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Petrographic Characteristics of the Mineralized and Barren Igneous bodies of the Tosham Igneous Complex, Bhiwani district, Haryana, Northwestern India

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Abstract: The Khanak and Tosham are the two main igneous bodies of Tosham Igneous Complex of the northwestern India. The complex exhibit ring like structures of the plutonic and volcanic igneous phases. The plutonic and volcanic igneous phases of Tosham igneous body shows intense post magmatic alteration effect, however the rock types of the Khanak igneous body are devoid from such post-magmatic alteration effect. At Khanak the igneous body is barren, whereas porphyry type Sn-W±Cu mineralization is associated with the Tosham. Petrographically, the plutonic and volcanic rocks of the Tosham and Khanak igneous bodies show more or less similar mineral assemblages. High content of quartz, total alkalies, muscovite and important accessories like, topaz, fluorite, and halite have been identified in the Tosham, whereas the rocks from the Khanak contains some proportion of amphiboles, pyroxenes and comparatively more biotite with less accessory minerals. The petrographic study suggests that the granites of the both the area are S-type, subsolvus two-feldspar granites containing minor plagioclase and dominant alkali feldspars. The mineralogical in the rocks of the Tosham and Khanak area indicates that rocks of the Tosham area are more magmatically differentiated than the rocks of the Khanak area. This might be the reason for the presence of mineralization in the Tosham and devoid of any mineralization in the Khanak area.

Key words: Haryana; Khanak; Petrographic characteristics; Tosham

Introduction

Tosham Igneous Complex (TIC) located in the northwestern part of the Indian shield. These rocks have been dated 940±20 ma old by Kochhar (1974), suggesting them to be pre-Malanies but post-Delhis. This igneous suite comprises the acid volcanis and high-level co-magmatic granites. The TIC comprises the overall at least five granite plutons of variable dimensions showing elliptical and/ or circular outcrop pattern of the plutonic and volcanic igneous phases. These granite plutons occur over a 16km from north and south and about 13km in width. Most of these plutons are very small in dimension and only the Khanak and Tosham are larger in size, which have been choose for comparative petrographic and Geochemical studies in the present paper. The presence of quartz porphyry ring dykes, association of explosion breccia with the felsite, and plutonic rocks suggest the ring type structure of the TIC. The igneous bodies of the TIC are mostly barren, however, at Tosham Sn-W±Cu mineralization is present. Many features of mineralization in the area show the similarity with the porphyry type of Precambrian mineralization. These features are epizona setting of granites; association of acid volcanics, wall rock alteration pattern, sharp contact between quartz porphyry and felsite and between granite and felsite which does not

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shows any metamorphic effects and also the association of the mineralization with the explosion breccia. Kochhar (1983, 1985) have suggested the porphyry type Cu and Sn mineralization in the area.

In the present paper two major igneous bodies of the TIC, which forms a part of Malani igneous suite situated at Tosham (mineralized) and Khanak (barren) area studied for their petrographic and geochemical characteristics. The purpose of study is to know whether the mineralized and barren igneous bodies (Tosham and Khanak), which have been considered to be a part of the Tosham Igneous Complex, belongs to the same source of the magma chamber or they belongs to the different source.

Geological Setting

Regional Geology

The present area formed a part of the Aravalli–Delhi metallogenic province in Northwestern India. The geology of the area is summarized in the **Table-1**.

Table 1. Geochronology of the Precambrian rocks in the Western Peninsular India

Rocks	Age
Vidhyan system (Jodhpur sandstone)	1400-500 Ma
Malani Igneous suite (acid volcanic and granites)	
Tosham area	750 Ma
Kirana area	870 Ma
Delhi System	1650 Ma
Raialo series	Unconformity
Aravalli System	20000-2500 Ma
Bundelkhand granite	2500 Ma
Berach granite Banded Gseiss Complex (BGC)	>2500 Ma

