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ZIRCON AND APATITE FISSION-TRACK DATING OF THE AMPIPAL ALKALINE MASSIF, THE NEPAL LESSER HIMALAYA

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ABSTRACT

Fission-track dates for the rocks of the Ampipal alkaline massif range from 2.60 0.19 Ma to 2.81 0.26 Ma for zircon and 1.58 0.17 Ma to 1.69 0.21 Ma for apatite respectively. These dates suggest uplift/erosion rates ranging from 2.00 to 2.22 mm/yr and the corresponding cooling rates of 80 to 89°C/Myr for the period between ca. 2.81 Ma and the present.

INTRODUCTION

The Ampipal massif, an elongated body measuring ca. 10km x 2km, comprises mainly of miaskitic nepheline syenites cross cut by a few mafic and ultramafic alkaline rock dykes (Lasserre et al., 1976). The nepheline syenites have undergone intense cataclasis and recrystallization giving alkaline gneisses. Lasserre (1977) assigned an igneous origin to the massif and suggested that the massif acquired the metamorphic paragenesis and tectonic fabric during the Miocene MCT-related tectonism.

This communication deals with the fission-track (FT) dating of the rocks from the massif in an attempt to provide a time-framework to the thermal history of the massif by using zircon and apatite fission tracks.

Fission-track dating was carried out on samples from three sites (A1, A2 & A3) out of the 8 sites, which were sampled for a paleomagnetic study of the massif. An outline of the massif is given in Fig. 1. According to thin section descriptions kindly made by Dr. K. Arita (pers. Communication), the rocks comprising sites A1, A2, A5, A6, A8 can be named after the medium term of biotite, garnet, nepheline, cancrinite, sodalite syenitic

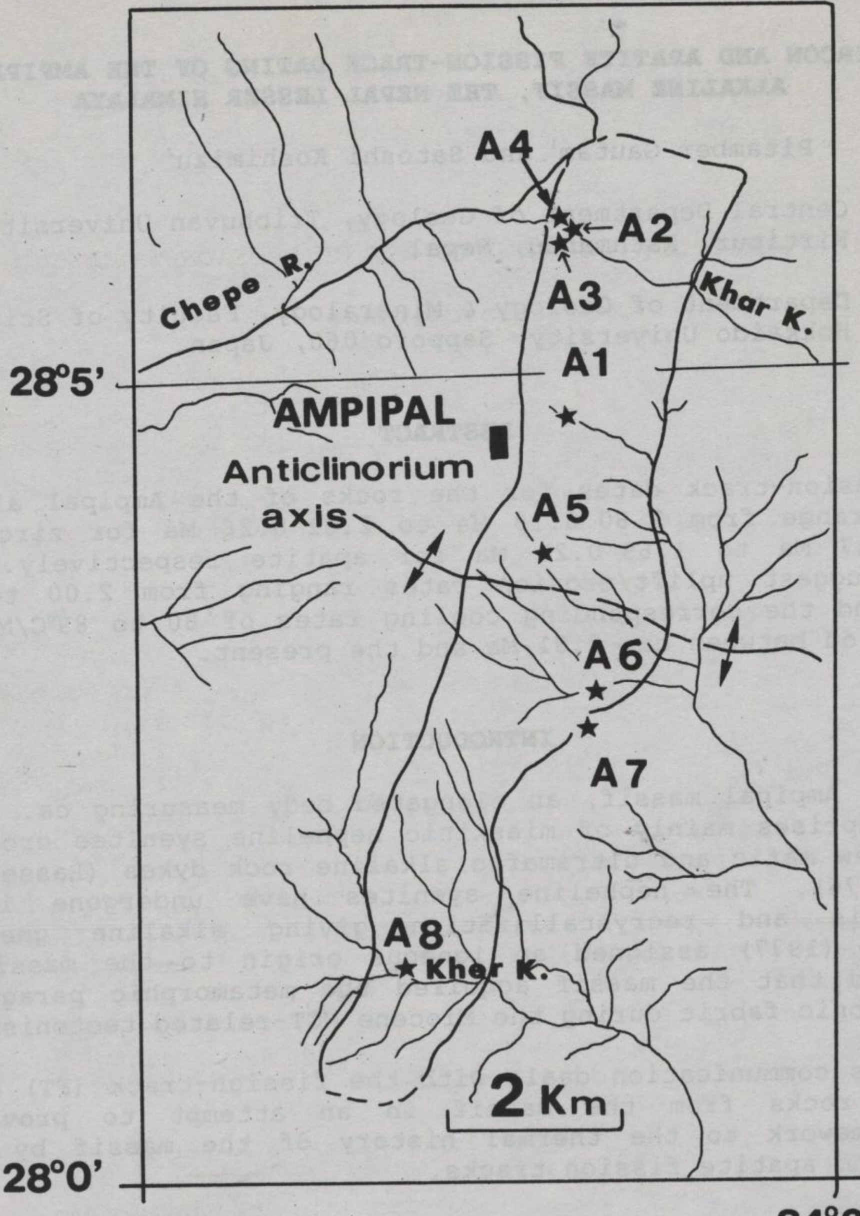

Fig. 1 Map showing the Outline of the Ampipal Alkaline Massif (Modified from Lasserre, 1977) with the Sampling Sites for the present study indicated

gneisses. Those from sites A3 can be termed either biotite-hornblende-garnet or biotite-hornblende-clinopyroxene nepheline syenites. Rocks from site A4 consist of very little or no nepheline and show a composition consistent with that of gabbro.

