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CORRECTION METHODS IN FISSION TRACK DATING

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ABSTRACT

Fission track technique is in use for dating minerals and rocks for more than two decades. Most of the ages reported in the literature are the observed ages and need corrections due to geothermal events in the geological past. The annealing effect on fission track age determination is discussed in this paper. A new annealing correction method based on the etch rate studies is given. The results are compared with the existing standard techniques viz. size correction and age plateau methods.

KEYWORDS

Apatite, Muscovite Mica, Fission Track Dating, Annealing.

INTRODUCTION

Fission track technique is an established method for dating minerals and rocks (Fleischer et al., 1975). Since the fission tracks are sensitive to thermal effects, the observed ages need to be corrected. It is now well known that moderate amounts of annealing are manifested as reduction in the length of the latent tracks. This reduction in etchable range is one of the reasons for reduction in track density encountered at any given surface. It is possible to establish the correlation between track density and track size reduction. Mehta and Rama (1969) were among the first to report reduction in the length of the spontaneous fission tracks in mica compared with the induced fission tracks. Storzer and Wagner (1969) obtained a plot between mean diameter of fission track and the observed track density in case of australite glass. Mark et al.(1980) proposed a relation to obtain the corrected value of fisssion track age and is given by.

$$T_c = 6.45 \times 10^9 \; [\, 1 + 9.30 \times 10^{-18} \{\rho_{sc}(0) \;/\; \rho_i\} \times \phi \,] \qquad \text{---(1)}$$

where $\rho_{sc}(0)$ is the corrected value of spontaneous track density and is obtained by using the relation

$$\rho_{sc}(0) = \rho_s \times l_i \;/\; l_s \qquad \text{---(2)}$$

where l_i and l_s are the average track length of induced and fossil tracks. This method known as track size correction technique has been used for correcting thermally lowerd fission track ages in case of minerals.

The other method known as plateau correction was first proposed by (Storzer and Poupeau, 1973). The principle underlying this approach was based on the experimental observation that the apparent fission track ages increased when both the samples with the fossil and induced tracks were slightly preannealed. Two procedures are generally adopted for the fission track age correction, one is isochronal plataeau technique and the other is isothermal plateau technique (Fleischer et al.,1975).

It is well established that the heavy ion tracks in crystalline minerals get shortend and the free energy deposited along the environs of damage gets reduced during thermal annealing. Due to decrease of free energy along fission tracks (two prong rediation damages) the reaction rate of chemical etchant along the damage decreases, which further cause the decrease in track etch rate V_T (Singh, 1990). This decrease in track etch rate can be correlated to the decrease in track length and hence to track density during annealing.

Since the temperature is a predominent parameter in case of track annealing and it has been analysed (Singh, 1990) that the track etch rate V_T is a sensitive parameter at low temperature annealing. Therefore the authors have applied this parameter for the f.t. age correction as a new technique. It is also due to the reason that spontaneous tracks bear annealing during geothermal history at low temperatures for long time. In the present investigation this new age correction technique underlying the principle of the reduction of track etch rate V_T during geothermal annealing, which consequently corresponds to the track density reduction has been applied for correcting observed fission track ages in case of muscovite mica and apatite collected from Andhra Pradesh, India and the results are compared with the track size correction and age plateau methods.

EXPERIMENTAL TECHNIQUE AND RESULTS

In the present work, the isochronal plateau technique was adopted to correct apparent f.t. ages. In this technique two aliquots of a sample are taken, one containing spontaneous fission tracks and the other freshly induced fission tracks. Each aliquot is heated with increasing temperature at constant annealing time (1 hr). The surviving track density in both the aliquots is measured at each temperature. It is observed that the induced track density falls more rapidly than does the spontaneous track density but eventually the ratio of the spontaneous to induced track density reaches a constant value or plateau value. The fission track age from this ratio is the true age and is termed as plateau age i.e. the age which would have been obtained if the fossil track population contained only thermally unaffected tracks. The data obtained in case of apatite and muscovite is

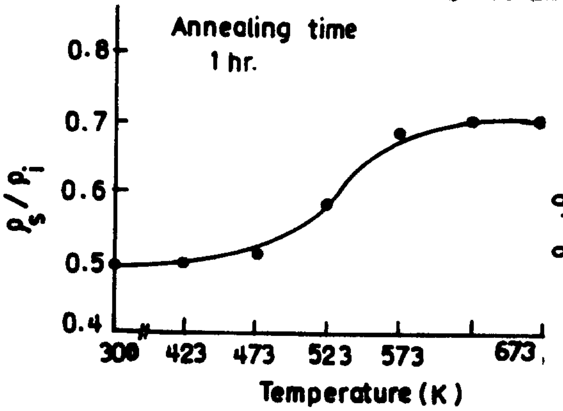

Fig.1. Plot of (ρ_s / ρ_i) versus annealing temperature for constant time (1 hr) in Apatite

