Dating fine-grained sericite and illite: new ideas in interpretation of $^{40}Ar/^{39}Ar$ age spectra using sample encapsulation

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The potassium-argon (K-Ar) and argon-argon ($^{40}Ar/^{39}Ar$) methods are commonly used to determine the ages of sericite and other potassium bearing mica/clay minerals. A problem in dating of fine-grained (<20 microns) clay-like material is that the K-Ar age is often younger than that from other geochronometers (e.g., Rb-Sr, biostratigraphy). This may be due to loss of ^{40}Ar in nature either by ejection of the ^{40}Ar atom by "recoil" during the decay of ^{40}K, or by diffusion from the "leaky" structure of these minerals resulting in an closure temperature lower (<150°C) than that determined from laboratory diffusion experiments.

As part of the $^{40}Ar/^{39}Ar$ dating method, samples are irradiated in a nuclear reactor to produce ^{39}Ar from ^{39}K. This allows both the parent and daughter to be measured simultaneously in the mass spectrometer and allows for step-heating and other experiments to assess the loss of ^{40}Ar during geologic time. For fine-grained minerals, the energy of the ^{39}K to ^{39}Ar transmutation during irradiation may cause ^{39}Ar to recoil from the mineral. For most minerals, the grain size is sufficiently large enough that recoil is insignificant. However for clays and sericites, up to 40% of all ^{39}Ar can be lost by recoil. Because age is proportional to $^{40}Ar/^{39}Ar$, this can significantly bias the age by the $^{40}Ar/^{39}Ar$ method (compared to the K-Ar age) if this recoiled ^{39}Ar is not measured. We present a process of encapsulating a sample in a quartz ampoule prior to sample irradiation that allows for the capture of recoil ^{39}Ar and the ability to measure this gas. The ratio of the radiogenic ^{40}Ar in a sample to the total ^{39}Ar (including the "captured" argon) would be proportional to the K-Ar age of the sample.

The "retention age" model for interpreting argon data (Hall et al., 2000, Econ. Geol., v. 95, p 1739-1752) is based on the idea that ^{40}Ar lost in nature is proportional to the ^{39}Ar lost in sample irradiation. Thus, the ratio of the total amount of ^{40}Ar in a sample to the ^{39}Ar in the sample following irradiation excluding the encapsulated ^{39}Ar (the integrated age of an unencapsulated sample) would yield the most geologically meaningful information and is more consistent with other geochronometers.

We present results from encapsulated and unencapsulated sericite, illite, biotite and muscovite samples, illustrating the effect of recoil on an age spectrum and the application of the retention age model for determining "true" ages of fine-grained material. In general, large (>100 micron), well crystallized, biotite and muscovite have negligible (<0.3%) ^{39}Ar recoil loss, while sericites and illites range from 5% to more than 40% ^{39}Ar recoil loss. With minor loss, classic "plateau analysis" and "isochron analysis" of $^{40}Ar/^{39}Ar$ spectra yield geologically "valid" results and can identify "reset" events. For the finer grained minerals with complex geologic histories, these approaches need to be modified to reflect the redistribution of ^{39}Ar within the mineral, however cooling (retention) and reset ages can still be determined.