The Precambrian rocks of this province have been subjected to two major orogenic events during the Proterozoic; these are Aravalli Fold Belt and Delhi Fold Belt, which comprise the Aravalli and Delhi Supergroups respectively. Banded Gneiss Complex (BGC) forms the Archean basement for these fold belts. The basement has also been referred as Bhilwara Supergroup (Gupta et al., 1980) or Mewar Gneissic Complex (Roy and Kroner, 1996) due to lack of unanimity on basement–cover relationships. The Aravalli Supergroup unconformable overlies the basement. The exact age of Aravalli Supergroup is not well constrained; however, based on the basement–cover relationship of the Berach granites (2.5 Ga), a model age for the Aravalli sequence Dewaka metabasalt (2.5 Ga: MacDougall et al., 1984), and the age of the Darwal synkinamatic granite (1.8 Ga: Crawford, 1970), Sinha-Roy et al (1998) suggested a time range of 1.8–2.5Ga for the Aravalli Supergroup. Pb-Zn mineralization at Zawar and Rampura Agucha and SEDEX type mineralization at Rajpura-Dariba are associated with the Aravalli Fold Belt.

The Middle - Upper Proterozoic rock sequence of Aravalli - Delhi metallogenic province is confined to a narrow linear fold belt known as Delhi Fold Belt. This belt, represented by Delhi Supergroup, extends from Gujarat in the south to Haryana in the north and hosted a number of granite plutons ranging in age from 1600 Ma to 730 Ma (Tobisch, 1994; Choudhary et al., 1984). This Late Proterozoic felsic magmatism commenced with the intrusion of the Erinpura granite (900 Ma: Choudhary et al., 1984). Sinha-Roy et al. (1998) suggested that the emplacement of the Erinpura granite and its equivalent along and adjacent to the South Delhi Fold Belt was caused by intense compressive tectonism that followed the Delhi Supergroup sedimentation. Culmination of this magmatism is represented by widespread and dominantly felsic (locally mafic) volcanism and plutonism collectively termed the Malani Igneous Suite (745 ± 10 Ma: Bhushan, 2000). Because of the contemporaneity of ages, Choudhary et al. (1984) suggested a common mechanism for the evolution of this suite. Available geochemical data for some of these granites suggest S- or A-type chemistry (Roy, 1988). Some of these granites plutons host the W±Sn mineralization in this belt **(**Srivastava and Sinha, 1997), Bhattacharjee et al. (1993) has named it Balda–Tosham Tungsten Belt. This 500 km-long linear belt contains several small W-Sn-mineralized plutons, including the Tosham tin-tungsten deposit also Bhattacharjee et al., (1993) Fig.1.

