FISSION TRACK AGES OF SOME MUSCOVITES OF BIHAR MICA BELT

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ABSTRACT

The fossil fission track technique has been used in dating Precambrian muscovite samples of Bihar Mica Belt (Kodarma, District Hazaribag). The average age obtained for this belt is 865 ± 72 million years which agrees with the age determined by radiometric methods.

INTRODUCTION

THE fossil fission track technique was introduced by Price and Walker (1963) for dating of rocks and mineral samples of geological origin. It utilises the fact that uranium is present in almost all the minerals and it undergoes spontaneous fission at a rate much slower than its usual disintegration through α-decay. The fission fragments which are produced travel inside the mineral leaving their tracks as radiation damaged regions. These tracks are of thickness 100 A and can be directly observed under an electron microscope[1]. However, they can be observed under an optical microscope[2] by etching the tracks with suitable chemical reagents.

Theory.—The formula used for calculating the age of the samples of Precambrian origin has been derived by Price and Walker[3-5]. It has been applied with success by Mehta and Nagpaul[6].

The density ρ_s of fossil fission tracks due to spontaneous fission of U^{238} present on any cleaved surface is given by

$$\rho_s = \frac{n_{238}\lambda_f R_0 (e^{\lambda_d T} - 1)}{2\lambda_d} \quad (1)$$

where n_{238} is the number of U^{238} atoms/c.c. of the mineral, λ_f and λ_d are constants for spontaneous fission and α-decay respectively, R_0 is the combined range of fission fragments in mineral and T is the time since the sample started registering the tracks after it was crystallised.

The concentration of U^{238} in the sample is determined by measuring the concentration of U^{235}, which is done by irradiating the sample with a known dose of thermal neutrons in a nuclear reactor and measuring the density ρ_i of induced fission tracks on a newly cleaved surface.

$$\rho_i = n_{235}\sigma\phi R_0/2 \quad (2)$$

where n_{235} is number of U^{235} atoms/c.c. of mineral, σ is cross section for thermal neutron capture and ϕ is the integrated (nvt) thermal neutron dose.

Eliminating R_0 from (1) and (2),

$$T = \frac{1}{\lambda_d}\log_e\left(1 + \frac{\rho_s I\phi\sigma\lambda_d}{\rho_i\lambda_f}\right) \quad (3)$$

where I is isotopic abundance of U^{235}. The values of various constants of eqn. (3) are :

$$\lambda_f = 7\cdot03 \times 10^{-17}\ \mathrm{yr}^{-1}$$
$$\sigma = 582 \times 10^{-24}\ \mathrm{cm}^{-2}$$
$$I = 7\cdot26 \times 10^{-3}$$
$$\lambda_d = 1\cdot52 \times 10^{-10}\ \mathrm{yr}^{-1}.$$

Substituting these values, the eqn. (3) reduces to age formula

$$T = 6\cdot57 \times 10^{9}\log_e\left(1 + 9\cdot25 \times 10^{-18} \times \frac{\rho_s}{\rho_i} \times \phi\right) \quad (4)$$

Experimental Details.—The muscovite samples selected for this study have been collected from the mica mines of Kodarma, District Hazaribag (Bihar). The tight books of muscovite were chosen, washed and cleaved along the horizontal plane to expose fresh surfaces for etching of radiation damage. The samples were cut to the dimensions 2 cm, × 1·5 cm, × 200 μm.

The samples are etched by immersing them for 1 hour in 48% HF at room temperature. The radiation damaged portions are attacked by chemical action and after washing and drying of samples the fossil fission tracks can be observed under the optical microscope using a magnification of 300–600 ×. The tracks appear as dark black rods and can be easily counted to find the surface density ρ_s. Care should be taken to count the tracks only on the cleaved surface without going inside the sample.

To determine the induced fission track density ρ_i, the samples are prepared from the original tight books of muscovite, washed with de-ionised water and alcohol respectively and packed in lexan bags to fit a cylinder of diameter 1·6 cm and of length 3·5 cm. These samples are sent to the Isotope Division, B.A.R.C., Trombay, for irradiation with an integral neutron dose of 10^{18} which is determined by enclosing a calibrated glass dosimeter alongwith the samples.

The induced fission of U^{235} takes place and the fission fragment tracks are deposited inside the samples as well as the glass dosimeter. The samples are etched as previously and the surface density ρ_i of induced fission tracks is determined. The glass piece is fractured to expose the fresh surface and etched in 20% HF for 30 seconds at room temperature. The surface density ρ of etch pits is measured and the integral neutron flux ϕ is calculated by using the calibration relation[7],

$$\phi = 2 \cdot 26 \times 10^{11} \rho \qquad (5)$$

Results.—From the measured values of ρ_s, ρ_i and ϕ, the fission track ages of muscovite samples have been calculated from relation (4). The results are summarized in Table I. It is evident that the

TABLE I

Fission track ages of Bihar Mica Belt (Kodarma Muscovites)

Total neutron dose (nvt) = $4 \cdot 3 \times 10^{18}$

Radiometric age[8-10] (m.Y) = 840–1100

Sample No.	ρ_s (cm^{-2})	ρ_i (cm^{-2})	T Fission track age (m.Y)
1	20	5415	901 ± 212
2	19	5531	844 ± 194
3	20	5708	856 ± 196
4	23	5354	1031 ± 206
5	19	5336	863 ± 199
6	19	5460	850 ± 195
7	16	5796	679 ± 176
8	19	5681	821 ± 188
9	20	5045	957 ± 220
10	20	5768	844 ± 194
		Mean	865 ± 72

ages lie between 700–1100 m.y. The average age comes out to be 865 ± 72 million year which agrees with other age determinations made by radiometric methods[8-10].

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THERMAL DECOMPOSITION KINETICS

Part VI*. An Absolute-Rate-Theory-Based Equation for the Evaluation of Kinetic Parameters from Nonisothermal Thermogravimetry

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ABSTRACT

A new equation, taking into account the temperature-dependence of the pre-exponential factor based on the absolute rate theory of reactions, is proposed for the evaluation of kinetic parameters of solid-state reactions from nonisothermal thermogravimetric data.

THE rate equation widely used by different workers in nonisothermal thermogravimetry (TG) can be put in the form[6]

$$d\alpha/dT = (A/\phi)(1-\alpha)^n \exp(-E/RT) \qquad (1)$$

where α = fraction decomposed at temperature T, ϕ = heating rate, A = pre-exponential term, R = gas constant and E = energy of activation. In integrating eq. (1) it has always been assumed that A is temperature-independent[7-11]. Ingraham and Marier point out that this assumption is not rigorously valid[12]. A critical review of this aspect has recently been made by Gyulai and Greenhow[13]. In this communication, we wish to present the derivation of a more accurate equation taking into account the temperature-dependence of A.

* For Parts I to V, *see* references 1 to 5.