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THE EFFECT OF ANISOTROPIC TRACK ETCHING AND ANNEALING ON FISSION TRACK AGE DETERMINATION IN MINERALS

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Abstract – Experiments have been performed to study the effect of crystallographic structure on fission track(f.t.) age determination in apatite. The observed f.t. age is maximum (83.1±3.8 m.y.) in a plane parallel to c-axis and minimum (63.0±2.4 m.y.) in the perpendicular plane. However, after applying some appropriate corrections, concordant results are obtained for each crystallographic direction.

1. INTRODUCTION

The mineral track detectors have a special place among SSNTDs due to their relatively high fission track retentivity during geological periods. These are generally used as a tool for dating rocks and for revealing geothermal history of an area. Since most of the minerals occur in the form of crystals with variable atomic spacing along different crystallographic orientations, their etching and annealing characteristic for radiation damage may vary with the crystal orientation[1-5]. In the present investigations, the f.t. age is measured on different planes of apatite and some corrections due to anisotropy are reported. Apatite crystal procured from Quebec Lavel Museum and of Wakefield area in Canada has been used for such studies.

2. EXPERIMENTAL PROCEDURE

The samples from 0001, 1$\bar{1}$01 and 10$\bar{1}$0 planes of apatite were separated and prepared after grinding and polishing. In the present work, population method[3] has been used for f.t. age measurement on different planes of crystal. Fossil and induced samples were etched in 2 % HNO_3 for 3 min at 25°C. The thermal neutron irradiations were carried out from the CIRUS Reactor, at BARC, Bombay. The f.t. age is calculated using equation[6]:

$$T = 6.57\times10^{9} \ln(1+9.25\times10^{-18} \times \frac{\rho_s}{\rho_i} \times \phi) \qquad (1)$$

where ρ_s and ρ_i are the fossil and induced track densities and ϕ is the total thermal neutron dose. The results are given in Table 1.

3. RESULTS AND DISCUSSION

The value of the observed f.t. age is maximum (83.1±3.8 m.y.) in a plane parallel to c-axis and minimum (63.0±2.4 m.y.) in the perpendicular plane (Table 1). This large difference in f.t. age (~24 %) with crystal orientation is mainly due to the large difference in the value of ρ_s. The variation in ρ_i with crystal orientation is small as compared to that of ρ_s. Since the apatite is a temperature sensitive crystal, the loss of fossil tracks due to geological annealing is quite large. It has been shown earlier[2], that the anisotropy of the annealing process causes tracks normal to the c-axis to be shortened more rapidly than the tracks parallel to this axis. This means that if the fossil tracks are measured in basal sections (0001 plane) most of the tracks analysed will be perpendicular to the c-axis, and will therefore show greater loss than the tracks measured in prismatic sections (10$\bar{1}$0) plane. This is responsible for the lower value of fossil track density in 0001 plane. However, concordant f.t. age may be obtained for different planes of apatite by applying corrections due to partial anisotropic annealing of fossil tracks, as follows:

In deriving eqn(1), it was assumed that Rs ηs = Ri ηi, where Ri and Rs are the mean etchable ranges of single induced and spontaneous fission fragments in the sample, respectively, while ηi and ηs are the respective etching efficiencies. The etching efficiency of fission tracks (η) is related to Θ_c as:

$$\eta = 1 - \sin \Theta_c$$

Table 1. Fission track age on different planes of apatite crystal
Thermal neutron fluence (ϕ) = 4.5×10^{14} n cm^{-2}.

Plane	Sample No	ρ_s ($\times 10^5$)	ρ_i ($\times 10^5$)	T$\pm$1σ (m.y.)
0001	AP-1	12.00	5.12	62.9$\pm$4.2
	AP-2	12.19	5.19	63.1$\pm$4.2
	AP-3	12.24	5.21	63.1$\pm$4.2
				Mean = 63.0$\pm$2.4
$1\bar{1}01$	AP-4	15.15	5.57	73.0$\pm$4.8
	AP-5	15.26	5.59	73.2$\pm$4.8
	AP-6	15.29	5.61	73.2$\pm$4.8
				Mean = 73.1$\pm$2.7
$10\bar{1}0$	AP-7	18.16	5.83	83.5$\pm$5.5
	AP-8	18.21	5.88	83.1$\pm$5.5
	AP-9	18.31	5.93	82.8$\pm$5.5
				Mean = 83.1$\pm$3.8

Khan and Durrani[7] have shown that Θ_c tends to increase with annealing and thus η is reduced. This means that during geological annealing of apatite, ηs and Rs are reduced. Due to anisotropic track annealing this reduction will not be identical for various planes of apatite. So the f.t. age determined under the assumption Rs ηs = Ri ηi (eqn.1) is then corrected by this factor as:

$$T = 6.57 \times 10^9 \ln(1 + 9.25 \times 10^{-18} \times \frac{R_i \eta_i}{R_s \eta_s} \times \frac{\rho_s}{\rho_i} \times \phi) \quad (2)$$

The values of Rs, Ri, ηs and ηi are summarized in Table 2. The results

Table 2. The values of Ri, Rs, ηi and ηs for different planes of apatite crystal using 2 % HNO_3 track etchant.

Crystal plane	Induced tracks R_i (μm)	Induced tracks η_i	Fossil tracks R_s (μm)	Fossil tracks η_s
$10\bar{1}0$	16.1$\pm$0.2	0.96	15.3$\pm$0.3	0.94
$1\bar{1}01$	15.1$\pm$0.3	0.94	13.6$\pm$0.4	0.86
0001	14.2$\pm$0.3	0.91	11.4$\pm$0.2	0.82

for corrected age, using eqn.2 are given in Table 3. It is observed (Table 2) that reduction in R_s η_s is more in basal plane during the geological history of the sample. The concordant f.t. ages (Table 3) are

Table 3. Fission track age (corrected for anisotropy) on different planes of apatite.

Plane	Sample No	ρ_s ($\times 10^5$)	ρ_i ($\times 10^5$)	$T \pm 1\sigma$ (m.y.)
0001	AP-1	12.00	5.12	86.87±5.8
	AP-2	12.19	5.19	87.05±5.8
	AP-3	12.24	5.21	87.07±5.8
				Mean=86.99±3.3
$1\bar{1}01$	AP-4	15.15	5.57	88.49±5.8
	AP-5	15.26	5.59	88.81±5.8
	AP-6	15.29	5.61	88.67±5.8
				Mean=88.66±3.3
$10\bar{1}0$	AP-7	18.16	5.83	90.66±5.9
	AP-8	18.21	5.88	90.14±5.9
	AP-9	18.31	5.93	89.88±5.9
				Mean=90.23±3.4

obtained on various planes of apatite, by applying the appropriate corrections for anisotropic annealing.

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