Jour. Assoc. Expl. Geophys.
April, 1984 : Vol. IV, No. 4 pp. 19-22

Radiation Damage Dating of Apatite and Zircon from Eastern Ghats (Andhra Pradesh)

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ABSTRACT

Etched radiation damage trails are used to determine fission track ages and uranium content of apatite from Kasipatnam and Borra mine, Visakhapatnam district and Zircon from Khammam district, Andhra Pradesh. The mean fission track ages correspond to the last phase of orogenic metamorphism of Eastern Ghats known as Indian Ocean Cycle. Uranium Content varies from 0.82 ppm in apatite to 1·56 ppm in Zircon.

INTRODUCTION

In recent years, radiation damage dating has become a powerful tool in the field of geochronology (Fleischer et al, 1975; Wagner, 1976). Since the technique involves the measurement of radiation damage produced in the form of fission fragment tracks both due to spontaneous and induced fission of uranium impurity in a mineral, it is popularly known as fission track (f. t.) dating.

Apatite is widely distributed as accessory mineral in all types of rocks. It has been vastly investigated for f. t. dating in the geochronology laboratories (Naeser and Faul, 1969 ; Mehta and Nagpaul, 1970 ; Wagner and Reimer, 1972 ; Nand Lal and Nagpaul 1975). F. T. dating has proved to be quite suitable for zircon due to its relatively high uranium impurity content and low annealing rate of radiation damage compared to other minerals. However, the chemical etching of radiation damage in zircon is a tedious problem (Fleischer et al, 1964 ; Naeser, 1969 ; Krishnaswami et al , 1974 ; Gleadow et al, 1976).

SAMPLE COLLECTION

Apatite veins of commercial importance occur, associated with charnockites and khondalitic rocks of the Eastern Ghats, near Kasipatnam. Samples of Borra mine and Kasipatnam area were supplied by the Director, Andhra Pradesh Circle (5), Geological Survey of India, Hyderabad. Geological setting and other features of these vein deposits are given in detail by Sitaramayya et al. 1982.

Zircon samples belong to Khammam district (A.P.) and were supplied by National Geophysical Research Institute, Hyderabed. The main rock types of this area are schists, gneisses, granites and amphibolites. Zircons of Khammam district occur in nepheline syenites belonging to unclassified crystallines including younger remobilisations.

EXPERIMENTAL METHOD

Experimental technique used for apatite samples is similar to that of Naeser and Faul (1969). Apatite grains were separated from the host rock and mounted on a glass slide in epoxy resin. Samples were polished with cerium oxide and final lap was given by diamond paste. Polished samples were etched by immersing the epoxy mounts in conc. HNO_3 at room temperature for 20 sec. Etched radiation damage trails were observed under

ation of 1500x and fossil track density recorded in each apatite grain separately. These samples were irradiated with a thermal neutron dose of 6.3×10^{14} (nvt) in the CIRUS Reactor at Trombay for producing induced radiation damage in apatite. The whole process of polishing, etching and scanning under microscope was repeated. Induced track density was recorded by using substraction method. Thermal neutron dose was estimated by using a standard dosimetric glass (Fleischer et al , 1965).

Zircon crystals, being rough and hard, were ground and polished for a longer time compared with apatite grains. They were etched in aq. NaOH at 230°C for 5 hrs. using a reflux condenser assembly. High fossil track density was recorded. Zircon samples were irradiated in a separate aluminium can with a thermal neutron dose of 1.2×10^{16} (nvt). Induced track density was recorded under identical conditions of etching. It was observed that track distribution is not as uniform in zircon as in apatite.

RESULTS AND DISCUSSION

The f.t. ages were calculated by using age equation first derived by Price and Walker (1963),

$$T = \frac{1}{\lambda_e} \ln (1 + \rho_s \sigma \phi I \lambda_d / \rho_i \lambda_f) \quad \ldots (1)$$

where the symbols have their usual meanings. On substitution of value various constants;

λ_d (1.54×10^{-10} yr^{-1}),

λ_f (7.03×10^{-17} yr^{-1}), σ (582×10^{-24} cm^2) and

I (7.26×10^{-3}), equation (1) reduces to

$$T = 6.49 \times 10^9 \ln (1 + 9.25 \times 10^{-18} \times \frac{\rho_s}{\rho_i} \times \phi)$$

$$= 6.01 \times 10^{-8} \frac{\rho_s}{\rho_i} \phi \quad \ldots (2)$$

where ρ_s and ρ_i are fossil and induced track densities respectively and ϕ is the thermal neutron dose for irradiation.

Uranium concentration of a mineral can be estimated from the induced track density recorded by using the relation (Virk and Koul, 1977) ;

$$C_u = 2 \rho_i A / \sigma \phi I R_o N d \quad \ldots (3)$$

where A is atomic weight of U^{238}, N the Avogadro Number, R_o the mean range of induced tracks and d the density of the mineral. For apatite and zircon, the mean ranges were 9 μm and 5 μm and average densities 3.2 and 4.6 gm/cm^3 respectively.

