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A TECTONIC INTERPRETATION OF "I" AND "S" TYPE TOURMALINE – MUSCOVITE GRANITOID OF GANGOTRI AREA UTTARKASHI DISTRICT, UTTARANCHAL

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ABSTRACT

In the Bhaironghati- Gangotri area, tourmaline muscovite Granitoid (TMG) occurs as elongated isolated intrusive body in the Biotite Granite Gneiss and forms a part of the Vaikrita Group. The tourmaline muscovite Granitoid is equigranular and hypidiomorphic and is classified as Granite and Granodiorite. The petrochemistry of major oxides and Rb/Sr indicate anatectic remobilization of older igneous rocks and suggest the formation of tourmaline muscovite Granitiod at crustal depth of more than 30 km. The variation of "I" and "S" type in TMG may be due to the involvement of a variety of crustal material in the anatexis which was caused by the variation in the rate as well as inclination of down-going plate. Multicationic diagram indicates magmatic activity during syn–collision and late orogenic periods.

Key words: Tourmaline-Muscovite Granitoid, Gangotri, Tectonics.

INTRODUCTION

The Himalayan granites show Early Precambrian to Late Tertiary history of plutonism and granitization. Leucogranites are reported from various parts of the Himalaya by several workers e.g., Gansser, 1964; Valdiya, 1973; Le Fort 1975a, 1981 and Andrieux *et al.*, 1977. The granites intrude the rocks of different ages which vary from Cambrian to Cretaceous. The tourmaline – muscovite granitoid (TMG), as leucogranite, occur as elongated isolated intrusive body in biotite – granite gneiss (BGG) (fig. 1). This granitoid body, confined to the Bhairoghati – Gangotri area of Uttarkashi, has been named as Gangotri Granite (Pant, 1986). The age of Bhagirathi valley leucogranite is calculated by whole rock Rb /Sr isochron as 64±14 m.y.(Stern *et al.*, 1983). The biotite – granite gneiss (BGG) is considered as extension of Kinnar Kailash Granite, which is 675±70 m.y. (Sharma, 1983). Both TMG and biotite – granite gneiss (BGG) form the part of Vaikrita Group. In the north, it is separated form Martoli Formation by Nilang Malari Thrust and in south by Harsil Fault.

The main lithological units present in Central Crystalline Zone in Bhagirathi valley are shown in Table-1. In the present investigation, a tectonic interpretation has been made to give a plausible explanation of the involvement of proto BGG and the overlying metasediments that gave rise to "I" and "S" type granitoids.

PETROGRAPHY

Texturally TMG is equigranular medium grained and hypidiomorphic (Pant and Dave, 1992). Quartz, plagioclase, microcline, muscovite±biotite, tourmaline, apatite and zircon characterise TMG. Exsolution growth as perthitic and antiperthitic is common and is indicated by K-feldspar enclosing the plagioclase and vise-versa. Microcline shows reaction with muscovite and in most of the