BASIC PRINCIPLES AND METHODOLOGY OF FISSION-TRACK DATING

General background

It is well known that the isotopic systems in minerals and rocks record specific times in the thermal history of a rock and, when deciphered, the age data can be utilized to define cooling and uplift rates and styles. FT dating technique has been successfully applied to study the low- temperature history of a rock in many active mountain belts (see Hurford et al., 1989).

Basic principles

Uranium isotope ^{238}U undergoes spontaneous nuclear fission which results in the passage of large, highly energetic fission fragments through the lattice of the host material leaving in their wake a damaged zone of disrupted ions. These tracks are stored in the host, provided that the host material remains below certain critical temperature thresholds. The number of spontaneous tracks depends upon the time during which tracks have been accumulating, the rate at which the fission occurs, the amount of uranium in the sample and the length of the tracks. Determination of the age, hence, involves counting the number of tracks in certain minerals and evaluation of relevant parameters following the standard procedures (see Hurford et al., 1989 and references therein). The most commonly used minerals for dating are apatite, zircon and sphene, having uranium contents between ca. 10 and 1000 ppm.

Interpretation of the FT ages/dates in terms of thermal history utilizes the concept of blocking or closure temperature, which for a mineral-isotopic system can be understood as "a critical threshold above which the radiogenic daughter product is lost and below which the system is 'blocked' against thermal disturbance and radiogenic products are accumulated" (Hurford et al., 1989). The blocking, in natural systems, seems to take place not instantaneously but within a temperature range which may depend upon the cooling rate and parameters of the system.

Analytical procedure

FT dating was carried out on zircon and apatite. The rock samples were crushed and ground to a grain size of 80- 200 mesh. Zircon and apatite grains were separated with the aid of heavy liquids and a magnetic separator. Zircon separates were obtained from three sites (A1, A2, & A3), whereas apatite - only from two sites (A2 & A3). Both zircon and apatite separates were dated by the population method.

For zircon FT dating using internal surface, each zircon separate was split into two aliquots, which were then mounted in teflon. The first aliquot was polished to ca. 30 micrometer and etched in a eutectic KOH-NaOH melt (Gleadow et al., 1976) for spontaneous FT counting while the second was polished ca. 30 micrometer after irradiation to expose an internal surface and then etched for measuring the total spontaneous and induced fission-tracks. The induced FT density was determined by subtracting the spontaneous FT density from the total (spontaneous and induced) FT density.

For apatite FT dating, each separate was split into two aliquots as for zircon. Since FTs in apatite are very sensitive to thermal effect, mounting of apatite in teflon is to be avoided. An epoxy resin was used for mounting the apatite. The first aliquot was polished ca. 30 micrometer to reveal an internal surface and then etched in 5N HNO_3 at 23°C for spontaneous FT counting. The second aliquot was first irradiated and only then was polished ca 30 micrometer for measurement of the total (spontaneous and induced) tracks. The induced FT density was determined also by subtraction method as for zircon.

Thermal neutron irradiations were carried out at the Triga Mark-II reactor, Rikkyo University, Japan, with the standard dosimeter glasses (NBS-SRM 612) covered with muscovite detectors. The induced FTs in muscovite were etched in 48% HF for 30 min. at 23°C.

Age calculations

Ages were determined by the zeta method (Hurford and Green, 1983). Zircon and apatite from the Fish Canyon Tuff were used as the age standards. A K-Ar age of 27.9 ± 0.7 Ma (Steven et al., 1967) has been adopted as the reference age for the Fish Canyon Tuff. Zeta values for each zircon and apatite were determined individually by using the respective standards. As the geometry factor is taken to be 1.0 throughout this study, zeta can be determined using The equation:

$$Z = (Pi * Ts)/(Ps * Pd)$$

where,

P_s: spontaneous FT density of a standard sample;

P_i: induced FT density of a standard sample;

P_d: induced FT density of the dosimeter glass measured in a muscovite detector; and,

T_s: reference age of the standard sample.

The zeta values against NBS-SRM 612 were 350 and 348 for zircon and apatite, respectively.

The unknown age (T_u) of the sample can be simply determined by the equation:

$$T_u = Z * P_{su} * P_d / P_{iu}$$

where, P_{su} and P_{iu} are the spontaneous and the induced FT density values of an unknown age sample, respectively.

