RESEARCH PAPER | Geology | Volume : 3 | Issue : 9 | Sept 2013 | ISSN - 2249-555X

The Fission Track Ages of Some Co-Genetic Minerals in the Granitic Rocks From Nongstoin Area of Central Assam- Meghalaya Plateau

KEYWORDS: F.T.age, U concentration, sphene, apatite, zeta calibration, alkaline rocks, Sylhet trap.

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ABSTRACT *Some granitic rocks including porphyritic and nonporphyritic granites, aplites and pegmatites of Nongstoin area belonging to Central Assam- Meghalaya Plateau have been selected for the present study. The plateau is considered as an extension of peninsular India and consists essentially of quatzo feldspathic gneiss with NE-SW strike of foliation. The gneisses together with the enclaves of various rock units are intruded by several generations of granitic rocks of different types. Fission Track (F.T) ages of sphene and apatite in studied samples were found to be discordant. The apatite ages are significantly lower than those of sphene. These ages range from 595+43 Ma to 525+40 Ma for sphene and 132+12 Ma to 110+10 Ma for apatite respectively. The F.T. ages in sphenes show that the granitic, aplitic and pegmatite veins in the area under study belong to different generations. The sphene ages can be considered as the cooling ages of the rock and mark the ages of Indian Ocean Cycle orogeny. The F.T. ages of apatite showing early to middle Cretaceous age are taken to be indicative of resetting of tracks during a thermal event associated with the extensive igneous activities during the Jurassic Cretaceous time which post dated the time of granitic emplacement in the area. The temperature of this thermal event might not have raised high enough to affect the tracks in sphene.*

Introduction

The Nongstoin area (Lat. 25^{0}33′ N – 25^{0}30′ N and Long. 91^{0}20′ E- 90^{0}12′30″ E) is a part of West Khasi Hills District of Meghalaya and is lying nearly at the center of the Assam Meghalaya Plateau (Fig 1). Some granitic rocks including porphyritic and non-porphyritic granites, aplites and pegmetites of Nongstoin area belonging to Central Assam-Meghalaya plateau have been selected for the present study. The plateau is considered as an extension of Peninsular India and consists essentially of gneissic rocks belonging to Precambrian age, with nearly east-west strike of foliation. Granulites, sillimanite schist and amphibolites occur in the gneisses. Porphyritic granite in the form of large bosses and aplitic and pegmatitic veins are emplaced into the above rock units. The gneisses include biotite gneiss, grey and pink coloured quartzofeldspathic gneiss and granitic gneiss and these gneisse together constitute the Gneissic Complex of the Assam Meghalaya Plateau. Gradations from one type to another are the most common features of the gneisses, yet they exhibit diversity in grain size, colour and texture.

The stratigraphy established from the exposed outcrops are given in Table 1.

Table-1: Stratigraphic Succession of Nangstoin area:

Geological age	Lithology
Quarternery and Recent	In situ covering of soil, mainly composed of sand, silt and clays.
--------------------Unconformity--------------------	
Precambrian	Quartz and feldspathic veins.
	Pegmatitic veins and lenticles, aplitic veins and dykes.
	Porphyritic granites and equigranular granites.
	Pyroxene granulites and amphibolites.
	Various types of quartzofeldspathic.
	Gneisses with enclaves of sillimanite schist.

Geological Map of the Area Under Study

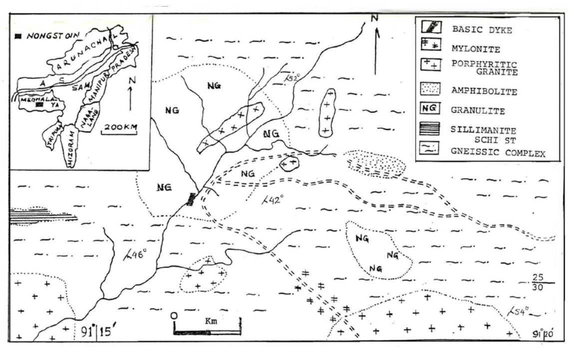

Fig. 2.3 : GEOLOGICAL MAP OF THE NONGSTOIN AREA.

Fig 1: Geological map of the Nongstoin area.

