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First fission-track dating experiments performed in Bulgaria

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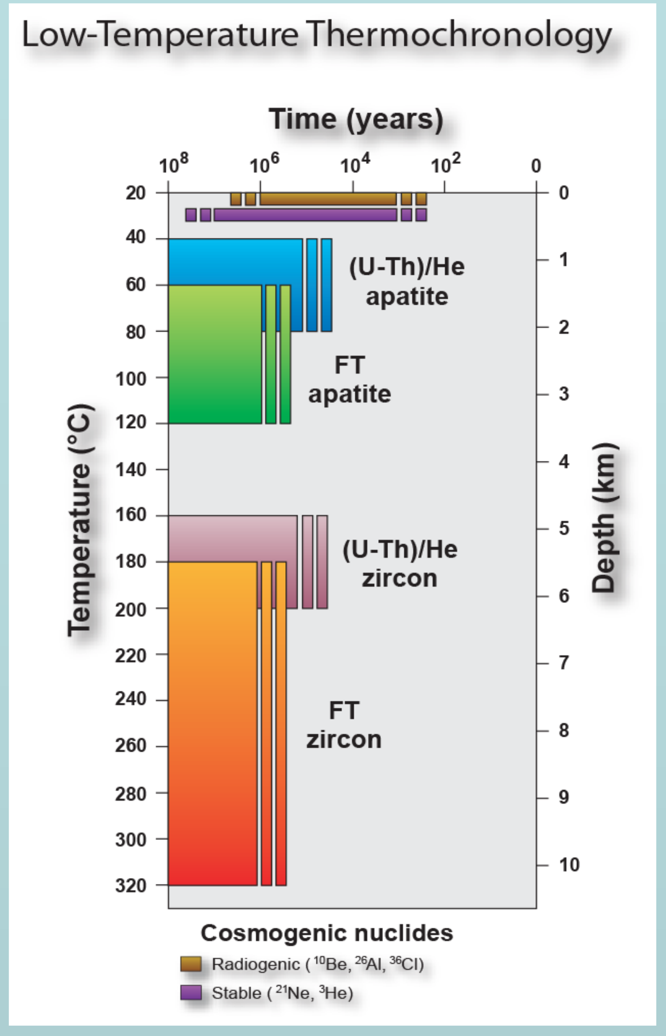
Fission-track (FT) dating is one of the methods of the low-temperature geochronology widely used to constrain the thermal histories of various rocks in different geological settings (orogenic belts, sedimentary basins, mineral deposits, faults, etc). Some of the most used applications of FT dating include reconstruction of time-temperature history of rocks, estimation of denudation/exhumation rates of mountain chains, dating of faults and ore mineralizations, deciphering sedimentary basin evolution as well as dating volcanic deposits. The method is based on the analyses of the damage trails (tracks) produced by the spontaneous decay of ^{238}U in U-bearing minerals.

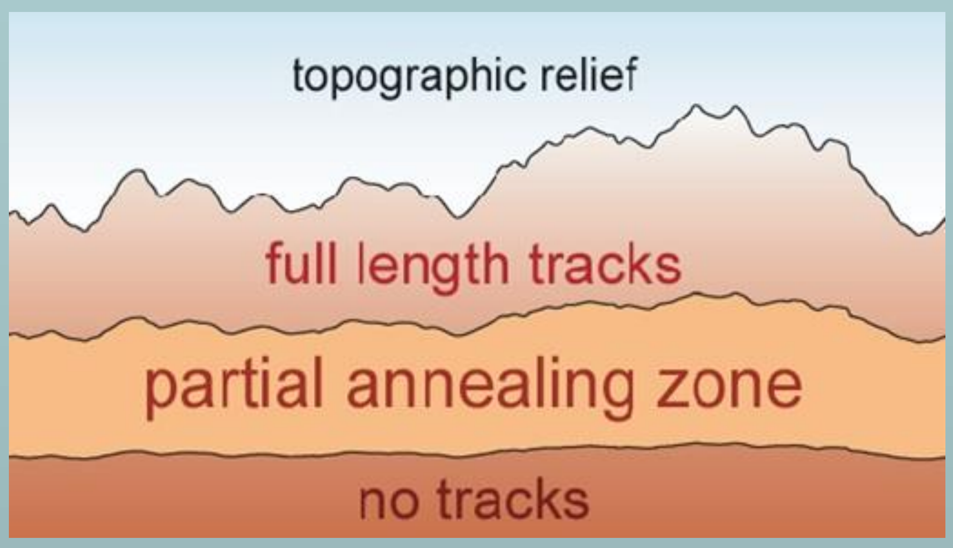


Low-temperature thermochronology methods and used minerals and the place of fission-track dating using apatite (green field) among them