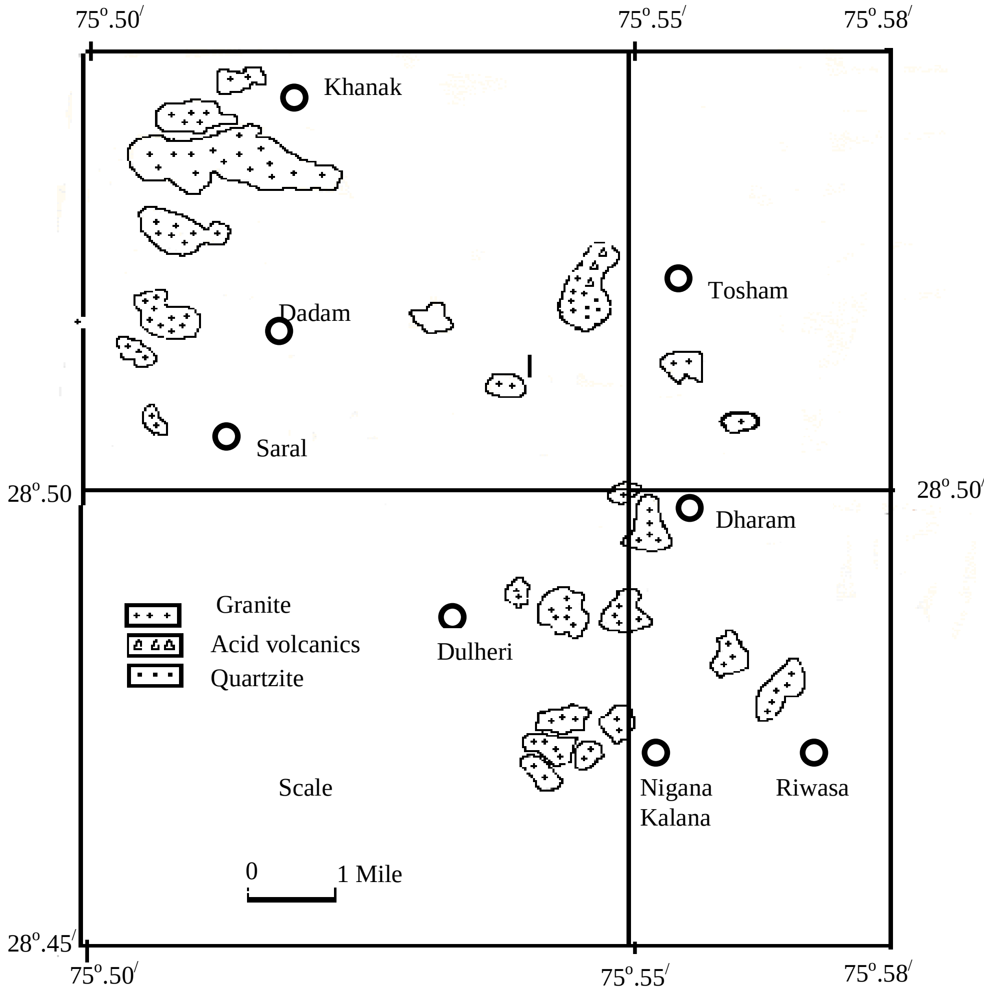

Fig.1. Regional Geological map of the area showing distribution of tungsten deposit in the Balda-Tosham tungsten belt (after Sugden et al., 1990).

Local Geology

Tosham Igneous Complex (TIC) is located on the northwestern part of the Indian Shield about 160km WNW of Delhi. This Igneous Complex comprises the small scattered (more than 5) elliptical granite bodies, which exhibit ring like structures. All these igneous bodies are barren except Tosham Igneous body, which hosts Sn-W-Cu mineralization. The geological map of the Tosham and Khanak Igneous bodies is given in Fig. 2. The outcrop of the Tosham is in form of isolated dome shaped hillock surrounded by aeolian sand and covers small area of 1.56sq.km. A barren igneous body is exposed at Khanak, which is 5 km west to the Tosham hill comprising the hillock in otherwise a flat alluvial terrain. Khanak is the largest igneous body in the TIC. The trend of the Khanak is E-W, whereas the Tosham hillock shows NE-SW. The Tosham and Khanak hillocks are separated by aeolian sand and no connectivity between the two hillocks is seen on the surface. Both Tosham and Khanak hillocks comprises same rock varieties. The area consists of two major lithounits, which comprises the plutonic and volcanic phases and the other is metasediments. The TIC is intruded into the meta- sediments of Delhi Supergroup. The nature of contact between the different phases in the area are well seen which varies considerably. The metasediments are represented by quartzite and quartz -mica -schists, which are exposed on the eastern and northwestern side of the hillock. The Tosham and Khanak pluton is texturally as well as mineralogically heterogeneous and is comprised of biotite granite, medium to coarse-grained granite, K-feldspar porphyry and quartz feldspar porphyry whereas the volcanic phase consists the felsites, explosition breccias and rhyolite.

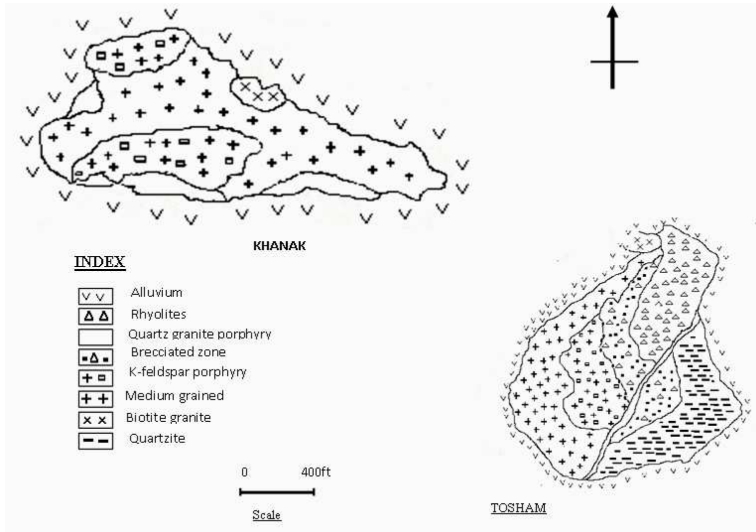

Fig. 2. Geological Map of the area (after Gupta and Eisdon, 1994)

