Visualization of latent alpha-recoil tracks in dark mica by scanning force microscopy

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As a natural mineral, dark mica contains α-emitters such as uranium and thorium. During their α-decay, part of the recoil energy is transferred to the daughter nuclei. These interact with the surrounding crystal lattice where they create 'nest-shaped' radiation damage, so-called alpha-recoil tracks (ART). If the volume density of such ART as well as the concentration of the α-emitters is known, one can evaluate the age of the sample [1]. For the registration of the ART volume density via optical phase contrast microscopy, the tracks have to be etched to a certain size. The etch pits are triangular in shape. If the track density is too high, the pits cannot be enlarged above the optical resolution of the microscope without overlapping. Therefore, up to now ART dating is restricted to dark micas of ages not exceeding 10^6 a.

To overcome this age limit, scanning force microscopy (SFM) was applied to visualize latent ART. Natural biotite from the Altai Mountains, China, was used to test whether SFM is able to image latent ART and, thus, suitable for the dating of older dark micas. Scanning the surface of freshly cleaved biotite did not reveal any tracks. Subsequently, this surface was kept in ambient conditions over a certain time period. Within several hours, small hillocks developed with an initial size as expected for latent ART in dark mica (see Figure 1).

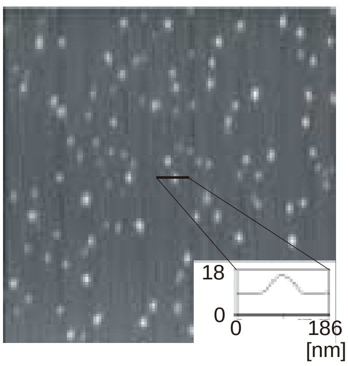

Figure 1: Topographic SFM image (2.4 µm x 2.5 µm) of a biotite cleavage plane kept in ambient conditions for several hours. Light areas represent hillocks. Both inset scales are in nm.

Diameter and topographic height increased with time, reaching a saturation limit several days after cleavage. The damaged material has a lower hardness than the intact surroundings. The areal density of tracks is similar to that of ART revealed by etching and phase contrast microscopy. After very short etching of the surface, the SFM image indicated triangular etch pits rather than the previously occurring hillocks (see Figure 2). These pits look similar to the etched ART in lower resolution (phase contrast microscopy).

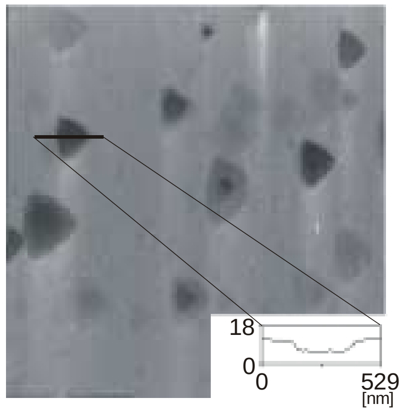

Figure 2: Topographic SFM micrograph (2.9 µm x 3.0 µm) of biotite after short etching, showing triangular etch pits.

Heating the biotite at 500 °C for 30 min annealed the latent ART. The annealed material was irradiated at the UNILAC of GSI with $^{136}Xe^{18+}$ and $^{238}U^{28+}$ ions at E_{kin} = 11.4 MeV/u and fluences of $5x10^{10}$ and $1x10^{10}$ ions/cm², respectively. Scanning these samples revealed hillocks. Etching develops the artificially created hillocks into circular rather than triangular etch pits (see Fig. 3), in contrast to the behaviour of the hillocks displayed in Fig. 1, which are attributed to alpha-recoil tracks.

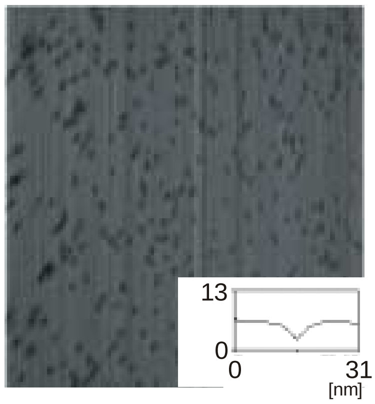

Figure 3: Topographic SFM image of irradiated ($^{136}Xe^{18+}$, fluence: $5x10^{10}$ ions/cm²) biotite after short etching (size: 830 nm x 860 nm).

In conclusion, visualization of latent ART by SFM enables us to reveal track densities beyond 10^8 cm^{-2} and thus extend the new ART dating technique to an age range > 10^6 a.

[1] Gögen, K., Wagner, G.A., 2000. Alpha-recoil track dating of Quaternary volcanics. Chemical Geology 166, 127-137.