

Determination of Zeta Calibration Constant for Fission Track Analysis

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Abstract Zeta constant has been determined for calibration in fission track dating. Three apatite age standards have been used for the calibration. The zeta value against a dosimeter glass IRM-540R has been calculated. A single weighted-mean zeta constant is given as 250 ± 1.40 (16).

Keywords Fission track; IRM-540R; Neutrons fluence; Zeta constant

1. Introduction

The Ambiguity of age calibration constants including (the spontaneous fission decay rate of ^{238}U), and the “B-value” encountered in thermal neutron dose measurements has been a controversial problem for a long time in fission track dating (FTD) (Bigazzi, 1981; Hurford and Green, 1981). To circumvent the problem, an alternative way of system calibration, named the zeta calibration, was proposed, in which a calibration constant zeta is determined experimentally against a series of age standards that are well established (Fleischer and Hart, 1972; Hurford and Green, 1982, 1983). The first systematic attempt at calibration was carried out against four zircon standards by Hurford and Green (1983). For determining on unknown AFT age using age standard approach, first the ζ value must be determined. According to Hurford (1900 a-b), a good ζ value requires a calculation of five pair of standard samples which are derived from five different irradiation cans. In this Study, three samples from Durango were counted. The track density on the dosimeter glasses is related to the neutrons fluence. The magnitude of the neutron fluence depends upon the position of the samples during irradiation; the closer a sample is to the radiation source, the larger its track density is derived from a linear regression line of several track numbers of each dosimeter glass in one can.

2. Experimental Procedure

The samples for this study were processed in the laboratory of the Geological Survey of India, Kolkata, after obtaining permission from the Director General, GSI, Kolkata, West Bengal. The samples were prepared using standard separation, grinding and polishing techniques. All the samples were prepared for the external detector method. AFT mounts were etched with 70% HNO_3 at room temperature for 30 s and were irradiated in the thermal facilities of FRM II at Garching, Germany

together with dosimeter glass IRMM-540R (15ppm). Mica sheets were etched using 48% HF at room temperature for 19 min. The fission tracks were counted under a total magnification of 1000x (Figure 1). The calibrated area of one grid is $0.64 \times 10^{-6} \text{ cm}^2$. Durango apatites were used as the age standard mineral, which was provided by Prof. Barry Paul Kohn, University of Melbourne, Australia.

Table 1: Fission track analytical data for zeta calibration and sample weighted mean zeta (SWMZ) value for age standard. Weighted Mean Value of Zeta $\approx 250 \text{ Ma}$
Standard Age of Durango Apatite = $31.4 \pm 0.5 \text{ Ma}$ (McDowell and Keizer, 1977)

Sample Name	N	N_s	N_i	$\rho_s \times 10^6$	$\rho_i \times 10^6$	N_d	ρ_d	Age(Ma) $\pm 1\sigma$	$P(\chi^2)\%$
DUR-1	16	98	750	0.266	2.034	1232	1.925	250 \pm 1.40	9.64
DUR-2	16	96	735	0.260	1.99	409	2.045	235.40 \pm 1.42	18.81
DUR-3	16	100	767	0.271	2.08	1168	1.820	265.49 \pm 1.39	7.8

All of the standard samples were analyzed using the external detector method, with a geometry factor $G=0.5$, N_s and N_i are numbers of spontaneous and induced tracks respectively, ρ_s and ρ_i are the density of spontaneous and induced tracks per cm^2 , N_d is the amount of induced tracks on the mica, and ρ_d is the density of induced tracks on mica per cm^2 . $P(\chi^2)$ – probability for obtaining χ^2 value for n degrees of freedom, where $n = \text{no. of grain} - 1$.