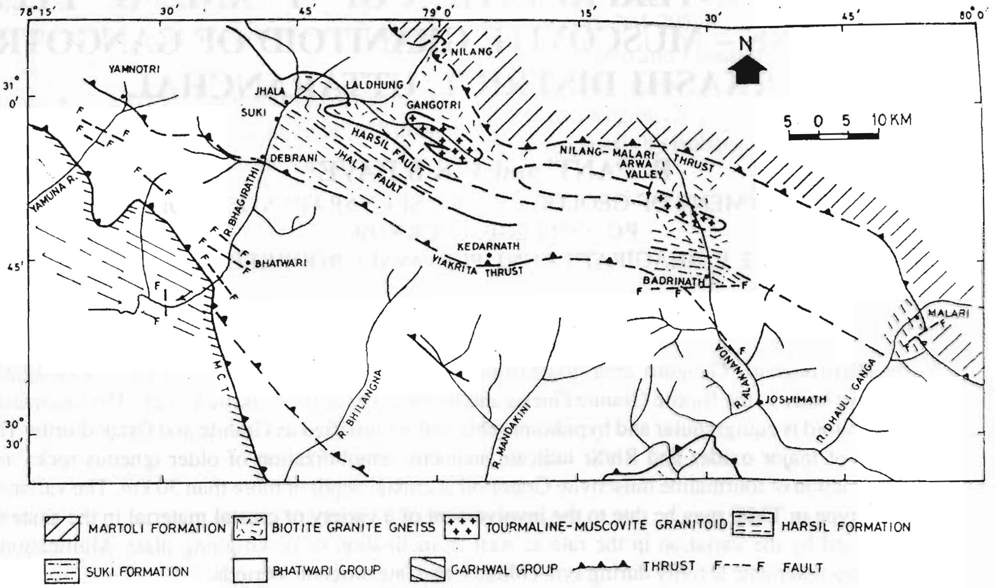

Fig. 1. Geological map of the central Himalaya between Yamuna and Dhauli Ganga valleys (Prepared from various sources and on the basis of this work)

cases the boundary between the two shows myrmekitic intergrowth. Muscovite and vein quartz are formed during late pneumatolytic activity. Tourmaline has crystallised subsequent to the formation of muscovite and vein quartz during pneumatolytic phase. The TMG can be classified as granite and granodiorite (fig.2) as per Streckeisen (1976) modal classification. According to de la Roche (1980) R1-R2 multicationic diagram the TMG falls mostly in the alkali granite, syenogranite and monzogranite field.

PETROCHEMISTRY

From chemical composition the TMG can be equated to alkali aluminous granite (Na_2O + K_2O ~ 9.00 % and Al_2O_3 upto 15.85% with an average of 14.7%) (Table-2), (Pant and Dave, 1992). Ploting the multicationic data on de La Roche (1980) Q_3^* - F_3^* - B_3^* diagram (fig. 3), TMG shows their formation by anatectic remobilization of older igneous rocks.

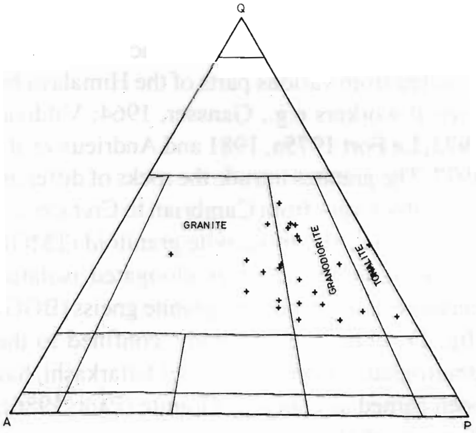

Fig. 2. Classificatin of tourmaline-muscovite granitoid. (After Streckeisen, 1979)

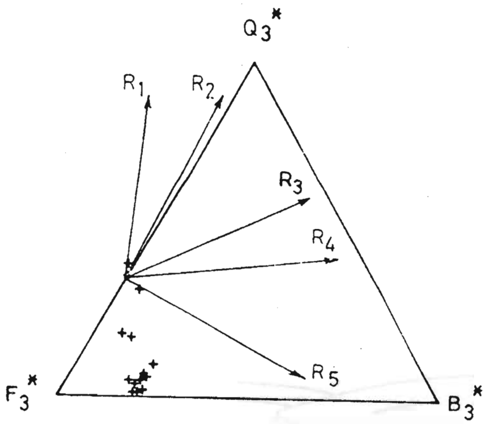

Fig. 3. Plot of Q_3*-F_3-B_3* for TMG samples lying between lines R1 to R4 resulted from the partial melting (anatexis) and underneath R5 line by the anatectic remobilization of old igneous products (after La Roche 1980)

