# May recovery of thermal history by K-feldspar $^{40}Ar/^{39}Ar$ thermochronology be limited by the thermal history itself? Constraints from the thermochronological study of the Panafrican Ethiopian basement

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Our recent $^{40}Ar/^{39}Ar$ thermochronological study on Panafrican Ethiopian basement has revealed a possible paradox between the K-feldspar and the mica data. The K-feldspar modelled cooling history (Lovera *et al.*, 1991; 1989) appears inconsistent with the mica data (Fig. 1a); this paradox is also outlined through the K-feldspar diffusion parameters which imply that the most retentive diffusion domains in K-feldspar ($T°_{closure}$ = 350–461°C) are more retentive than micas even though they yield a younger age. Because this paradox affects all the analysed K-feldspar, from post-tectonic granitoids as well as from high-grade metamorphic rocks over 1500 km in Ethiopia, it does not seem to be a coincidence but may reflect a similar behaviour for all these samples. Various hypotheses can be envisaged to explain such a paradox:

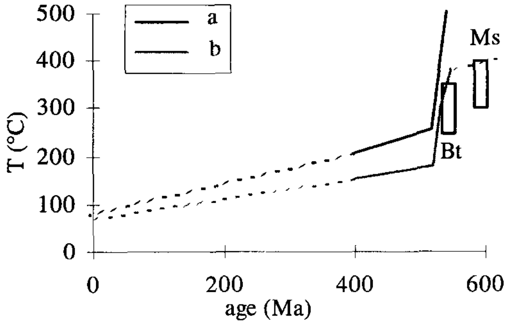

FIG. 1. K-feldspar modeled cooling history for a leucogranite sampled in Western Ethiopia, using different activation energies E. a: E = 65kcal/mol; b: E = 50kcal/mol. Open boxes represent the micas experimental data: Bt = biotite; Ms = muscovite. Choosing a lower activation energy E allows to model a cooling history consistent with the experimental micas data. The dashed line represents the unconstrained part of the cooling history.

## Erroneous data for micas

Systematic excess Ar in micas is not outlined from inverse isochron diagrams. Moreover, the logical closure order muscovite-biotite is maintained for all samples, which is not realistic in case of excess Ar in micas for different samples over 1500 km.

On the contrary, very little is known regarding the diffusion properties in micas and the bulk closure temperatures usually used may be underestimated. Higher closure temperatures for micas than those used in our study could resolve the paradox outlined between the K-feldspar and the micas data; however, this criticism rather appears as a basic limitation of $^{40}Ar/^{39}Ar$ thermochronology applied to hydrous minerals and would require studies on Ar diffusion behaviour in micas.

## Lattice defects in K-feldspars

The Ar retention for high temperature outlined in K-feldspar from diffusion experiments could be related to Ar trapping in vacant sites or lattice defects during the heating in laboratory, as has been outlined for a gem-quality orthoclase (Arnaud and Kelley, 1997); the very retentive diffusion domains outlined by the modelling of diffusion parameters thus may reflect an artefact related to the experiment in the laboratory. However, even though some K-feldspar may contain more lattice defects than a gem-quality orthoclase where Ar trapping characterizes 1% of degased $^{39}Ar$, it seems surprising that more than 50% of degased $^{39}Ar$ would have been trapped during the heating in the laboratory. Moreover, it does not seem realistic that Ar trapping during the heating in the laboratory has systematically affected such mineralogically and spatially different samples.

This hypothesis could be tested through chemical analyses in order to outline systematics between chemistry and possible structural traps.

## Thermal history and lattice defects

Although a pure cooling history associated with complex textural interplays does not allow to explain the paradox outlined between the K-feldspar and the mica data, a pulse reheating (low temperature, limited duration) could help. Indeed, when a mineral is reheated, its structure is progressively rehomogenized and lattice defects are thus reduced; however, if temperature and duration are not important enough, some lattice defects will be preserved. Nevertheless, even though temperature is not important enough to reduce all the lattice defects, temperature could be important enough to allow Ar diffusion in the mineral; in this case, thanks to defects spread in the lattice, the whole K-feldspar behaves as if only composed of low retentivity domains, being globally affected by Ar loss.

Finally, the heating in the laboratory, which is more important than in the nature, allows to reset the lattice defects in the K-feldspar and thus, Ar diffusion in the laboratory appears to be slower than it was in the nature during the reheating. This could explain the retentive domains outlined by the modelling of the diffusion parameters; these retentive domains are not an artefact but may reflect the diffusion domains in the K-feldspar during its first cooling, while at the same time the age is partially reset because of the later reheating related to magma transfer through the crust undergone by the mineral in the nature in Ethiopia.

However, this hypothesis requires to be tested with new $^{40}$Ar/$^{39}$Ar thermochronological analyses on the subvolcanic granitoids associated with the Oligo-Miocene volcanism in Ethiopia, which should have undergone a pure cooling history, and thus should not express such a paradox.

## Overestimated activation energy E

According to a recent statistical study, we can assume that the activation energy E reflecting the global Ar diffusion behaviour in K-feldspar is 46 ± 6kcal/mol (Lovera *et al.*, 1997). On the contrary, the activation energy E we defined from experimental Arrhenius diagrams is higher (55-70kcal/mol) for some of the samples, probably because we estimated E from the high-temperature data. Indeed, above the melting point (1150±20°C; Schairer and Bowen, 1947), the lattice is modified and the diffusion parameters which can be defined do not reflect anymore the Ar diffusion behaviour in the K-feldspar and are often too retentive for reasons largely unknown presently. Choosing a lower activation energy E thus allows to resolve the paradox; indeed, although the distribution of diffusion domains in K-feldspar is different, the new modeled cooling history is consistent with the micas data (fig.1b). However, it is not certain at the moment that a lower activation energy will resolve the paradox for all the samples; moreover, even though some of the analysed K-feldspars are characterized by a more usual activation energy (40-50kcal/mol), they also yield such a paradox.

Therefore, although the thermal history undergone by a sample associated to complex textural interplays seems to play a major role in the paradox outlined between the K-feldspar and the mica data obtained on various Ethiopian basement samples, the different hypotheses envisaged to explain such a paradox require to be more tested. Better understanding and resolving such a paradox is very important as it could imply serious consequences regarding the interpretation of some of $^{40}$Ar/$^{39}$Ar thermochronological data.

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