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Annealing studies of fission damages in muscovite

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Arrhenius plots of fission damages in muscovite have been plotted under laboratory conditions and the data have been extrapolated to geologically significant times and temperatures. Fossil fission tracks in muscovite will start fading if it remained at ~ 60°C for 1000 m.y. whereas in the same period, all the tracks will be annealed at a temperature of ~160°C. The activation energy of fission damages in the mineral ranges from 1.4 to 1.8 ev.

1. INTRODUCTION

It has been observed by many workers that muscovite is one of the most promising minerals having high potentiality for unfolding geothermal and geochronological history by fission track dating analysis (Fleischer *et al* 1964; Miller *et al* 1968; Mehta & Rama 1969; Nagpaul *et al* 1974). Tracks are readily etched in 48% HF and are easily recognisable under an optical microscope. Annealing studies of both range and density of fission tracks in cogenetic/coexisting minerals are carried out in the laboratory, in order to reveal the geothermal history of a region, in the case of muscovite, no doubt range annealing studies have been made in detail (Mehta & Rama 1969) but the experimental analysis of density annealing *i.e.*, the Arrhenius plots of the mineral are lacking in the literature. The present report supplements the graphs which are used for computation of the cooling rate of region.

2. EXPERIMENTAL PROCEDURE AND RESULTS

The samples of muscovite of size ~15×10 mm cleaved from the tight books collected from Pokharia mica mine of Bihar mica belt, were heated at a temperature of 700°C for six hours, to erase fossil fission damages. They were packed and got irradiated with a thermal neutron dose of ~10^{17} nvt. at CIRUS Reactor Bombay. The annealing studies were carried out by following the technique of Naeser & Faul (1969). The irradiated samples were divided into different lots. These were overetched, scanned for induced tracks and annealed by placing the sample in a preheated crucible placed on an iron block in a furance, temperatures of which, monitored with a thermocouple, could be controlled within ±5°C. The annealing temperatures ranged from 570°C to 480°C at an interval of 30°C in each step. The upper 30–40 micron thickness of each of the annealed sample was removed by cleaving. The fresh surface was overetched and scanned for remaining tracks.

The percentages of tracks faded after each run at a fixed temperature versus log of time are drawn in figure 1. Figure 2 shows the annealing data of the mineral on an Arrhenius diagram. Individual points on this graph represent 0%, 25%, 50% and 100% track reductions determined at various temperatures corresponding to different times of figure 1. The data are extraploated to geologically significant times and temperatures.

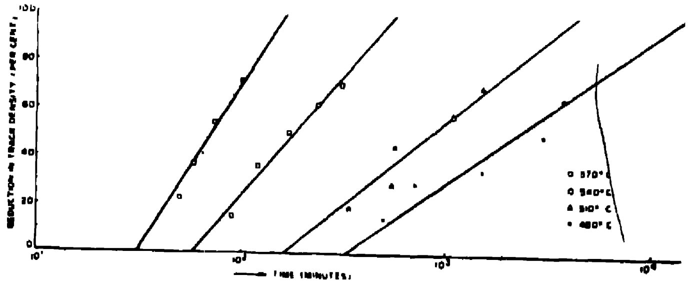

Fig. 1. Experimental results for annealing of fission tracks in muscovite.

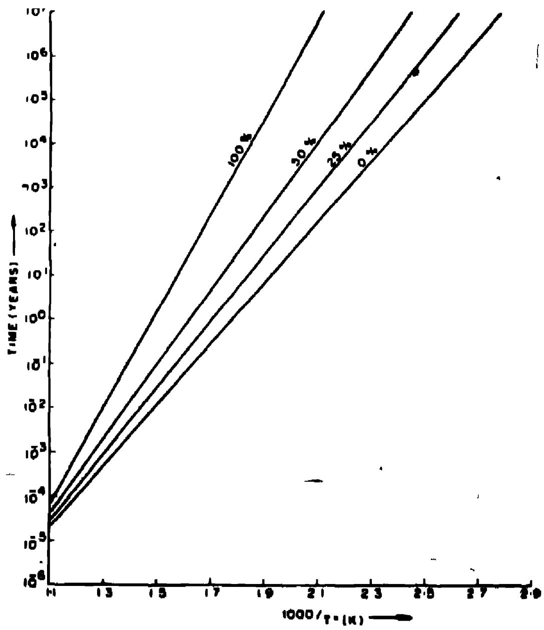

Fig. 2. Arrhenius plots for muscovite.