Experimental Procedure

A total of seven granitic rocks have been selected for the present study. Cogenetic minerals sphenes and apatite were separated, mounted, cleaned and polished following the usual procedure. The mounted, polished grains were then etched with suitable solvent (Table – 2) till the fossil tracks were rendered visible under an optical microscope. The fossil tracks were observed and scanned under Binocular Microscope in transmitted light using a magnification of 1000 X (oil immersion)

Table- 2 The etching condition used in the study

Mineral	Etchant		Temperature
Time			
Apatite	6% HNO_3	Room Temperature	25-30 sec
Sphene	1(conc. HF): 2(conc. HNO_3): 3(conc. HCl):6H_2O	Room Temperature	12-20 min.
Muscovite	40% HF	Room Temperature	30-45 min

For the measurement of induced track density the same mounted samples were irradiated with a known dose of the thermal neutrons (~10^{16}) in the thermal column of CIRUS Reactor of Bhaba Atomic Research Center, Trombay. In the muscovite detector the replica of the grains were observed. Thermal nutron fluencies were monitored by counting tracks recorded in muscovite detectors attached to the pieces of standered glass SRM $_{612}$. The induced tracks were scaned using a magnification of 1000X. About 1000 tracks were counted for the dosimeter glass.

Working Formula
Ages were calculated according to the standard fission track age equation using the zeta calibration method (Hurford and Green, 1983).

Zeta calibration Method
In Zeta calibration method, a dosimeter glass is calibrated against standard/standards and then the calibrated factor zeta is applied for age determination of unknown sample.

The age equation using external detector method is given by,

$$T_{unknown} = \lambda_D^{-1} \ln [1 + \lambda_D.\xi.(\rho_s/\rho_i)\, g\, \rho_d \quad \text{-----------------}\blacktriangleright \quad (1)$$

The ξ factor for a given glass dosimeter is evaluated from age standard/standards according to the relation:

$$\xi = \frac{(e^{\lambda D.\, T\, std} - 1)}{\lambda_D\, (\rho_s/\rho_i)_{std}\, g\, \rho_d} \quad \text{------------------------}\blacktriangleright \quad (2)$$

$$\text{Where} \quad \xi = \frac{B\sigma I}{\lambda_f}$$

Correlation coefficient

$$c.c = \frac{\sum_{k=1}^{k=N} \{\rho_{i\,(k)} - x_i\}\{\rho_{s\,(k)} - x_s\}}{\sqrt{[\sum_{k=1}^{k=N} \{\rho_{i\,(k)} - x_i\}^2 \sum_{k=1}^{k=N} \{\rho_{s\,(k)} - x_s\}\}^2}} \quad (3)$$

$$x_i = \frac{\sum_{k=1}^{k=N} \rho_{i\,(k)}}{N} \; ; \quad x_s = \frac{\sum_{k=1}^{k=N} \rho_{s\,(k)}}{N}$$

Where T= Fission track age, in years

λ_D= Total decay constant for ^{238}U = 1.55125 x 10^{-10} Yr^{-1}

λ_f = Spontaneous fission decay constant ^{238}U

Φ= Total integrated thermal neutron dose

σ= Cross-section for thermal neutron in fission of ^{235}U= 580.2 x $10^{-24}cm^2$

I = Isotopic abundance ratio of ^{235}U to ^{238}U= 7.2527x10^{-3}

ρ_s= Spontaneous track density of the sample

ρ_i= Induced track density of the sample

ρ_d= Induced track density of the dosimeter glass

g= Geometry factor

Uranium Concentration measurement

$$C_x = C_s \left(\frac{I_s}{I_x}\right) \left(\frac{\rho_x}{\rho_s}\right) \quad \text{------------------}\blacktriangleright \quad (4)$$

Where the subscript s and x refer to the standard and the unknown respectively.

$$\delta_T = T \sqrt{\{ \frac{1}{N_s} + \frac{1}{N_i} + \frac{1}{N_d} + (\frac{\delta\xi}{\xi})^2 \}}$$

Statistical error
Where N_s= Number of spontaneous tracks counted in the sample.