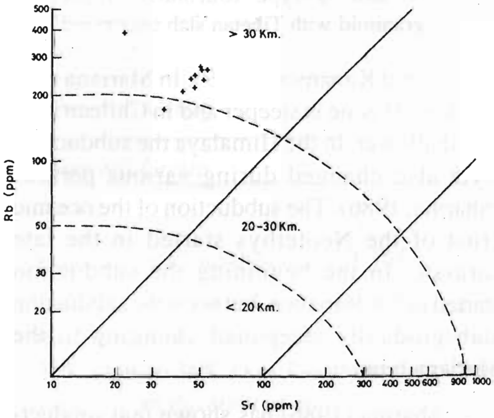

Fig. 4. Plot of Sr Vs Rb for TMG (After Condie, 1973)

The Rb/Sr distribution (fig.4) (Condie, 1976) suggests that TMG must have formed at crustal depth of more than 30 km. About the origin of leucogranite of higher and southern Tethyan Himalaya, Andrieux *et al.* (1977) are of the opinion that partial melting took place along MCT at depth of about 35 km. The leucogranites from Makalu were produced by partial melting at a depth estimated to be less than 12 km (Visona and Lombardo, 2002).

The molar $Al_2O_3/(Na_2O_3 + K_2O + CaO)$, in most cases, is less than 1.1, except in a few where it is more than 1.1. In I-type granite, the ratio is less than 1.1 and in S-type granite, it is more than 1.1 (Chappel and White, 1974). This shows that are of the source of TMG are of both igneous and sedimentary nature. Since TMG is intrusive and magmatic in origin, the mixed I and S – type chemistry indicate the anatexis of crustal components as well as overlying sediments. The remnants of quartz – muscovite schist (metasediments of Harsil Formation) in TMG also point towards such an eventuality. The involvement of sediments (not exposed on the surface now) or of the metasediments of Vaikrita Group or BGG can not be ruled out. The authors are of the opinion that proto – BGG is likely to be the major component which undergone anatexis. Didier (1973) considered the involvement of sedimentary and crustal igneous component in the formation of granitoids and proposed the terms Cs (crustal sedimentary) and Ci (crustal igneous) for such granitoids. The TMG can be put in Cs and Ci groups of classification proposed by Didier (1973). Batchelor and Bowden (1985) have plotted granitoid rock compositions from a range of tectonic environments on a multicationic diagram proposed by de la Roche (1980), and are of the opinion that large volume of felsic liquids can be generated by partial melting of felsic crust which may form large batholiths of anatectic leucocratic granites. While plotting the TMG on multicationic diagram of de la Roche (1980) (fig. 5), it is found that it lies in syn-collision to late –orogenic field, which shows the spectrum of magmatic activity during syn-collision and late–orogenic period.

DISCUSSION AND TECTONIC MODEL

The Himalayan orogenic belt has been

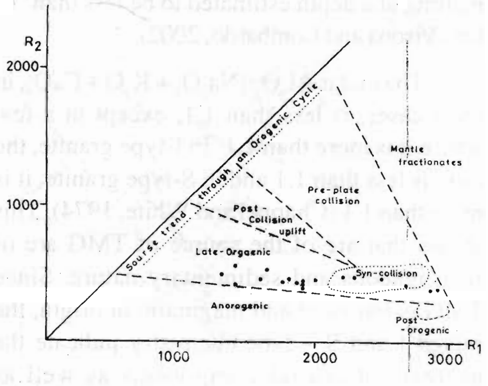

Fig. 5. Plot of R1-R2 for TMG samples R1=4 Si-11 (Na+K) -2 (Fe + Ti) R2=6 Ca + 2Mg + Al

considered as a continent-continent collision (e.g. Dewey and Bird, 1970), i.e.collision of Indian plate with the Asian plate along Indus-Brahmaputra suture. Powell and Conaghan (1973) proposed that the Himalayas have developed in two stages. The first stage shows the convergence of the northward drifting Indian block with proto-Tibetan landmass during late Cretaceous and Palaeocene. The second stage in the development of fundamental crustal fracture within the Indian block during late Eocene and Oligocene and the underthrusting thereof along this fracture from Miocene to Recent. Various workers, e.g., Le Fort (1975b), Klootwijk *et al.*(1979), Gansser (1980) and Thakur (1981), also favour a two-stage collision with converging continental mass, crustal shortening, metamorphism, anatexis, magmat-ism, southward thrusting of crustal slabs and deformation. According to Le Fort (1975b) the Palaeocene age of the Bhagirathi pluton indicate that thrusting in this area developed soon after late cretaceous collision of India with Eurasia.