3. Discussion

The Arrhenius plots show that muscovite will start losing the tracks if it remained at a temperature of ~60°C for 1000 m.y. whereas in the same period, all the fossil tracks will be wiped out if the sample remained at an ambient temperature of ~160°C. The temperatures corresponding to different timings for various reductions of density as calculated from the Arrhenius plots are given in column 4 of table 1. The temperature values for different reductions (table 1) indicate that muscovite will yield fission track ages close to the true ages of metamorphism, as observed by (Mehta *et al* 1971) in case of three mica belts of India *i.e.*, Rajasthan, Nellore and Bihar. Also the reduction in fossil track density as a result of geological annealing is zero, indicating thereby that the average temperature of pegmatites after the last major metamorphic event must have remained to the right of the zero percent track reduction curve.

The Arrhenius plots which represent the thermal and temporal stability of tracks in the mineral in terms of different degrees of annealing are described by the equation (Fleischer *et al* 1965).

$$\ln t = \ln a + \frac{E}{kT}, \qquad \dots (1)$$

where t and T are the annealing times and temperatures respectively, E is the activation energy and k is the Boltzmann constant. The activation energies calculated with help of the following relation for various reductions in the Arrhenius plots are given in column 3 of table 1.

Table 1

Sr. No.	Density Reduction (%)	Activation Energy, E (eV)	Temperatures °C required for the reduction in time					
			1 hr.	1 m.y.	10 m.y.	50 m.y.	500 m.y.	1000 m.y.
1	2	3	4					
1.	0	1.4	550	105	85	70	55	50
2.	25	1.5	575	125	105	90	75	60
3.	50	1.6	595	150	135	115	100	95
4.	100	1.8	620	215	195	180	165	155

$$E = k\left[\frac{1}{T_1} - \frac{1}{T_2}\right]^{-1} \ln\left(\frac{t_1}{t_2}\right).$$

The variation of activation energy as a function of density reduction as plotted in figure 3, is linear and it indicates that there is a continuous spectrum of activation energy of fission damages in the mineral. Figure 3 also shows that for the beginning of the track facing, the minimum activation energy for muscovite, as observed in other minerals, is $\gg 0$. It may be explained as follows:

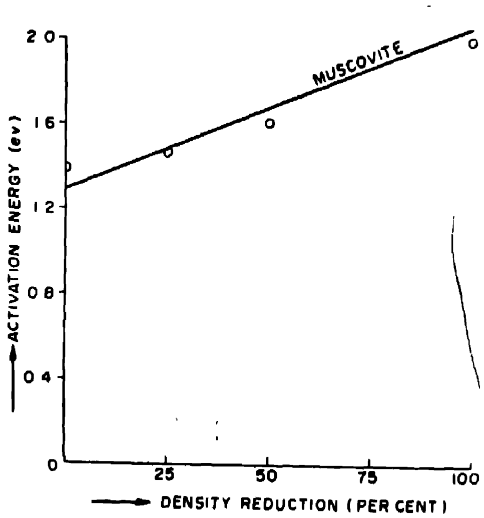

Fig. 3. Variation of activation energy with density reduction.

(i) *For Range Annealing*

It has been observed that the length of the etched portion of the track is smaller than the entire range of the damage in muscovite (Debeauvais *et al* 1963; Price *et al* 1973). This is because in the end of the range, the fragments are slowed down to such an extent that they accumulate the electrons already lost and thus become less heavily ionised. When the sample is heated the annealing of the tracks proceed from both the ends of the fission track. Zero reduction of the etchable range in the annealed sample does not imply that annealing is not there. It is possible that annealing effects may be there causing the fading of the unetchable region of the fission damage. It shows that although the observed annealing lie on 0% curve, the radiation damage is annealed giving rise to the finite value of the activation energy.

(ii) *For density annealing*

Mehta & Rama (1969) indicated that for no loss of density of fission tracks in muscovite, there is always a finite reduction in etchable range which accounts for non-zero value of activation energy for beginning of the track fading.

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