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A zero-damage model for fission-track annealing in zircon

MEINERT K. RAHN,[1,*] MARK T. BRANDON,[2] GEOFFREY E. BATT,[3] AND JOHN I. GARVER[4]

[1]Institut für Mineralogie, Petrologie und Geochemie, Albert-Ludwigs-Universität, Freiburg, Germany
[2]Department of Geology and Geophysics, Yale University, New Haven, Connecticut, 06520-8109 U.S.A.
[3]Department of Geology, Royal Holloway University of London, Egham, Surrey, U.K.
[4]Geology Department, Union College, Schenectady, New York, 12308 U.S.A.

ABSTRACT

A zircon fission track-annealing model is calculated on the basis of annealing experiments from the literature with induced tracks in α-decay event damage-free zircon samples. Empirically derived parallel and fanning equations for this "zero-damage" model yield an excellent fit to the data, with the fanning model providing slightly better statistical parameters. A comparison between annealing models with fanning iso-annealing lines but different α-decay event damage densities reveals that annealing temperatures and closure temperatures for the estimated partial annealing zone are highest for the zero-damage model.

Compilations of existing geologic constraints on the zircon partial-annealing zone on one hand and the zircon closure temperature on the other show that these constraints do not or only partly overlap with curves of proposed models for the zircon partial-annealing zone and closure temperature. This finding is consistent with the fact that the annealing behavior of zircon from long-duration temperature evolutions is increasingly influenced by the accumulated α-decay event damage. Zircon samples of young age or low U content show a behavior closest to the predictions of the zero-damage model, and are in the predicted range of published models with low α-decay event damage density. For thermal events of more than 10 myr duration, however, constraints from field studies show marked differences from proposed partial-annealing zone boundaries of the zero- or low-damage models.

The applicability of the zero-damage model is threefold. (1) It predicts correct closure temperatures in the case of very rapid cooling across the partial annealing zone where basically no α-decay event damage is accumulated. (2) It predicts an uppermost boundary for complete annealing of a mixture of zircon components of different age, as found in sedimentary samples, and in this case may be used as a thermometer. (3) It represents an important reference for the establishment of a more comprehensive model of zircon fission-track annealing that also includes the influence of α-decay event damage. For such a model, two different equations are discussed. However, additional detailed experimental and field data are needed for a more robust annealing model that includes the influence of α-decay event-damage annealing.