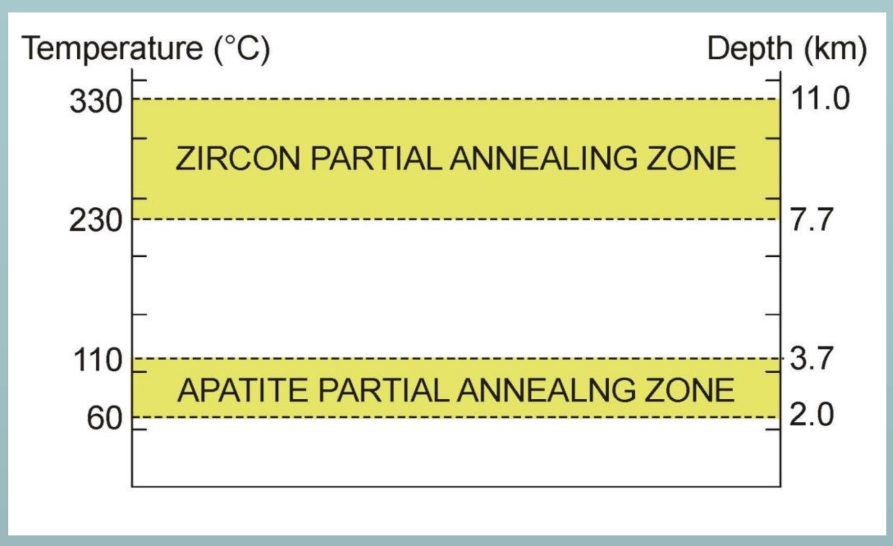
The density of the fission tracks corelates with the cooling age of the sample and with uranium content that needs to be determined independently. Fission tracks can be enlarged and made visible in an optical microscope by chemical etching. The method is based on the process of annealing of fission tracks – becoming unstable with sample heating. The factors that influence the stability of tracks are temperature, time, chemical composition of sample, orientation of tracks according to the crystal lattice. On the basis of experiments on annealing of tracks, partial annealing zone (PAZ) is defined characterized by lower and upper temperature boundaries. Under this zone all the tracks in the sample are annealed. When the sample crosses the PAZ and its upper boundary, fission tracks begin to accumulate. One of the most used minerals in FT dating is apatite (Donelick et al., 2005) for dating events at about 110 ± 10˚C (effective retention temperature).

Durango apatite used as a standard in fission-track dating

Here we present the first attempts to prepare and process apatite samples in Bulgaria. The experiments have been performed on standards (Durango apatite) with well-known FT age in order to check the efficiency of the method. Sample preparation was processed in the Chemical laboratory of the Geological Institute of BAS. Fragments of Durango apatite were arranged in arrays of 5 x 5 grains of almost same size on a glass covered by bifacial tape and mounted in epoxy resin where adhesive and hardener were mixed. The mounts were dried for more than 24 hours at room temperature and then easily detached from the tape. After mounting, pre-grinding, grinding and polishing of mounts was performed in order to remove a certain thickness to observe the tracks in the whole volume of the crystal. For pre-grinding and grinding 1500 grit silicon carbide paper was used. Mounts were pre-ground gently in one direction at least 20 times in order to observe grinding scratches on most of the grains. After that the mounts were ground perpendicular to the direction of pre-grinding until all the previous scratches disappeared. This was repeated 8 times in order to remove at least 8 µm from the surface of the crystals (half of the etchable track length) as the depth of the grinding scratch is found to be at least 1 µm for 1500 grit silicon carbide paper.

