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Himalayan Geology

DATING OF MOVEMENTS ALONG THRUSTS AND FAULTS IN THE HIMALAYA

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Radiometric dating of movements along the MCT (Vaikrita Thrust), two local but deep seated thrusts and the Sumdoh Fault Zone bordering the Kinnar Kailas Granite in the Baspa and Satluj valleys, NE Himachal Himalaya, has been attempted for the first time by fission track method. Garnet and apatite fission track ages suggest the age of the latest phase of movements around 14 and 7m.y. respectively along the MCT and Sumdoh Fault. The vertical uplift rate along them were 1.1mm/year from 14 to 7m.y. and 0.6mm/year from 7m.y. to recent geologic past respectively, as against the value 0.036mm/year during the period from 210 to 17m.y. in the undisturbed area.

Keywords : **Dating; Thrust; Fault; Garnet; Apatite**

INTRODUCTION

THE Vaikrita Thrust which represents the Main Central Thrust (MCT) defines the southern tectonic boundary of the Great Himalaya against the populated Lesser Himalaya. This thrust separates the high grade metamorphics of the Great Himalaya from the mildly metamorphosed sediments and granites of the Lesser Himalaya. The Sumdoh Fault Zone is an important geologic feature that separates transversely the Great Himalayan crystallines from the sediments of the Tethyan domain. This fault as well as the MCT are tectonically still active. Fission-track (F–T) dating technique has been applied to measure the rate of movements in the geological past along the MCT, the Sumdoh Fault and two local thrusts in the Baspa and Satluj valleys.

GEOLOGICAL SETTING OF THE AREA UNDER STUDY

The geology of the Satluj valley has been described by Hayden (1904), Berthelsen (1951) and Sharma (1977). Valdiya (1973, 1977) recognised the Vaikrita Thrust in Kumaun Himalaya and traced it from the Kali valley in the east through Lilam (Gori), Joshimath (Alaknanda), Gauri Kund (Mandakini) to east of Karcham in the Satluj valley. Sharma (1977) traced it in the Baspa valley. The Kinnar Kailas Granite, which now occurs as a thrust slice, is delimited either side by local but deep seated thrusts (Fig. 1). The deep seated nature of these thrusts is indicated by hot water (60 °C) sulphur springs located on the lower thrust zone. The Sumdoh Fault in the Kinnaur region has been described by Sharma (1977).