N_i= Number of induced tracks counted

N_d= Number of induced tracks counted in the dosimeter glass

δ ξ= The statistical counting error of ξ and is given by,

$$\delta\xi = \xi \sqrt{\{ (\frac{\delta_{T\,std}}{T_{std}})^2 + (\frac{1}{N_s} + \frac{1}{N_i})_{std} + (\frac{1}{N_d}) \}}$$

Results
A total of seven granitic rocks have been selected for the present study. The F.T. ages in sphene and apatite grains and uranium concentration in them were determined following equation 1 and 4. The data obtained are shown in table 3 and 4.

The results of annealing charecteristics of sphene and apatite are shown in fig. 2.1 and 2.2 respectively. The 100%, 50% and 0% track loss curves for sphene and apatite are shown in fig. 2.3 & 2.4 respectively. The results of the isochronal plateau study of sphene and apatite are shown graphically in fig. 2.5 and 2.6 respectively.

Annealing Studies of Fission Tracks

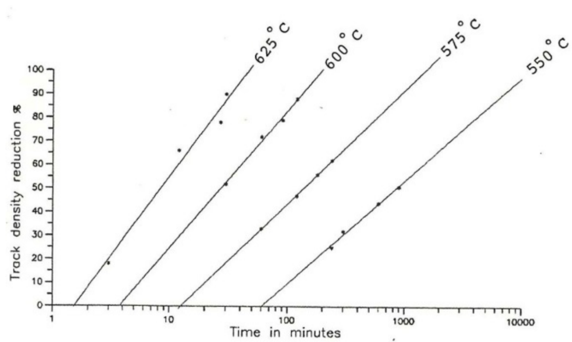

Fig: 2.1- Experimental annealing data of sphene

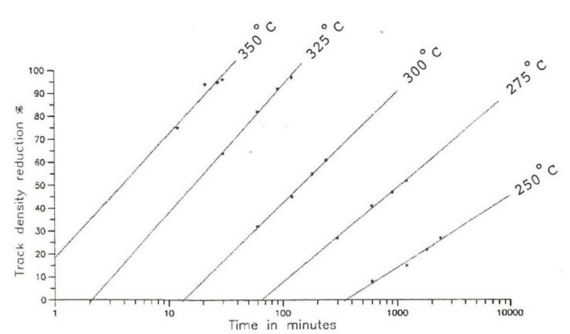

Fig 2.2- Experimental annealing data of apatite

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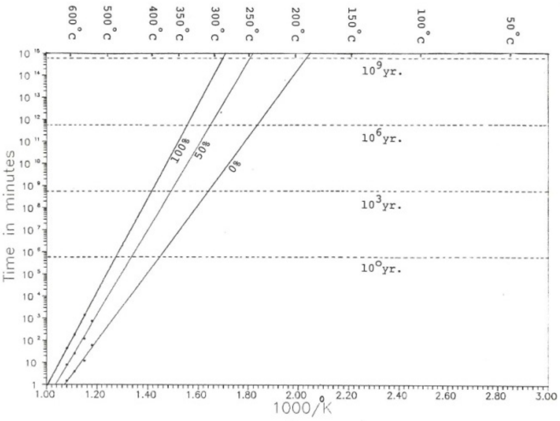

Fig: 2.3- Arrhenius plots of sphene

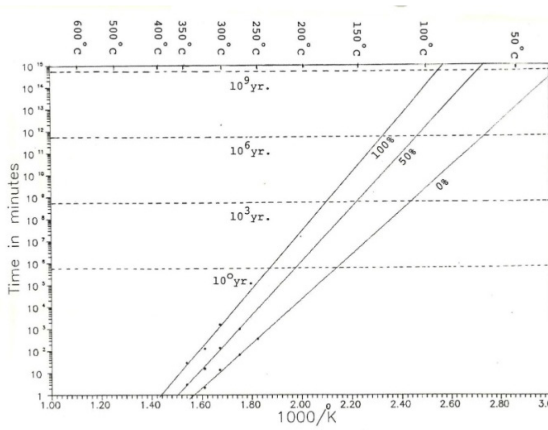

Fig 2.4- Arrhenius plots of apatite

Table-3 Fission Track ages in sphenes and uranium concentration in the samples under study (Nongstoin Area)

