The effect of long-term low-temperature exposure on fission track stability and helium diffusion in apatite

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The influence of very low temperatures on the apatite fission track (AFT) and the (U-Th)/He (AHe) systems is still poorly understood, largely because due to sluggish annealing kinetics, it cannot be quantified by laboratory annealing experiments. To overcome these uncertainties, we studied volcanogenic sediments from deep-sea cores that were exposed to low temperatures over ~10^7-10^8 yr. The thermal histories of the sample sites were independently reconstructed. The mean track lengths (MTLs) observed were compared to MTLs predicted by the annealing models of [1,2]. Samples that experienced long-term exposure to temperatures between ~15-40°C yield MTLs of 14.4-15.0 µm, indicating that even in a relatively low temperature environment significant track shortening has occurred. Samples that remained at temperatures below ~10°C, by contrast, yielded MTLs of 15.0-15.5 µm. The algorithm of [1] yields good results for samples with a higher Cl-content and which experienced T >30°C, whereas for low-Cl samples which experienced T <30°C, annealing is underestimated. Predictions by the model of [2] are largely consistent with the measured MTLs. Use of this model thus allows the extraction of thermal histories with a high degree of confidence.

In addition to AFT analysis, we measured AHe ages for select samples. Samples that remained at temperatures <10°C are obviously unaltered, reflecting formation ages of their volcanic source areas. By contrast for samples which experienced temperatures of 20 to 30°C, our data indicate a slight shift towards younger ages, as compared to deposition ages, suggesting that, although AFT and AHe ages still overlap at ±2σ, long-term exposure to temperatures below the conventional He partial retention zone has had a measurable influence on He diffusion. Furthermore, one sample yielded anomalously old but reproducible ages, which we tentatively explain by He injection into the grain from the surrounding environment.

References

[1] Laslett et al. (1987) *Chemical Geology* **65**, 1-13.

[2] Ketcham et al. (1999) *American Mineralogist* **84**, 1235-1255.