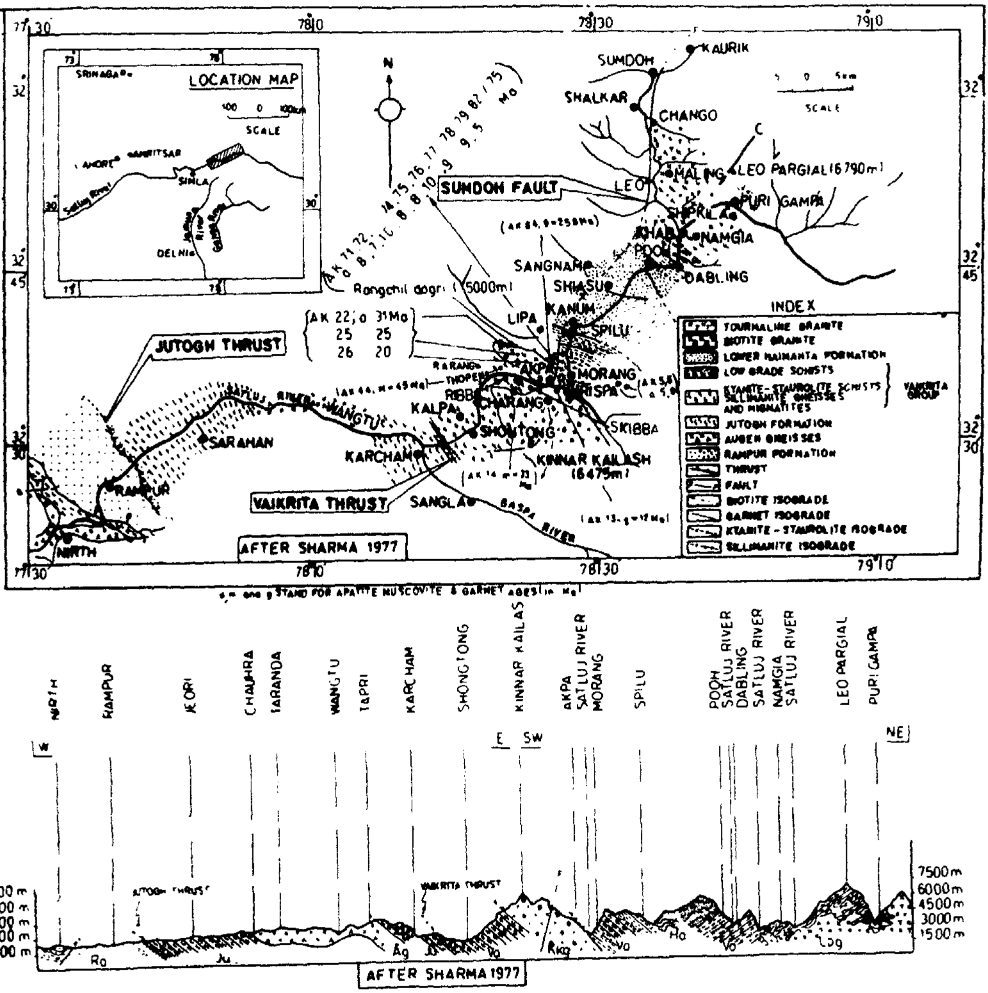

FIG. 1. Geological and sample location map giving cross-section of a part of the Kinnaur region, Himachal Himalaya (After K. K. Sharma, 1977).

FISSION-TRACK AGES

The F–T ages of apatite (30) and garnet (15) have been determined on rock samples from zones of two thrusts around Akpa (AK) in the Satluj valley (Fig. 1), the Main Central (Vaikrita) Thrust exposed at Sangla in the Baspa valley, Shongtong-Karcham section through the MCT in the Satluj valley and the Sumdoh Fault Zone exposed near Spilu, Akpa and Charang in the Satluj and Spiti valleys. The apatite age data thus obtained from the Kinnaur region in the Satluj valley are listed in the Table I. The garnet ages from the Satluj and Baspa valleys are given in the Table II. F–T ages have been determined using equation ($\lambda f = 7 \times 10^{-17}$ yr^{-1})

$$T = 14.9 \times 10^4 \log_{10} (1 + 9.32 \times 10^{-18} \rho_s \phi/\rho_i) \text{m.y.},$$

TABLE I

Fission track ages of apatites from Akpa granitic body exposed in Satluj valley in the Himachal Himalaya