In continent–continent collision two types of subduction zones have been recognised (1) the Mariana type, and (2) Chilean type. The two types differ in the state of stress between underthrusting and over riding plates (Uydea and Kanamori, 1979). In Mariana type the Benioff zone is steeper and in Chilean type it is shallower. In the Himalaya the subduction style also changed during various periods (Sharma, 1986). The subduction of the oceanic crust of the Neotethys started in the late Jurassic. In the beginning the subduction started as Chilean type, but soon the subducting slab gradually steepened changing to the Mariana type.

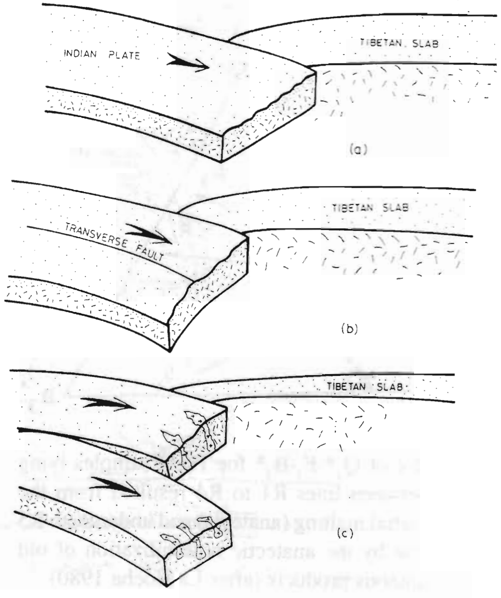

Fig. 6. Simplified cartoons shwoing development of 'I' and 'S'-type tourmative-muscovite granitoid with Tibetan slab uncovered

Sharma (1986) has shown that subducting oceanic crust changed its angle in two adjoining regions of Kohistan – Ladakh and Lhasa. To explain this, he assumed that Benioff Zone changes its dip in those regions. Sharma (1986.) has marked "a transform fault" in the oceanic crust between Lhasa and Ladakh sectors after reaching the subduction site soon after the initiation of subduction resulting in tearing of the subducting slab and hence caused the change in subduction angle". Sharma's idea with modification may be able to offer a plausible

Table 1: Geological succession in Bhagirathi Valley

Vaikrita Group	Martoli Formation		Alternate sequence of phyllite and quartzites
		Nilang-Malari Thrust	
	Gangotri Granite		Tourmaline-muscovite granitoid
		Instrusive Contact	
	Bhaironghati Granite		Biotite granite gneiss
		Harsil Fault	
	Harsil Formation		Schist showing progressive regional metamorphism, Pegmatite instrusives
		Jhala Zone	
	Suki Formation		Augen gneisss, migmatite, Schist, inverted progressive metamorphism from garnet to sillimanite isograd.
		Vaikrita Thrust	
Garhwal Group (Schuppen Zone)			
		Tectonic Contact	
Bhatwari Group			
		Main Central Thrust	
Garhwal Group			

explanation about the origin of TMG.