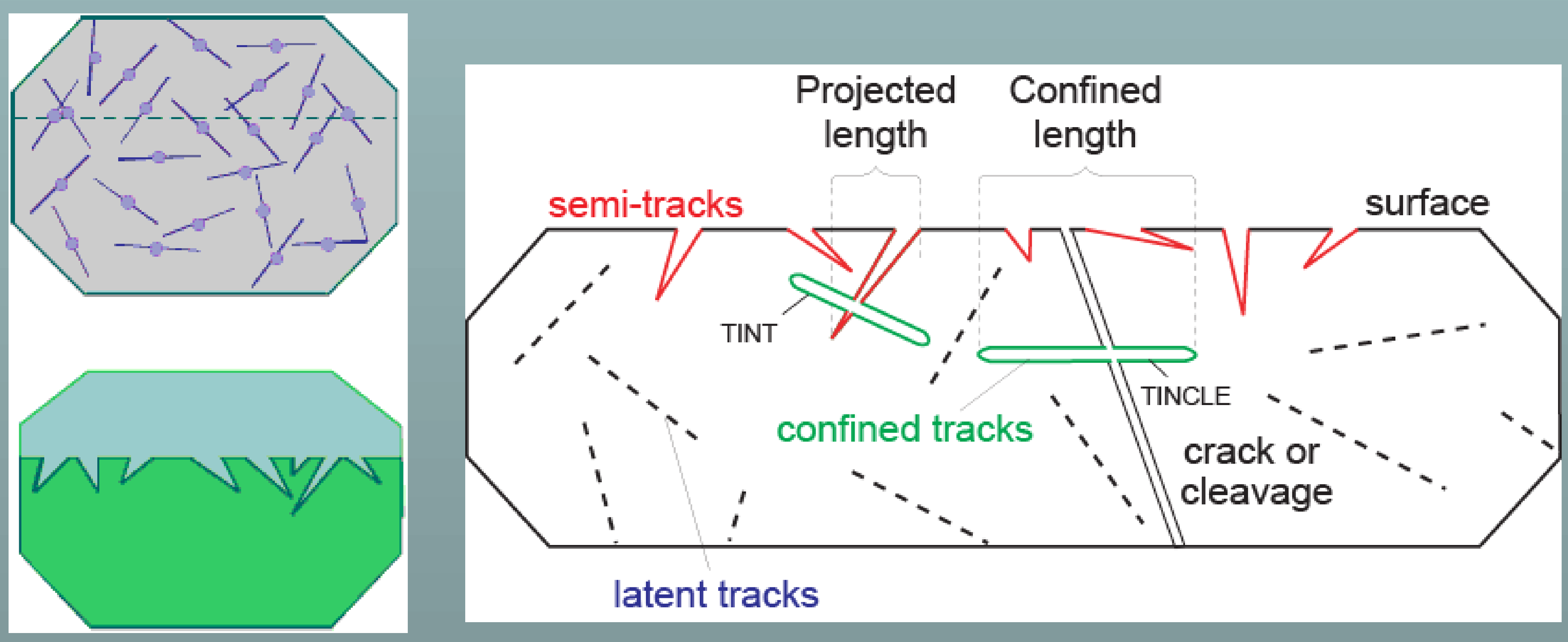


Position of partial annealing zone according to topographic relief and the presence/absence of fission tracks