3. Results and Discussion

Zeta was determined empirically by analyzing a set of standard mineral of known age, and it is given by inputting the measured data of standard (i.e., ρ_s , ρ_i and ρ_d) and the reference age t into the following equation:

$$t = \frac{1}{\lambda_D} \ln \left\{ 1 + \lambda_D \zeta \rho_D \left(\frac{\rho_s}{\rho_i} \right) QG \right\}$$

Where λ_D is total decay constant of ^{238}U , viz. $1.55125 \times 10^{-10} \text{ yr}^{-1}$, G is the geometry factor, taken to be 0.5; t is the reference age of the standard sample. The statistical error of zeta was calculated by the “conventional analysis” described by Green (1981). ρ_s was counted on the etched internal surface of each mineral grain, ρ_i was counted on the external detector surface (mica) attached to the mineral grain, whereas ρ_d was counted on mica firmly attached to the dosimeter glass. Table 1 shows the results of repeated measurements on three apatite age standard samples. The presented zeta value in Table 1 does not contain an error component from the reference age at this stage. All the repeated analyses for individual samples show high consistency and sample weighted mean zeta (SWMZ) values were calculated. The consistency of repeated measurements ensures the reproducibility of the FTD analysis in our experiment. The overall weighted mean zeta (OWMZ) value was calculated as 250 ± 1.40 (16).

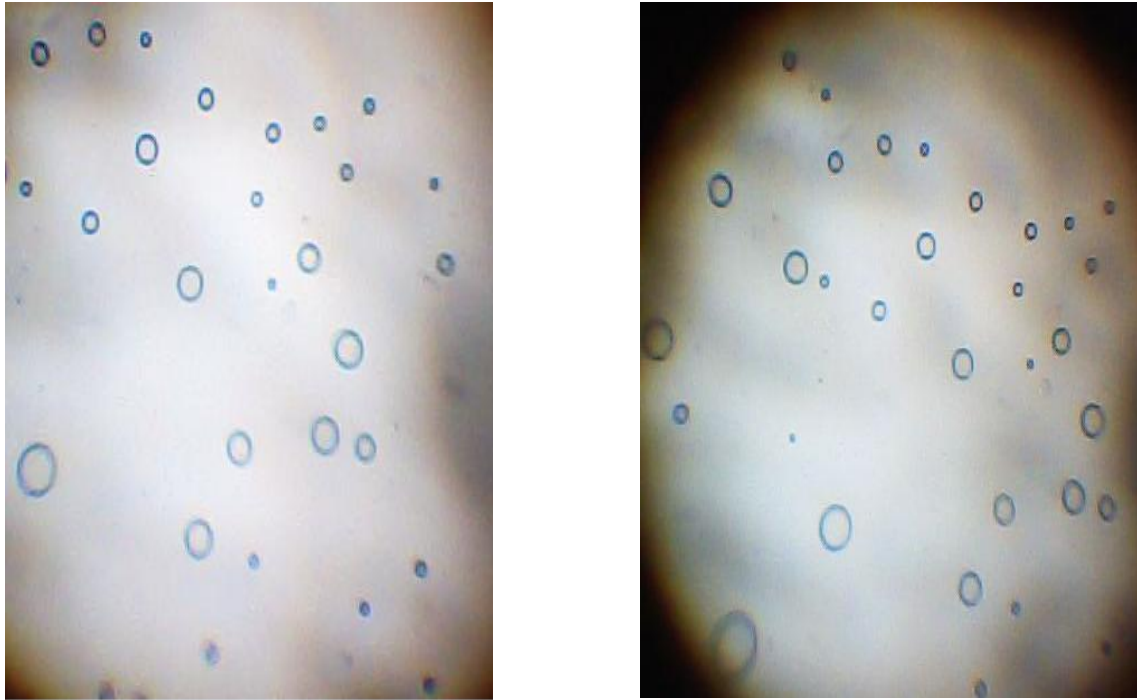


Figure 1: Induced Tracks on Dosimeter Glass (IRM-540R)

4. Conclusion

The personal zeta factor was calculated from three standard samples. The zeta value itself is counted as a weighted mean of individual zeta values of all standard samples (Table 1). Using the Zeta Mean program by Brandon (2001), the weighted mean is determined and yield the zeta value of 250 ± 1.40 with 1σ error.

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