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A Correction for Thermally-affected Fission Tracks in Phlogopite Mica by Age-Plateau Method

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Age of phlogopite rock samples of Eastern Ghat belt has been determined using fission track method. The age so determined has been corrected for annealing following the age-plateau method and the correction rechecked following standard calibration method. The annealing correction of 23% which gives the corrected age as 687 My indicates that the mineral sample must have passed through major geothermal events in the Indian Ocean cycle (450-700 My).

Geologically, the phlogopite sample belongs to the Eastern Ghat Belt of India. The Eastern Ghats are composed of parallel layers of khondalites and their variants, viz. granites, gneisses and charnockites which are characterized by granulite facies metamorphism. Values of fission-track (FT) ages determined for rock samples have to be corrected for annealing. Two methods are followed for such annealing correction, viz. (1) the age plateau method developed by Storzer *et al.*¹ and Burchart *et al.*² and (2) the standard calibration curve in which reduction in track length is plotted against reduction in track density. We have determined the correction following both the methods and find these to agree. The age of the rock samples collected from Borra mines, Visakhapatnam and corrected for annealing is reported.

The procedure for age determination of phlogopite, using fission-track method is the same as reported elsewhere^{3,4}. The method involves the preparation, etching, irradiation by thermal neutrons and finally scanning of samples. The tight block of phlogopite was cleaved into thin section along basal planes. A thin sheet of phlogopite was cut into pieces of size 2 cm × 1 cm × 200 μm. These samples were washed with distilled water and alcohol. In order to measure the fossil-track density (due to spontaneous fission of ²³⁸U), the phlogopite samples were etched in 48% HF for 10 min at 25°C. The fossil fission tracks were counted under the Olympus binocular microscope at a magnification of 600×. A few samples of phlogopite containing fossil tracks were heated in a muffle furnace at a temperature of 500°C for 4 hr for complete erasure of fossil tracks. These samples were then irradiated from CIRUS reactor at the Bhabha Atomic Research Centre, Trombay, Bombay, with a total thermal neutron dose

of 5 × 10¹⁶(nvt). After irradiation, the samples were etched under the identical conditions as for fossil tracks and the induced tracks (due to induced fission of ²³⁵U) were counted as before. The fission-track (FT) age of phlogopite was determined using the formula⁴

$$T = 6.01 \times 10^{-8} \times \frac{\rho_s}{\rho_i} \times \varphi \quad \dots (1)$$

where ρ_s and ρ_i are the fossil- and induced-track densities respectively and φ is the total thermal neutron dose. The thermal neutron dose was determined by irradiating the calibrated glass dosimeter (supplied through the courtesy of Price and Fleischer, General Electric Research Laboratory, Schenectady, USA) along with the samples. The glass dosimeter was etched for 5 s in 48% HF at 25°C. The track density (ρ_d) of induced fission tracks in glass dosimeter was recorded and the thermal neutron dose was calculated by using the relation⁵:

$$\varphi = 2.26 \times 10^{11} \times \rho_d \quad \dots (2)$$

The FT ages calculated by using Eq. (1) are given in Table 1.

For estimating annealing correction by age-plateau method, different pairs of phlogopite samples were taken. In each pair, one sample contained only fresh fossil tracks which have been thermally affected in the past and the other contained only freshly cleaved neutron-induced tracks. The pair of samples were heated in muffle furnace at 100, 200, 300, 400, 500 and 600°C for 1 hr, in each case, and the track density reduction was calculated for each pair after etching and scanning of the samples. For the pair of samples, FT age was calculated corresponding to each temperature by using Eq (1). The results are given in Table 2. The apparent age increases at low temperature but reaches a plateau at the temperature above that corresponding to a previous heating event or at a temperature at

Table 1—Fission-Track Age of Phlogopite

Sr. No.	Laboratory symbol	Fossil-track density $\rho_s (\times 10^3)$	Induced-track density $\rho_i (\times 10^3)$	Fission-track age T(My)
1.	PBA-I	6.785	35.8	569 ± 39*
2.	PBA-II	7.296	41.5	528 ± 33
3.	PBA-III	7.924	45.0	529 ± 35
			Mean =	542 ± 36

* Statistical counting error, $\sigma = 100/\sqrt{N}$; and N, No. of tracks counted

Table 2—Correction for Fission-Track Age by Age-Plateau Method

Annealing temperature °C	(Annealing time = 1 hr)		Fission-track age T(My)
	Fossil-track density $\rho_f (\times 10^3)$	Induced-track density $\rho_i (\times 10^3)$	
Unannealed sample	7.958	45.3	528
100	7.947	44.5	537
200	7.892	42.5	558
300	7.821	35.8	656
400	6.809	29.8	686
500	3.921	17.5	674
600	2.683	11.8	684

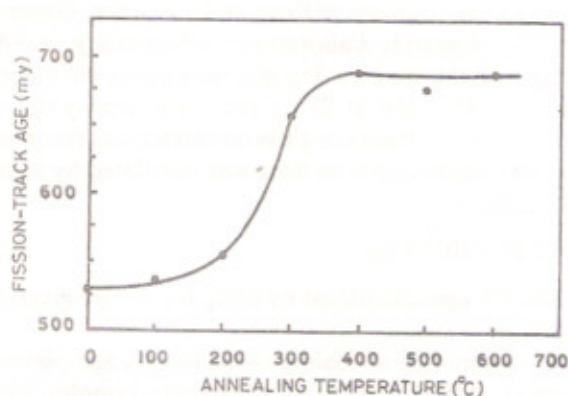


Fig. 1—Fission-track age versus annealing temperature for phlogopite

which the tracks fade naturally. The curve obtained is shown in Fig. 1. The true age obtained by this method is 687 My and observed age is 527 My. Thus the annealing correction to FT age of phlogopite is 23%.

Annealing correction to FT age can also be determined by drawing a curve of reduction in length of translating track versus the reduction in fission-track density. For this, irradiated samples of known induced fission-track density were heated at 500°C, for different time intervals in the range 25-180 min. Reductions in track length and track density were determined corresponding to each heating event. The calibrated scale and graticule, provided in the

microscope, were used for the measurement of track length and track density respectively. A linear relation was observed between the track-length reduction and track-density reduction. The present study reveals that the track-density reduction in phlogopite lags behind the track-length reduction by 10%. The mean length of fossil tracks in phlogopite has been observed to be 10 μm and that of induced fission tracks under identical conditions is found to be 15.17 μm . The mean length of fossil fission tracks is thus less than the mean length of induced fission tracks by 34%. This much reduction corresponds to a 24% decrease in fossil-track density since the latter is always 10% less than the former. Hence the annealing correction to FT age of phlogopite determined by this method is in good agreement with that obtained by the age-plateau method.

On the basis of radiometric data, a widespread metamorphism around 500 My (generally referred to as the Indian Ocean cycle) has been recognized in the eastern coast of India by various workers⁶⁻⁸. A mean FT age of 687 ± 35 My for phlogopite determined in the present work corresponds to the Indian Ocean cycle (450-700 My). Calculated ages of phlogopite samples following the present study show an excellent agreement with ages determined by Kere⁹ for Gudur biotites and those for apatites of the same region determined by Nand Lal and Nagpal¹⁰. The error ranges for the ages are within the statistical counting limits.

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