ar recoil redistribution has affected the high temperature part of the age spectra and suggest as a general rule, that high-temperature mini-plateaus should not be used for deriving the age of rocks affected by recoil. Extrapolating the [Age vs. % 39Ar] correlation curve to 100% of 39Ar released yields an age indistinguishable from the total fusion weighted mean ages ($\sim$382 Ma). The concordance of all the total fusion ages, the convergence of the extrapolation curve and petrographic observations suggest that the Siljan melt rocks have been solely affect by irradiation artifacts and therefore, that the total fusion ages represent the best estimate of the emplacement age of the Siljan crater. If the absence of alteration can be demonstrated, multi-aliquot measurements on fine-grained groundmass might represent a solution for resolving the emplacement age of rocks otherwise affected by recoil redistribution.

[1] Jourdan et al., (2007) GCA 71, 2791-2808; [2] Fernandes & Burgess (2005) GCA 69, 4919-4934. [3] Renne et al. (2010) GCA 74, 5349-5367.