RESULTS AND INTERPRETATION

The results obtained are listed in Table 1. FT ages vary from 2.60 ± 0.19 to 2.81 ± 0.26 Ma for zircon and from 1.58 ± 0.17 to 1.69 ± 0.21 Ma for apatite. These ages/dates are interpreted to reflect cooling history of the minerals, i.e. cooling from their respective closure temperatures to the present surface temperature, as a result of uplift/erosion process in the area. Uplift/erosion rates and the cooling rates are calculated following the scheme after Zeitler et al. (1982).

Table 1 Fission-track data from the rocks of Ampipal

Sample	Altitude	Mineral	No. of grains	N_s	P_s (cm^{-2})	N_{i+s}	P_i (cm^{-2})	N_d	P_d (cm^{-2})	Age (Ma)
A2-3	620 m	apatite	121/32	97	6.62×10^3	1594	5.16×10^5	3200	3.54×10^5	1.58 ± 0.17
do.	do.	zircon	25/11	223	5.66×10^4	1835	8.95×10^5	3200	1.18×10^5	2.60 ± 0.19
A3-4	625 m	apatite	62/30	71	5.01×10^3	1540	2.94×10^5	3200	2.84×10^5	1.69 ± 0.21
A3-3	do.	zircon	38/18	147	1.19×10^4	556	1.65×10^5	3200	1.09×10^5	2.74 ± 0.26
A1-2	1000 m	zircon	10/8	160	1.81×10^5	515	2.40×10^6	3200	1.06×10^5	2.81 ± 0.26

Ages are determined by population method using internal surface. Two values in the fourth column are numbers of grains used to count spontaneous and induced tracks, respectively. N_s: spontaneous fission-track number counted, Ps: spontaneous fission-track density, N_{i+s}: spontaneous and induced fission-track number, Pi: induced fission-track density, N_d and P_d are induced fission-track number and density produced by standard glass (NBS-SRM 612), respectively, Unpublished data after Koshimizu & Gautam (1989).

Calculated uplift/erosion rates and the cooling rates are given in Table 2. The uplift/erosion rates are in the range 2.00 - 2.22 mm/yr while the cooling rates range between 80 and 89°C/Myr for the period 2.81 Ma to the present.

The similarity in the estimated uplift/erosion rates from zircon-apatite, zircon-surface and apatite-surface methods suggest nearly uniform uplift during the period 2.81 Ma to the present. It is worthwhile to note that slightly higher rates ranging from 2.5 mm/yr to 9.2 mm/yr are obtained by Arita & Ganzawa (1989, pers. communication) using zircon fission-track dates (2.1 to 0.6 Ma) obtained from the amphibolite facies metamorphic rocks in the Higher Himalaya, Nepal. Youngest fission-track ages (as low as 1.3 Ma for zircon and 0.4 Ma for apatite) in the Himalaya are reported from the Nanga Parbat-Haramosh massif in Pakistan where the maximum values of the uplift/erosion rate based on zircon-apatite mineral pair reach 5 mm/yr for the period 2.0-0.5 Ma and as high as 9 mm/yr over the past 0.5 Myr derived from the apatite-surface method (Zeitler et al., 1982).

Table 2 Calculated uplift and cooling rates*

	Zircon-surface		Zircon-apatite		Apatite-surface	
Sample	R_u(mm yr^{-1})	Rc(°C Myr^{-1})	R_u(mm yr^{-1})	R_c(°C Myr^{-1})	R_u(mm yr^{-1})	R_c(°C myr^{-1})
A2-3	2.16±0.16	86.5±6.3	2.08±0.52	83.0±20.7	2.22±0.24	88.6±9.5
	(0 to 2.60 Myr)#		(1.58 to 2.60 Myr)		(0 to 1.58 Myr)	
A3-3 & 4	2.05±0.19	79.2±7.5	2.02±0.64	80.9±25.8	2.07±0.19	82.8±10.3
	(0 to 2.74 Myr)		(1.69 to 2.74 Myr)		(0 to 1.69 Myr)	
A1-2	2.00±0.18	80.1±7.4				
	(0 to 2.81 Myr)		-	-	-	-

* R_u & R_c are the uplift rate and the cooling rate, respectively.

Assumed values: Geothermal gradient is 40°C Km^{-1}. Closure temperatures: Zircon, 235°C; apatite, 150°C. Surface temperature, 10°C. Uncertainties are derived from age uncertainties.

\# Duration of time for which the rates are applicable.

CONCLUDING REMARKS

Fission-track ages on zircon and apatite yield 2.60 to 2.81 Ma and 1.58 to 1.69 Ma respectively. Uplift/erosion rates of 2.00-2.22 mm/yr and the corresponding cooling rates of 80 to 89°C/Myr for the period between 2.81 Ma and the present are suggested, accordingly. The Ampipal area seems to be a rather high-uplift zone and supports the idea of youthfulness and continuing activity of the Himalaya.

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