Structure and stability of latent ion tracks in minerals

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Fission-track dating is an important technique used to determine the age and thermal history of geological samples and to date archaeological specimens. This method is an empirical technique based on the number density and length distribution of chemically etched trails of damage, which are produced by highly energetic particles resulting from the spontaneous fission of uranium. The etching produces µm-sized hollow channels and completely erases the initial damage structure such that essential information on the actual scale of the underlying radiation damage is irrevocably lost. Our work aims to gain a detailed understanding of the latent 'un-etched' damage tracks and their stability in geological environments that can ultimately lead to a much-improved accuracy in current dating techniques.

We have utilized high-energy heavy ions produced at the ANU Heavy Ion Accelerator facility as well as heavy ion accelerators at GSI in Germany to 'simulate' fission track formation in several minerals such as apatite and olivine. This includes the formation of ion tracks under high-pressure to imitate crustal conditions. The latter was facilitated by the use of diamond anvil cells in combination with extremely high ion energies of ~35 GeV, sufficient to penetrate 2 mm of diamond before impinging on the sample. The "latent" ion tracks and their annealing kinetics were studied using synchrotron small-angle x-ray scattering (SAXS). Our recently developed SAXS protocols enable determination of ion track morphology and track radii with unprecedented precision [1-3], and provide an effective means for in-depth studies of ion-tracks in minerals under a wide variety of geological conditions. For example, we have determined the annealing kinetics of ion tracks in Durango apatite facilitated by *ex situ* and *in situ* annealing experiments. Results suggest structural relaxation followed by recrystallization of the damaged material [2]. The application of high-pressure *during* track formation leads to a decrease in the ion track radii, albeit at pressures exceeding those of normal crustal conditions. Application of pressure *subsequent* to ion track formation leads to a reduction in track radius that is reversed upon pressure release.

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[2] B. Afra *et al.*, Phys. Rev. B **83** (2011) 064116
[3] M. Rodriguez *et al.*, J. Non-Cryst. Sol. **358** (2012) 571