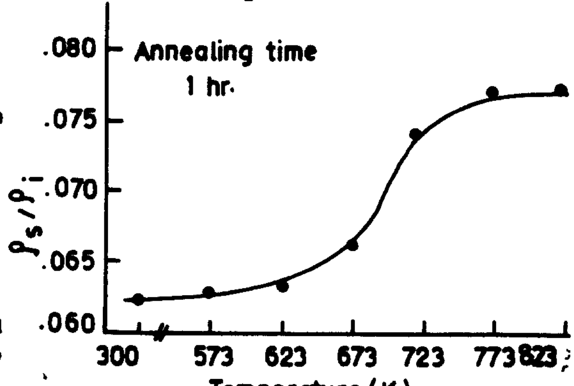

Fig.2. Plot of (ρ_s / ρ_i) versus annealing temperature for constant time (1 hr) in muscovite mica

shown in Figures 1 and 2 respectively. In the new age correction technique we use the two aliquots of the same sample, one containing the natural tracks and the other freshly induced fission tracks. Each aliquot pair is thermally treated for constant time (1 hr) at varying temperatures. The track etch rate V_T is measured in both the samples of each pair at each heating event. At first it is found that the track etch velocity of the induced track decreases at a faster rate than that in case of spontaneous fossil tracks. But eventually the ratio of the track etch rate of induced tracks to spontaneous fission tracks reaches a constant value (Figs. 3 and 4). This constant value of the ratio is termed as a new correction factor.

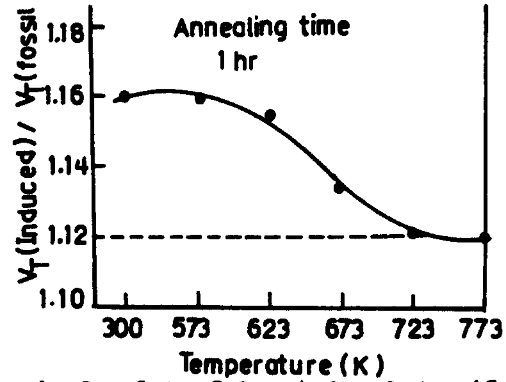

Fig.3. Plot of [V_T(induced)/ V_T(fossil)] versus annealing temperature for constant time(1 hr) in Apatite

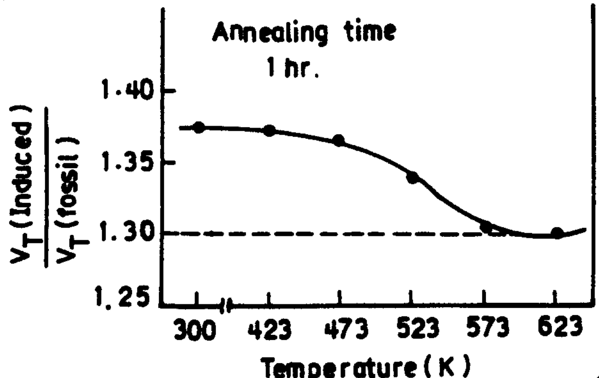

Fig.4. Plot of [V_T(induced)/ V_T(fossil)] versus annealing temperature for constant time (1hr) in muscovite mica.

The corected value of age can thus be obtained by multiplying this factor with the apparent age and is given by the relation

$$T_C = 6.45 \times 10^9 \ln [1 + 9.30 \times 10^{-18} \times \rho_{ta}(0)/\rho_i \times \phi) \quad --(3)$$

where $p_{ta}(0)$ is the corected value of the spontaneous track density and is given by:-

$$\rho_{ta}(0) = \rho_s [V_T(\text{induced}) / V_T(\text{fossil})]_c \quad ---(4)$$

$[V_T(\text{induced}) / V_T(\text{fossil})]_c$ being the correction factor.

DISCUSSION OF THE RESULTS

The values of the apparent and corrected ages of apatite (Visakhapatnam distt.) and muscovite (Nellore mica belt) are reported in Tables 1 and 2 respectively. The uncertainity following the individual ages represents the

Table 1. Corrected f.t. ages after applying different correction techniques in case of apatite.

Sample code		Apparent age(Ma)	Corrected age (Ma) by different methods: Size correction	Plateau	New etch rate
A 1	0.49	481±24* —	577±24*	686±24*	625±24*
A-2	0.51	500±25	601±25		650±25
A-3	0.53	519±25	622±25		674±25
A-4	0.47	462±26	554±26	-	600+26
	Mean	490±25	558±25	686±24	637±24

Table 2. Corrected f.t. ages after applying correction methods in case of muscovite mica.

Sample code		Apparent age(Ma)	Corrected age (Ma) by different methods		
			Size correction	Plateau	New etch rate
MS-1	.068	665±35*	724±35*	748±35*	744±33*
MS-2	.065	637±36	694±36	-	713±36
MS-3	.061	600±36	654±36	-	672±36
MS-4	.68	665±35	724±36	-	718±36
	Mean	642±35	699±35	748±35	718±35

* Statistical counting error.

standard deviation which is calculated from the induced and fossil tracks counted in sample and dosimeter. The mean apparent f.t. ages of apatite and muscovite mica are 490±25 and 642±35 Ma respectively. On comparing the corrected age results, it is found that the plateau ages are higher than the ages determined by track size correction method. This may be due to the reason that the assumption followed in track size correction method viz. the reduction in average track length is equal to the reduction in track density may or may not hold in all the minerals. The ages obtained by new technique lies between the ages calculated by other two techniques. This technique gives the mean fission track age of 637±24 Ma for apatite and 718±35 Ma for muscovite mica. These ages correspond to the Indian Ocean cycle, the range for which has already been reported (Aswathnarayana, 1964).

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