Goldschmidt 2000
September 3rd–8th, 2000
Oxford, UK.

Journal of Conference Abstracts
Volume 5(2), 364
© 2000 Cambridge Publications

Helium Diffusion in Apatite Revisited: Is the High Temperature Diffusion Mechanism an Artefact or a Reality?

Tibor J. Dunai (dunt@geo.vu.nl)

Free University, De Boelelaan 1085, 1081 HV Amsterdam, The Netherlands

Data from previous studies of helium diffusion in apatite (Farley, 2000; Wolf et al., 1996; Zeitler et al., 1987) suggest that helium diffusion at low temperatures (<290ºC Wolf et al. (1996); Zeitler et al. (1987); or <265ºC , Farley, (2000)) has a different activation energy than diffusion at higher temperatures. Above 265-290ºC the diffusivity deviates from linearity toward lower activation energies. Wolf et al. (Wolf et al., 1996) suggested a reversible change of the physical mechanism of helium diffusion as a cause for that change. Recently Farley (2000) suggested that annealing of lattice damage caused by fission tracks may be responsible for the relative lowering of diffusivity at higher temperatures. If the observed effect is real and the explanation of Farley (2000) is right the retentivity of apatite for helium is a complicated function of its age (i.e. accumulated lattice damage and (partial) annealing thereof).

The existing studies used stepwise heating experiments. It is known from experimental data (Fechtig and Kalbitzer, 1966) and theoretical considerations (e.g. Fechtig and Kalbitzer, 1966; Lovera et al., 1997) that stepwise heating experiments are sensitive to depletion which can cause an apparent lowering of diffusion coefficients. In the previous studies the samples were >50% depleted upon reaching the higher temperatures (Wolf et al., 1996; Zeitler et al., 1987). Thus it is indicated that the observed lowering of diffusion coefficients at high temperatures could be an experimental artefact caused by variable grain sizes/geometries that deplete at different rates.

To test this and to avoid the potential methodological pitfalls mentioned above, I conducted a new series of experiments using similar samples but a different approach. Gem quality apatite (Durango, Mexico) was crushed and wet-sieved. Aliquots of the 160-180 micron fraction were individually heated in isothermal experiments and then subsequently fully degassed. Thus with the two measurements of an aliquot the diffusion coefficient at a given temperature is determined by the fraction of helium released. This approach has the advantage that the isothermal experiments can be designed to keep the fractional release well below 50%, thus avoiding effects arising from depletion of helium from the grains. At temperatures between 250 and 450 C the diffusion coefficients obtained are indistinguishable of those of (Wolf et al., 1996). Thus I do not observe the deviation from linear relationship in the Arrhenius diagram as described by (Wolf et al., 1996; Zeitler et al., 1987). In contrast I observe a perfectly linear relationship, the correlation coefficient of the linear regression of the data points, at both sides of the proposed transition points at 265 or 290ºC proposed by (Farley, 2000; Wolf et al., 1996), is better than 0.9999. The activation energy obtained, 35±1kcal/mol, is indistinguishable of those derived by Zeitler et al. (1987) and Wolf et al. (1996) for apatites from Durango, i.e. 38.5±8 and 36±1kcal/mol, respectively. It is only slightly higher than the value of 33±.5kcal/mol as derived by (Farley, 2000). While my value for the activation energy confirms the low temperature experiments of Wolf et al. (1996) and Zeitler et al. (1987) it clearly disproves the existence of a change of physical diffusion mechanisms in apatite at 265 or 290ºC as it was derived from measurements including those above these temperatures. The deviations that can be seen in the data of Wolf et al. (1996) and Zeitler et al. (1987) are therefore a experimental/mathematical artefact, most likely attributable to the methodological pitfalls described above.

The results of the new diffusion study do not alter the application of apatite as a low-temperature thermo-chronometer as the relevant low temperature data of Wolf et al. (1996) is confirmed. The importance of the finding is that there is no change of physical diffusion mechanisms above 265-290ºC. Thus there is no need to invoke an elaborate physical process to explain helium diffusion in apatite (Farley, 2000). Helium diffusion in apatite can simply be described in terms of well-behaved volume diffusion. Therefore the thermo-chronological information of U-Th-He-dating in apatite is not complicated by lattice damage and (partial) annealing thereof.

Farley KA, *J. Geophys. Res.*, **105(B2)**, 2903-2914, (2000).

Fechtig H & Kalbitzer S, *The diffusion of argon in potassium bearing solids, Springer*, 68-107, (1966).

Lovera OM, Grove M, Harrison TM & Mahon KI, *Geochim. Cosmochim. Acta*, **61**, 3171-3192, (1997).

Wolf RA, Farley KA & Silver LT, *Geochim. Cosmochim. Acta*, **60**, 4231-4240, (1996).

Zeitler PK, Herczeg AL, McDougall I & Honda M, *Geochim. Cosmochim. Acta*, **51**, 2865-2868, (1987).