Sample Number	Rock Type and Sample Location	Altitude (m)	$\rho_i \times 10^5$ t/cm^2	ρ_s/ρ_i	T(m.y.)
AK 5/75	Fine to medium grained biotite granite from contact zone, 3km E Rispa	2800	20.6	0.017	5.2 ± 1.3
AK 6/75	Biotite granite, 1km E Rispa near Nallah joining Satluj	2400	7.9	0.029	9.0 ± 1.9
AK 7/75	Biotite is coarse grained in granite, 7km E Rispa	—	12.8	0.039	12.3 ± 2.4
AK 8/75	Granite, ½km E Rispa W Nallah	—	9.5	0.042	13.3 ± 3.2
AK 9/75	Tourmaline bearing pegmatite, E Rispa W Nallah	—	14.5	0.04	12.6 ± 2.7
AK11/75	Mylonitized granite, W Rispa	2400	11.4	0.039	12.3 ± 2.2
AK13/75	Pegmatite intruding granite, E Rope bridge Akpa N bank of Satluj	—	16.0	0.015	4.7 ± 0.5
AK22/75	Coarse grained biotite granite, Rangchil Dogri	3900	5.8	0.1	31.4 ± 6.2
AK25/75	Gneissose granite, below Rangchil Dogri	3500	5.0	0.075	23.6 ± 4.6
AK26/75	Coarse grained biotite granite, below Rangchil Dogri	3200	5.7	0.064	20.0 ± 4.4
AK29/75*	Coarse grained biotite granite, above OHTR on Akpa	2800	5.1	0.11	7.2 ± 1.8
AK40/75	Massive granite, Thopan(0) 6km SW Akpa	2100	18.4	0.035	11.1 ± 1.3
AK41/75	Biotite migmatite, 5km SW Akpa	2000	19.3	0.029	9.0 ± 1.0
AK58/75	Granite, Kharo bridge, 3.5km SW Akpa	2000	7.8	0.048	15.1 ± 2.4
AK61/75	Gneiss, with recrystallised biotite, Skiba	2300	10.6	0.055	17.3 ± 4.1
AK63/75	Granite from *in situ* granitic body, Akpa	2300	10.0	0.052	16.3 ± 3.8
AK67/75	Leucogranite, 1200–1300m NE Akpa on NHTR	—	9.2	0.052	16.4 ± 3.4
AK68/75+	Leucogranite near contact zone, 1400m NE Akpa on NHTR	2300	3.2	0.09	8.5 ± 2.1
AK69/75	Biotite granite from sharp contact zone 1500m NE Akpa on NHTR	2300	11.6	0.014	4.4 ± 0.9
AK71/75	Biotite granite from uncrushed block near Sumdoh fault zone, 2km NE Akpa on NHTR	2300	15.4	0.023	7.2 ± 0.8
AK72/75++	Biotite granite from crushed granitic block where Sumdoh fault zone is sharply marked 5m NE sample AK71	2300	5.3	0.089	6.8 ± 1.9
AK74/75**	Biotite granite, 1km NE Akpa on OHTR	2600	8.6	0.15	10.7 ± 1.4
AK75/75+	Leucogranite, 1.5km NE Akpa on OHTR	2600	3.2	0.09	8.5 ± 2.1
AK76/75++	Biotite granite, 1.6km NE Akpa on OHTR	2600	5.6	0.11	8.4 ± 2.2
AK77/75++	Granite, 2km NE Akpa on OHTR	2800	2.9	0.14	10.4 ± 2.7
AK78/75+	Folded granite, 2.5km NE Akpa on OHTR	2800	4.2	0.1	9.5 ± 2.5
AK79/75++	Folded granite, 2.5km NE Akpa on OHTR west of Sumdoh fault zone	2900	5.7	0.11 }	8.6 ± 1.4
AK79/75*	—do—	2900	9.8	0.13 }	8.7 ± 1.2
AK82/75*	Granite, 2.5km NE Akpa on OHTR, from Sumdoh fault	2900	18.0	0.08	5.3 ± 0.4
SH 2/75	Porphyroblastic gneiss, 1km NE Shongtong	2000	23.6	0.019	6.1 ± 1.0
SH10/75	Leucogranite massive rock 1.5km SW Thopan	2100	39.1	0.019	6.1 ± 0.3

Thermal neutron fluences ($10^{15} n cm^{-2}$) are $\phi = 5.24$, $\phi^{*} = 1.1$, $\phi^{**} = 1.2$, $\phi^{+} = 1.58$, $\phi^{++} = 1.27$

where T represents the F–T age, ϕ is the integrated thermal neutron fluence ($n cm^{-2}$), ρ_s and ρ_i are the fossil and induced track densities ($tracks/cm^2$) respectively.