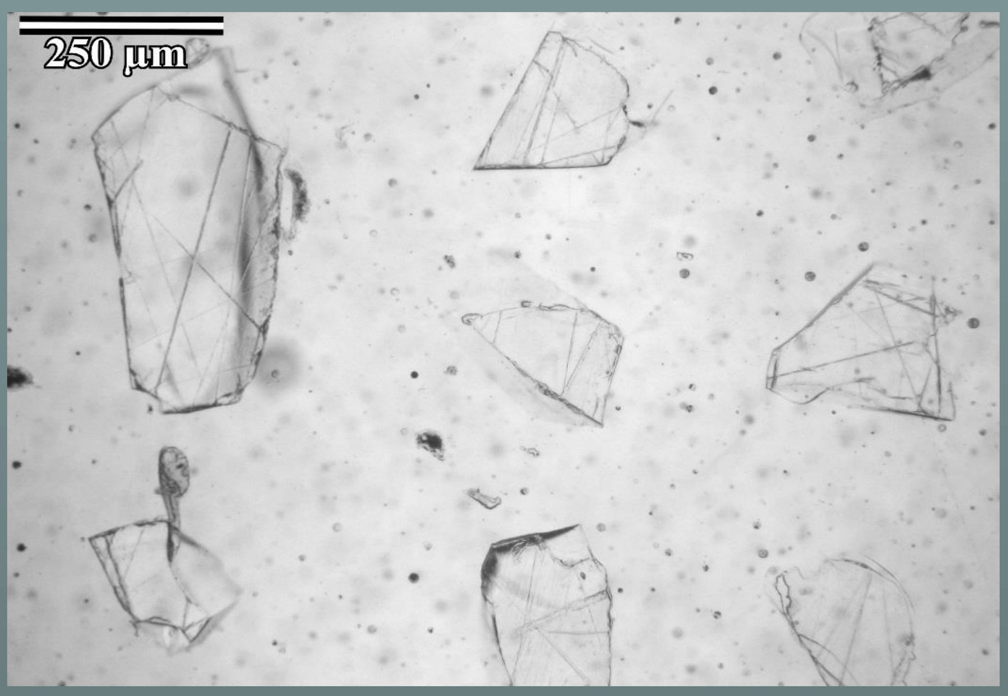


Zircon and apatite partial annealing zones defined by temperature and depth

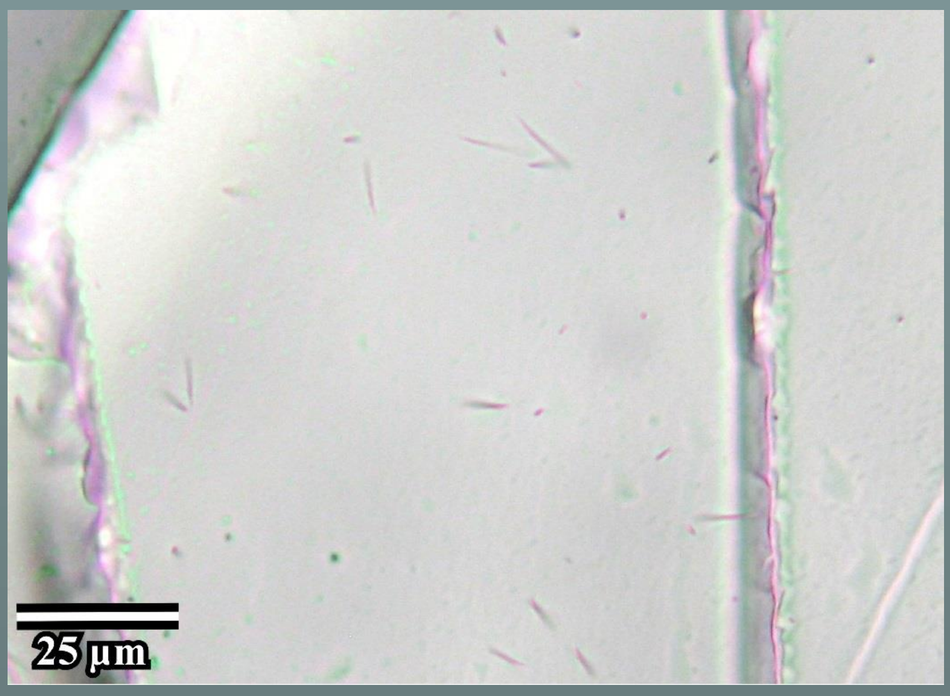
Polishing was done using 6, 3 and 1 µm diamond pastes. For every step of polishing the direction was changed by 90º from that of the preceding polishing. After polishing the mounts were washed in ultrasonic cleaner for 5 minutes. In order to reveal the fission tracks and made them visible under optical microscope chemical etching of the samples was performed. Apatite mounts were etched in 5.5 N HNO_3 for 20 s. at temperature of 21ºC.