Standard Sample & Reference Age	Sample No.	Rock Type	Number of crystal	pd X 10^6 (cm^{-2})	N_s	p_sx10^6 (cm^{-2})	N_i	p_i X 10^6 (cm^{-2})	c.c	F.T age (Ma) ± σ	U Concentration (ppm)
Fish Canion Tuff (Sphene) T= 27.9 ± 0.7 Ma ξ=328.65 ± 15.56	SN/13	Fined grained hypersthene bearing aplite.	10	0.721	3333	14.952	634	2.842	0.933	595±43	48±2.4
	SN/9	Porphyritic granite with gradational contact with the Gneissic Complex.	10	0.721	2758	12.368	531	2.381	0.588	588±44	40±2.1
	SN/3	Porphyritic granite boss showing crosscutting contact with the Gneissic Complex.	9	0.721	2548	12.869	494	2.494	0.613	584±44	42±2.3
	SN/2	Medium grained aplite crosscutting porphyritic granite.	7	0.721	2046	11.691	434	2.48	0.676	536±42	42±2.4
	SN/7	Pegmatite(Garnet bearing)	8	0.721	1724	9.473	372	2.044	0.715	527±43	34±2.1
	SN/5A	Coarse grained pegmatite, not crushed.	10	0.721	2326	10.863	501	2.351	0.755	525±40	39±2.1
	SN/5B	Crushed coarse grained pegmatite	7	0.721	1879	10.738	406	2.32	0.534	526±42	39±2.2

Table-4 Fission Track ages in apatites and uranium concentration in the samples under study (Nongstoin Area)

Standard Sample & Reference Age	Sample No.	Rock Type	Number of crystal	pd X 10^6 (cm^{-2})	N_s	p_sx10^6 (cm^{-2})	N_i	p_i X 10^6 (cm^{-2})	c.c	F.T age (Ma) ± σ	U Concentration (ppm)
Fish Canion Tuff (apatite) T= 27.9 ± 0.7 Ma ξ=356.68 ± 19.04	AN/13	Fined grained hypersthene bearing aplite.	12	1.34	253	0.958	461	1.746	0.586	130 ±13	13 ± 0.73
	AN/9	Porphyritic granite with gradational contact with the Gneissic Complex.	15	1.34	278	0.911	498	1.633	0.704	132 ± 13	12 ± 0.66
	AN/3	Porphyritic granite boss showing crosscutting contact with the Gneissic Complex.	16	1.34	286	0.932	519	1.691	0.568	130 ± 13	13 ± 0.70
	AN/2	Medium grained aplite crosscutting porphyritic granite.	12	1.34	191	0.749	355	1.392	0.487	127 ± 14	10 ± 0.62
	AN/7	Pegmatite(Garnet bearing)	10	1.34	220	1.028	458	2.14	0.497	114 ± 12	16 ± 0.90
	AN/5A	Coarse grained pegmatite, not crushed.	18	1.34	506	1.446	1090	3.114	0.513	111 ± 9	23 ± 1.0
	AN/5B	Crushed coarse grained pegmatite	15	1.34	519	1.724	1121	3.761	0.634	110 ± 9	28 ± 1.2

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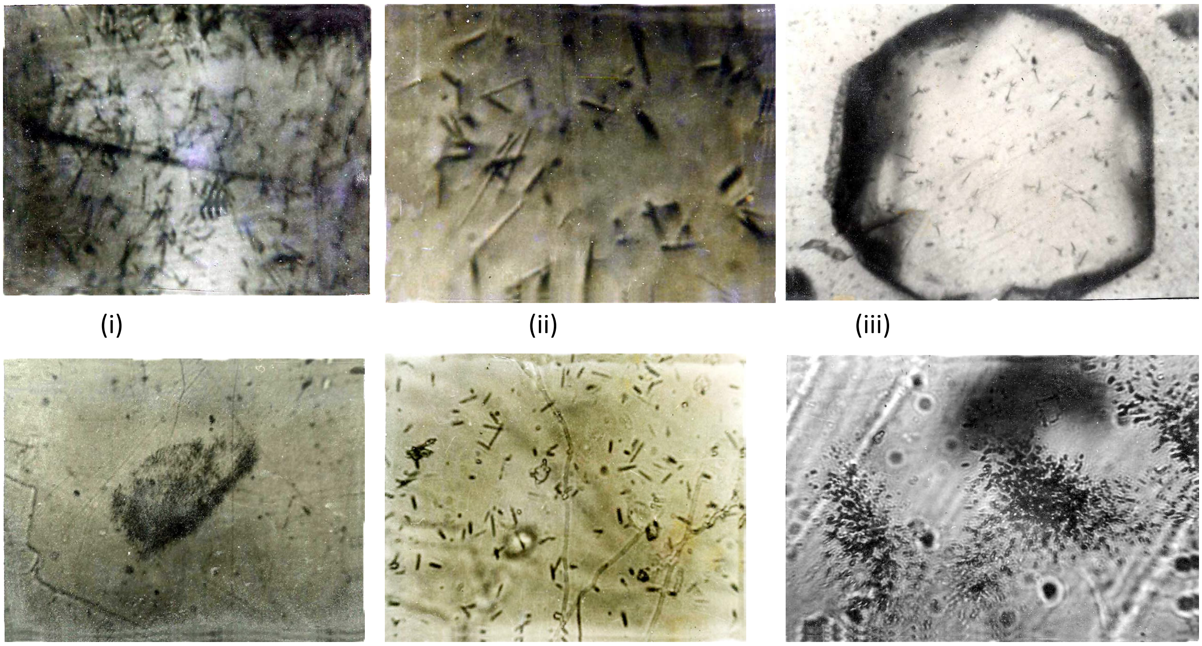