TABLE II

Fission track ages of garnet from Satluj and Baspa Valleys in NW Himachal Himalaya, India

Sample Number	Rock type and sample location	$\rho_i \times 10^4$ t cm^{-2}	ρ_s/ρ_i $\times 10^{-3}$	Age $\pm$ 1σ (m.y.)
AK 13/75	Pegmatite, W Rispa & E Rope bridge Akpa near thrust zone, 2.3km MSL height	69.5	3.3	12 ± 1.6
AK 17/75	Pegmatite, above Rangchil Dogri & below Chingchang Thatch, 4.0km	4.8	78	280 ± 30
AK 28/75	Pegmatite emplaced by feldspar, below Rangchil Dogri, 2.9km	8.7	45	162.8 ± 38
AK 36/75	Metamorphic garnet, below Raurang near thrust	55	3.6	13.2 ±1.3
AK 43/75	Pegmatite in migmatite, 4km SW Akpa (NHTR), 2.0km	5.0	60	217 ± 28
AK 51/75	Pegmatite in migmatite, 3km SW Akpa (NHTR), 2.0km	4.2	50	182.2 ± 26
AK 52/75	Gneiss, 3km SW Akpa (NHTR), 2.0km	8.1	53.1	192 ± 18
AK 57/75	Pegmatite in migmatite, Kharo bridge 3.5km SW Akpa on NHTR, 2.0km	2.2	50.2	181.4 ± 29
AK 64/75	Pegmatite in granite, Akpa, 2.3km	5.0	72	258.4 ± 33
AK 3/76	Pink garnet in pegmatite, 6km SW Akpa near Thopan where a local thrust is exposed	58.8	4.4	16.2 ± 1.6
AK 12/76	Pegmatite near Morang	3.8	57	206.4 ± 25
SH 1/75	Metamorphic garnet from Shongtong, 9km NE Karcham	62.7	4.1	15 ± 1
BSP 6/76	Pegmatite in migmatite from contact zone near Rakchum	57.8	4.4	16.2 ± 1.7
	—do—	43.5	2.5	16.6*
	—do—	42.9	2.1	14.8*
BSP 21/76	Vaikrita thrust zone, 7km W Sangla	68.5	3.9	13.9 ± 1.5
BSP 22/76	Gneiss, 7.5km W Sangla	75	3.8	13.6 ± 1.4
	—do—	23.2	1.8	12.5*

Thermal neutron fluence $\phi = 6.1 \times 10^{16}$ $n$cm^{-2}
Sample numbers AK & SH are from Satluj valley and BSP from Baspa valley
*Ages by R. Parshad (1979) using $\phi = 11 \times 10^{16}$ $n$cm^{-2}.

DISCUSSION

F-T mineral ages, in general, do not precisely date magmatic crystallization or metamorphic event, however, they are useful in understanding cooling and tectonic histories of a region and in dating the movements along faults (Bar *et al.*, 1974). With altitudes a systematic linear variation in apatite ages has been observed with respect to overburden, as noted in the case of Pandoh-Baggi Tunnel, Mandi Granite (Saini *et al.*, 1978) and of the sampling location from the present area (Fig. 2). The older apatite ages for samples from higher altitude may be explained by an uplift-cooling model as a result of which higher parts of a vertical rock column would cool earlier and hence, the critical isotherm for track stability would reach first higher and then the lower altitudes. According to the above model, during the cooling cycle if any part of rock column is vertically displaced due to structural dislocation such as thrusting or a faulting, the F–T ages of that part of the rock body will not follow the earlier established linear trend. The apatite ages from Kinnar Kailas Granite and its surrounding rocks maintained a linear trend of age in relation to altitude except, for the samples from the zones of thrust (Main Central and two local) and fault (Sumdoh) where subsequent temperature rise during movements disturbed the earlier linearity and a new trend, nearly parallel to the previous one, representing the subsequent cooling cycle was superimposed (Fig. 2).