Hydrothermal Alteration

Though the rock varieties of the Tosham and Khanak igneous bodies are same but one of the major differences between the two is the post magmatic hydrothermal alteration. However at Tosham, post magmatic hydrothermal alterations effect is observed. The intensity effect of the alteration in the different rock types varies. Mica granite shows least effect of post magmatic alteration effect, whereas the acid volcanic (rhyolite), porphyritic varieties of in the area are highly affected by the K-alteration (Fig. 3a). The various types of the alteration, which have been observed in the field and under the microscopic examination, are potassic alteration, sericitization and kaolinization, which show the overlapping, pattern. The rhyolite contains the small patches of the granite. The periphery of these granite patches shows intense potassic alteration effect (Fig. 3b). In the periphery of the mineralized quartz veins the wall rock alteration effect such as sericitization, tourmalinization and muscovitization has been observed (Fig. 3c). This post magmatic hydrothermal alteration effect has not been observed in the field as well as under the microscopic examination of the Khanak rocks.

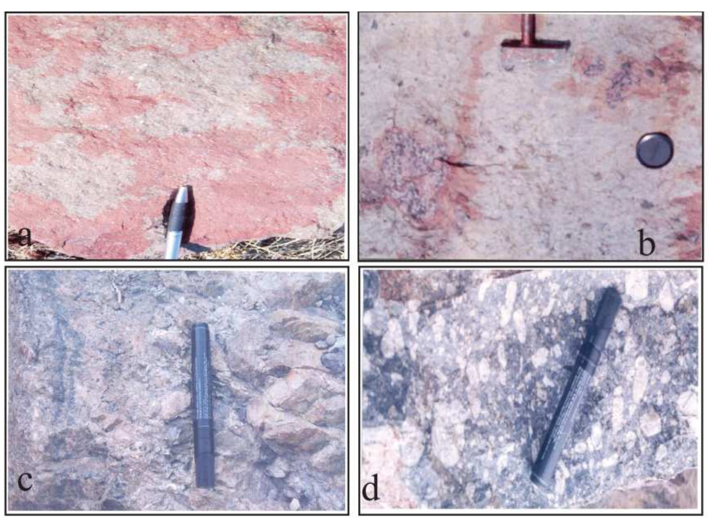

Fig. 3. Field photographs of the Tosham igneous body showing hydrothermal alteration effect. **(a)** intensive shows K- alteration effect in the rhyolite, **(b)** shows the patches of the granite within the rhyolite which are surrounded by intensive k-alteration effect, **(c)** shows the wallrock alteration effect near the mineralized quartz vein, and **(d)** shows the field photograph of quartz feldspar porphyry containing the phenocrysts of quartz and feldspar.

Mineralization

The mineralization in the Tosham has been studied by the Kochhar (1985) according to him the mineralization in the present area is porphyry type copper and tin deposit. The mineralization contains the Sn-W and associated sulfide mineralization, which is present in disseminated form and also in quartz veins. However, in the Khanak area mineralization is totally absent. In the dissemination type of mineralization at Tosham tin and tungsten mineralization is present in form of cassiterite and wolframite, which occurs as minute grains, specks, blades, massive, and dissemination in mica granite, and quartz feldspar porphyry and explosion breccias. The copper mineralization is in form of malachite and azurite occurs as encrustations and even as disseminations along the western contact of the central rhyolite and mica granite whereas the primary sulphide minerals occurs (chalcopyrite) in disseminated form. The vein type mineralization is present on the western side of the hillock in form of quartz-biotite-sulphide veinlets and small networks of quartz-cassiterite veins. These mineralized veins intruded in the quartz feldspar porphyry and mica granite in the area. The tin and tungsten mineralization in the veins occurs as erratically distributed cassiterite and wolframite ores as disseminations and/or pockets of thin bladed crystals in the quartz veins.

Petrographic Characteristics

The petrographic study of the different rock varieties in the Tosham and Khanak area is done in order to know the different mineral assemblages and textural variations in rock types. The model composition of the different rock types in the Tosham Igneous Complex, which also includes the Khanak, is given in Table 2.