Fig: 3 (i) Tracks in Sphene, (ii) Tracks in Apatite, (iii) Apatite grains with tracks, (iv)Replica of sphene grain formed by tracks in detector, (v) Tracks of standard glass SRM-612 in detector, (vi) Replica of apatite grains formed by tracks in detector.

Discussion and Conclusions

The F.T. ages of sphene and apatite in studied samples are found to be discordant. The apatite ages are significantly lower that that of the sphene ages. These ages ranges from 595$\pm$43 Ma to 525$\pm$40 Ma for sphene and 132$\pm$12 Ma to 110$\pm$10 Ma for apatite respectively. The F. T. ages in sphenes show that the granitic, aplitic and pegmatitic veins in the area under study belong to different generations. From the annealing studies in sphenes it is found that there is no annealing of tracks (Fig 2.1, 2.3 & 2.5). Therefore, the sphene ages can be considered as the cooling ages of the rock and mark the episode of Indian Ocean Cycle Orogeny (400-650 Ma) during which severe metamorphism and pegmatite intrusion took place (Sarkar, 1980).

The F.T. ages of apatite showing Early to Middle Cretaceous age are taken to be indicative of resetting of tracks during a thermal event which post dated the time of granitic emplacement in the area. From the annealing studies it is found that there is no geological fading of fission tracks in apatite (Fig 2.2, 2.4 & 2.6). Therefore the apatite ages are either related to very slow cooling of complete overprinting of ages due to thermal event which postdated the granitic intrusions and the "Indian Ocean Cycle" orogeny. Geological history reveals (Krishnan, 1956), that during Jurassic-Cretaceous times, there took place a number of igneous intrusions in the Assam Meghalaya Plateau. Notable among them are alkaline rocks of the Sung Valley type and the Sylhet Traps and their equivalents. The apatite ages showing early to middle Cretaceous ages might have indicated a complete resetting of the apatite tracks during the last thermal event that took place in the plateau. The temperature of this thermal event might not have raised high enough (but greater than 120^0) to affect the tracks in sphenes.

The Assam-Meghalaya plateau has experienced geological disturbances since the earliest geological times as evident from the occurrences of several episodes of deformation, sheer belts, igneous activities and uplift and submergence of it. The said apatite ages might have recorded the time of re-setting of the tracks in them during one of these events. The most probable of the events that caused the re-setting of the tracks in apatites is supposed to have been associated with the extensive igneous activities during the Jurassic- Cretaceous time when the alkaline rocks of Sung- Valley type and their equivalents are the Sylhet traps were emplaced in the Assam-Meghalaya plateau.

Although neither the traps nor the alkaline rocks occur at the immediate vicinity of the area, occurrences of basaltic and doleritic dikes presumed to be intrusive equivalents of the sylhet traps (Krishnan, 1956) are found in the area under study. Also Bhattacharya and Mazumdar (1996) have reported two isolated patches of trap rocks in the north western part of the Assam Meghalaya plateau. According to them these traps might represent the relict of an once extensive volcanic flow of the Sylhet trap type that have extended to the area under study.

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