The garnet F–T ages from MC (Vaikrita) Thrust Zone in Baspa and Satluj valleys and two local thrusts in Satluj valley vary between 12–16m.y.(average 14m.y. for 7 samples) against 163–280m.y.(mean value at 210m.y. for 8 samples) age for the samples away from these zones. As garnet escaped the effect of thrusting and faulting elsewhere, it indicates that temperature in the Kinnaur and surrounding regions could not rise above 350 ± 50 °C, the closing temperature of garnet (Saini, 1978). Since tracks in garnet are stable at higher temperature compared to that of apatite, the last datable movement along the thrust in the area seems to have taken place around 14m.y. i.e., Middle Miocene. The apatite samples collected from the fault zone gave youger age between 4–10m.y.(average 7m.y.) against 9–31m.y. age (with the mean as 17m.y.) for samples away from it. Apatite age data (9–31m.y.) from the undisturbed area indicate prevalence of temperature above 130 ± 30 °C, the closing temperature of apatite (Saini, 1978), but less than 350 °C. The lower ages for apatite (4–10m.y.) as compared to that of garnet ages (12–16m.y.) probably indicate gradual cooling along the zone subsequent to thrusting. The apatite ages

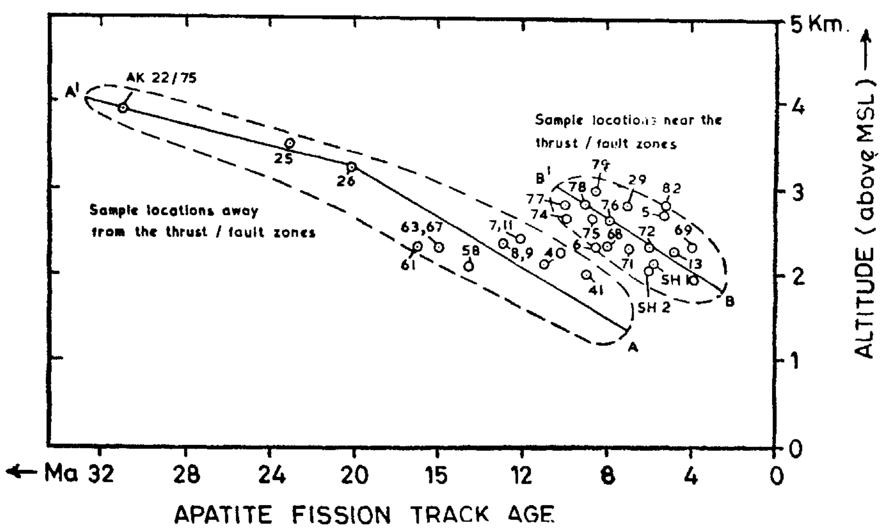

FIG. 2. Elevation of sampling location *vs.* apatite F–T age in Kinnaur region, Himachal Himalaya.

(4–10m.y.) from Sumdoh Fault Zone, which lies 20km NE of MC (Vaikrita) Thrust, point to the latest phase of movement along it around 7m.y. ago.

It is possible to decipher cooling history and uplift rate, using mineral-pair method. In the structurally undisturbed region, garnet-apatite ages have yielded cooling and uplift rates of 1.1 °C/m.y. and 0.036mm/year respectively for the period 210–217m.y. Faster cooling and uplift rates of movement along the thrusts have been found to be 32 °C/m.y. and 1.1mm/year respectively for the interval 14–17m.y. The cooling and uplift rates of movement along Sumdoh Fault Zone have been calculated as 18 °C/m.y. and 0.6mm/year respectively from 7m.y. ago to the present.

Conclusion

The present radiometric age data suggest the last datable movements along the Vaikrita and two local thrusts in this part of the Himalaya around 14m.y. i.e., during Middle Miocene with an average tectonic uplift of 1.1mm/year. The age data, therefore, confirm the views of Valdiya (1964) and Gansser (1964) that the Middle Miocene epoch witnessed the strongest upheaval and violent impulses of diastrophism culminating in severe folding, overturning and thrusting in the Himalaya. The movement along the Sumdoh Fault Zone followed after 7m.y. with an average tectonic uplift of 0.6mm/year.

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