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Effect of orientation on ion track formation in apatite and zircon

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Abstract

Fission track (FT) thermochornology is essentially based on empirical fits to annealing data of FTs revealed by chemical etching, because, until now, unetched, latent FTs could not be examined analytically at the atomic-scale. The major challenge to such an analysis has been the random orientation of FTs and their extremely small diameters. Here we use high-energy ions (2.2 GeV Au or 80 MeV Xe) to simulate FT formation along specific crystallographic orientations. By combining results from transmission electron microscopy (TEM) of single tracks and small-angle X-ray scattering (SAXS) for millions of tracks, a precise picture of track morphology as a function of orientation is obtained. High-resolution analysis reveals that orientation affects the shape of tracks in apatite and zircon through the preferential creation of damage along directions with highest atomic density. However, track radius does not depend on orientation, contradicting previous reports. Independent of track orientation, track radii, as measured at each point along the entire length of 80 MeV Xe ion tracks in apatite, can be understood using the thermal spike model of Szenes. Thus, the well-known track annealing anisotropy of apatite is not due to track radius anisotropy. The combination of ion-irradiations with TEM and SAXS analysis provides a unique opportunity to understand and model track formation and annealing under various geologic conditions.

Keywords: Ion tracks, fission tracks, apatite, zircon, orientation effects, thermal spike, TEM, SAXS