Fission-track thermochronology: its principles and application to fault studies

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Fission-track (FT) analysis has developed into one of the most useful techniques used throughout the geologic community to reconstruct the low-temperature thermal history of rocks over geological time. The FT method is based on the accumulation of narrow damage trails (i.e., fission tracks) in uranium-rich mineral grains (e.g., apatite, zircon, titanite) and natural glasses, which form as a result of spontaneous nuclear fission decay of 238U in nature (Price and Walker, 1963; Fleischer et al., 1975). The time elapsed since fission tracks began to accumulate is estimated by determining the density of accumulated tracks in a particular material in relation to the uranium content of that material. Chemical etching can be used to enlarge fission tracks that have formed within a mineral in order to make them readily observable under an ordinary optical microscope (Price and Walker, 1962).

If a host rock is subjected to elevated temperatures, fission tracks that have formed up to that point in time are shortened progressively and eventually erased by the thermal recovery (i.e., annealing) of the damage (Fleischer et al., 1975). Because thermal diffusion basically governs the annealing process, the reduction in FT length is a function of heating time and temperature. Importantly, fission tracks are partially annealed over different temperature intervals within different minerals. This characteristic allows for the construction of time-temperature paths of many different rock types by (a) plotting FT (and other isotopic) ages from different minerals versus their closure temperatures, which is applicable in the case of a monotonous cooling history (e.g., Wagner et al., 1977; Zeilter et al., 1982), and/or by (b) the inverse modeling of observed FT age and confined track length data (e.g., Corrigan, 1991; Lutz and Omar, 1991; Gallagher, 1995; Ketcham et al., 2000).

Finally, as an example of recent geological applications of the technique, the results of zircon fission-track analysis of the Nojima fault zone, Japan, are presented. These rocks were the target of systematic drilling of an active fault system using five boreholes and a trench.

For more details of these topics, see recent reviews (Tagami, T., 2005; Tagami and O'Sullivan, P. B., 2005; also other papers in the Rev Mineral Geochem volume 58 that highlights a vairiety of aspects of low-temperature thermochronology).

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