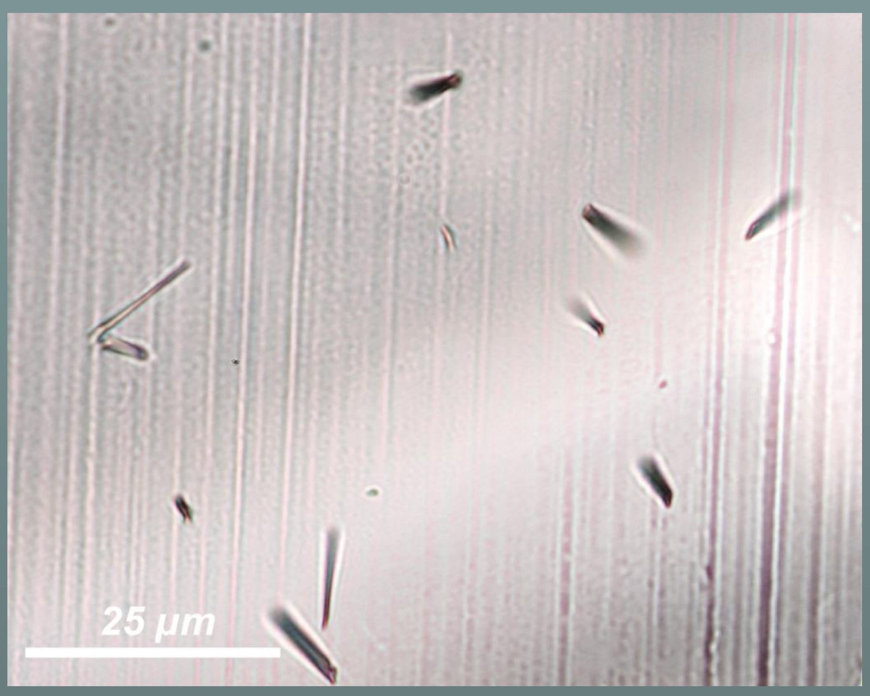


Geometry and types of visible fission tracks after grinding, polishing and etching

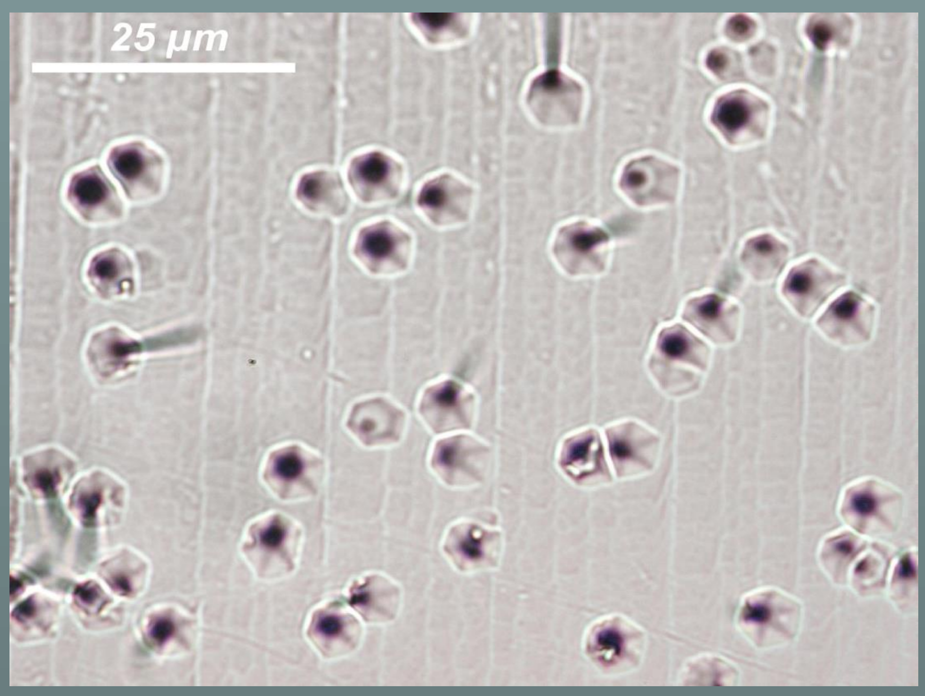


Fragments of Durango apatite arranged in arrays for grinding and polishing





Diamond shaped tracks pits on the prism plane of Durango apatite, parallel to C axis, used for fission track dating, transmitted light



Funnel shaped tracks with hexagonal pits on the basal plane of Durango apatite, perpendicular to C axis, not usable for counting, transmitted light

Leica DM 2 500 POL optical microscope used for observation and counting of fission tracks in Durango apatite

Laser ablation ICP-MS system used for measuring ^{238}U concentration in Durango apatites

Spontaneous tracks were counted under a Leica DM 2 500 POL optical microscope in the Department of Geology, paleontology and fossil fuels, Sofia University. 100x dry and immersion objective lens were used for observation and counting.

After counting of fission tracks in the Durango grains, uranium concentration is needed to be directly measured on the same grains using laser ablation system in order to be used in the formulas for calculation of FT ages. This stage is ongoing in the Laboratory of laser ablation in the Geological Institute, BAS where ^{238}U concentrations are calibrated against NIST 610 and NIST 612 standard glasses.

The accomplishment of consistent results with the Durango apatite will give good premise for measuring and obtaining reliable results of the natural samples in the new laboratory.