Geothermal gradient in various parts of the Himalayas (Sharma, 1985) vary between 31°C / km. to 34°C / km. Geothermal gradient is not uniform throughout and it can be assumed that it was higher in this region than the average value and further that the values vary in space and time. This variation may be due to the behaviour of the subducting Indian plate which could be far from uniform in terms of rate of subduction as well as inclination of down-going plate (fig.6a). The down-going plate developed buckling and due to the stress between over riding and underthrusting plates, transform faults are developed on the plate (fig. 6b). Soon after the initiation of subduction, this resulted into the tearing of the transform faults at different angles (fig.6c). The change in the angle of subduction led to the anatexis of crustal components varying in time and space. Initially, the anatexis produced alkali rich mobilizates which invaded the overlying rocks leading to the metasomatism of proto-BGG. With the subduction continuing below the Tibetan plate, anatexis led to comparatively large scale magma generation which gave rise to TMG. It is proposed that due to varying angles of blocks, a variety of crustal material (figs. 3, 4) suggest the involvement of crustal material from depth and became involved in the anatexis, viz., BGG in some parts (I-type) where inclination was less, overlying metasediments in other parts

Table 2: Chemical analysis of tourmaline-muscovite granitoids of Gangotri

Name	H8/205	H8/221	H8/285	H8/294	H8/301	H8/310	H8/311	H8/312	H8/334	H8/335	H8/336	H8/357	H8/371	H8/417	H8/420	H8/423	H8/426
SiO_2(w.t.)	74.00	70.00	71.43	72.00	71.33	71.33	70.65	71.78	75.33	73	72.66	71.43	72.33	73.33	71.33	72.33	69
Al_2O_3	15.33	15.75	15.57	14.34	14.24	15.33	15.30	15.32	13.87	14.53	13.58	14.49	13.65	13.68	14.90	14.25	15.85
Fe2O3	0.92	0.52	1.24	0.57	1.15	0.73	0.69	1.08	0.23	0.45	0.28	0.95	1.44	0.44	0.66	1.32	0.80
FeO	0.34	0.32	0.14	0.20	0.04	0.42	0.18	0.46	0.08	0.38	0.54	0.22	0.14	0.32	0.32	0.04	0.28
MgO	0.3	0.43	0.40	0.45	0.53	0.37	0.72	0.80	0.16	0.26	1.06	0.84	0.33	0.36	0.60	0.69	0.56
CaO	0.79	1.15	0.42	1.27	1.34	1.33	1.63	1.00	0.80	0.87	1.49	1.16	0.82	1.02	0.99	0.89	1.21
Na_2O	4.15	4.71	6.31	4.45	5.05	5.45	5.73	3.79	4.04	4.71	4.04	5.05	5.19	5.05	4.71	4.88	5.05
K_2O	3.31	6.62	3.61	5.57	4.36	3.31	4.21	3..91	3.46	5.57	4.66	4.82	4.66	4.96	5.87	5.57	6.39
TiO_2	0.12	0.22	0.10	2.24	0.18	0.04	0.01	0.20	0.07	0.09	0.15	0.12	0.07	0.17	0.21	0.15	0.17
P_2O_5	0.34	BDL	0.22	0.44	0.28	0.44	0.48	0.44	BDL	BDL	1.16	0.55	0.81	0.33	1.39	0.33	0.22
MnO	0.04	0.007	0.008	0.008	0.003	0.006	0.008	0.009	0.007	0.01	0.01	0.01	0.005	0.005	0.003	0.004	0.00
H_2O	1.29	0.92	1.04	0.92	0.92	1.02	0.90	1.26	1.29	1.09	0.95	0.99	0.90	0.88	0.94	0.91	0.91
Mol. Al2O_3 Na_2O + K2O+CaO																	
Rb (ppm)	160	259	-	268	207	-	260	180	169	264	386	-	238	465	232	246	246
Sr (ppm)	36	54	-	50	41	-	48	40	34	51	22	-	45	45	52	52	48
Multicationic R_1	2676	1409	1640	1890	1898	2010	1162	2485	2773	2988	2289	1803	1848	1908	1683	1753	1293
Scheme R_2	400	542	367	441	449	463	510	448	364	393	480	452	373	394	422	409	462

(S-type) where inclination was more, e.g., in Nepal and a combination thereof (in intermediate case, e.g., in present case of Garhwal – Kumaun Himalaya).

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