The mean F. T. ages and uranium concentration for apatite and zircon samples are summarised in Tables-1 and 2. The apatite samples from Kasipatnam yield the lowest mean F. T. age of 389 ± 3 m. y., whereas apatite of Borra mine dates to 471 ± 5 m. y. and zircon of Khammam area to 621 ± 7 m. y. Mean uranium content in apatite and zircon is 1.07 and 1.22 ppm respectively.

It is a well established fact that radiation damage anneals out when minerals are subjected to intense thermal events and the annealing rate is much faster in apatite as compared to zircon and sphene. Our earlier investigations (Koul and Virk, 1978) proved that apatites of Eastern Ghats were subjected to the orogenic metamorphic event known as Indian Ocean cycle which occurred in the circa 500 m. y. (Aswathanarayana 1964 ; Sarkar 1968). According to Sarkar (1968), K-Ar ages of muscovite, biotite, amphibolite and charnockites from different parts of the Eastern Ghats, range between 505 and 650 m. y. Rb-Sr and K-Ar ages reported by Aswathanarayana (1964) also confirm the age of metamorphism and upliftment which the charnockites and granites of the Eastern Ghats experienced during post-Cuddapah period around 500 m. y.

Evidently, our F. T. ages of Borra apatite and Khammam zircon correspond to the Indian Ocean cycle, the latest metamorphic event in the Eastern Ghat orogenic belt. Further annealing experiments on cogenetic minerals are required to investigate the nature of metamorphic event that affected apatite vein deposits of Kasipatnam area.

F. T. ages of apatites determined by other authors (Mehta and Nagpaul, 1970 ; Nand Lal and Nagpaul, 1975) also corroborate our findings. It will be of interest to record that phlogopites of Borra mine also yield a F. T. age of 491 + 16 m. y. (Singh and Virk, 1977).

The errors reported are ony counting statistical errors (1σ). Total error contributed by fluctuations of thermal neutron flux during irradiation and due to non-uniform distribution of uranium in the samples is much higher. Despite these limitations, radiation damage dating has future role to play in the field of geochronology, not merely as a dating tool, but also as a geological clock to record the sequence of various thermal events in the geotectonic history of rocks.

Table - 1 Fission Track And Uranium Content of Apatites

Sample Location	Lab Symbol	Track density $\rho_s \times 10^4$	$\rho_i \times 10^4$	U Content (ppm)	F. T. Ages (m. y.)	Mean Age (m. y.)
Borra Mine, Visakhapatnam, district	ABV I	11.68	0 96	0.99	460± 5*	
Andhra Pradesh	ABV II	13.60	1.12	1.15	459±4	471±5
	ABV III	10.56	0 80	0.82	500±6	
	ABV IV	11.60	0.88	0.91	499±5	
	ABV V	12.00	0.96	0.99	473±5	
	ABV VI	11 92	1.04	1.07	434±4	
Kashipatnam Visakhapatnam	AKV I	10.72	1.12	1.15	362±3	
Andhra Pradesh	AKV II	12.32	1.20	1 24	389±3	389±3
	AKV III	10.56	0.96	0.99	416±4	
	AKV IV	11.04	1.04	1.07	402±4	
	AKV V	12 64	1.28	1 32	374±3	

Total thermal neutron dose = 6.3×10^{14} (nvt)
*Counting statistical error (1σ) from fossil and induced tracks.

Table 2. Fission Track Ages and Uranium Content of Zircon

Sample Location	Lab Symbol	Track density $\rho_s \times 10^4$	$\rho_i \times 10^4$	U Content (ppm)	F.T. Ages (m. y.)	Mean Age (m. y.)
Khammam District, Andhra Pradesh	ZKM I	15.50	17.10	1.56	653±7*	
	ZKM II	14.40	16.40	1.11	633±6	
	ZKM III	11.50	16.10	1.09	515±7	
	ZKM IV	14.00	17 20	1.17	587±7	621±7
	ZKM V	16.40	17.90	1.21	661±7	
	ZKM VI	14.40	17.40	1.18	613±7	
	ZKM VII	14.40	16.30	1.10	637±6	
	ZKM VIII	18.20	19.50	1.32	673±8	

Total thermal neutron dose = 1.2×10^{16}(nvt)

*Counting statistical error (1σ) from fossil and induced tracks.

ACKNOWLEDGEMENTS

The authors wish to express their sincere appreciation to the Director, Andhra Pradesh Circle (5), Geological Survey of India and Shri G. V. Rao, NGRI, Hyderabad for the supply of samples. This work was supported by Council of Scientific and Industrial Research, New Delhi through project No. 24 (101)/74-EMR-GAU. II.

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