Table 2. Modal composition of the Khanak and Tosham Igneous bodies of the Tosham Igneous complex

Rock type/	S. No	Quartz	Alkli feldspars	Plagiocase feldspars	Muscovite	Biotite	Pyroxenes & Amphiboles	Groundmass	Clasts	Accessories	Total
Medium grained granite	T41	30.8	30.2	6.4	3.5	10.2	0.0	13.2	-	0.5	99.0
	T32	31.1	35.2	5.1	11.2	4.6	0.0	14.3	-	1.2	99.2
	T16	31.5	30.8	7.0	4.1	7.6	0.0	12.6	-	1.5	99.1
	K6	32.2	30.1	5.3	11.3	3.2	1.3	9.7	-	1.1	99.9
	K7	30.6	29.2	5.7	9.0	8.5	3.1	9.1	-	0.8	99.4
	K8	30.1	34.6	6.1	10.2	4.0	1.6	10.4	-	0.5	99.6
	K12	32.2	30.1	6.3	10.1	6.8	1.2	11.2	-	0.4	99.8
	K13	32.7	30.0	5.4	11.1	8.8	2.8	4.0	-	0.9	99.4
Biotite Granite	T70	32.8	30.2	7.2	2.9	10.8	3.5	5.9	-	1.0	99.9
	T69	33.1	29.8	6.8	3.3	11.1	4.0	5.6	-	1.2	99.9
	T65	29.2	30.8	4.9	3.5	10.5	3.1	5.2	-	0.5	99.8
	K20	29.1	27.6	5.7	2.3	11.4	3.8	4.8	-	0.1	98.6
	K21	29.6	28.5	7.5	2.5	12.6	4.1	3.8	-	0.0	98.8
	K14	30.2	32.4	4.6	0.5	13.2	0.0	4.6	-	0.6	99.8
K-feldspar porhyry	T38	28.7	24.5	5.6	0.0	1.3	0.0	67.7	-	0.3	99.8
	T35	1.3	27.9	4.1	0.2	0.2	0.0	70.3	-	0.5	100
	T30	5.9	30.3	3.0	0.3	1.1	0.0	66.8	-	0.0	99.3
	T8	6.0	5.4	0.5	0.4	0.3	0.0	62.1	-	0.4	99.8
	K19	1.2	26.3	0.0	0.5	0.8	0.2	69.0	-	0.4	98.4
	K18	3.6	24.4	0.5	0.9	0.7	0.1	69.2	-	0.3	99.9
	K10	2.2	25.7	1.2	1.0	0.6	0.0	60.2	-	0.4	99.0
	K9	3.0	26.6	1.0	0.8	0.1	0.0	60.1	-	1.0	99.7

Quartz-feldspar porphyry	T74	14.0	17.0	2.3	5.2	4.6	0.0	49.5	-	1.3	99.9
	T6	17.8	14.2	3.1	4.2	5.2	0.0	50.0	-	0.0	99.6
	T9	18.1	18.6	3.6	4.8	6.1	0.0	49.1	-	0.0	99.0
	T5	19.0	17.5	3.5	5.3	1.3	0.0	50.2	-	0.0	99.4
	K17	18.0	17.9	2.3	1.2	7.3	0.1	47.2	-	0.0	99.7
	K16	19.8	18.1	3.2	2.4	6.4	0.2	51.0		0.0	99.3
	K15	20.4	19.4	3.6	2.1	3.4	0.0	50.2	-	0.0	99.1
Rhyolite	T80	4.6	6.9	0.1	0.0	0.6	0.0	69.8	15.3	0.0	99.9
	T31	5.1	7.0	0.0	0.0	0.5	0.0	69.3	14.3	0.0	99.6
	T28	3.9	6.5	0.2	0.0	1.9	0.0	69.3	16.3	0.0	98.7
	T13	3.2	7.6	0.0	1.0	4.2	0.0	70.2	13.5	0.0	100
	T75	3.0	6.2	0.0	1.0	4.2	0.0	68.6	14.8	0.0	98.1

The Modal composition plot is shown in Fig. 4. The scattering of the Tosham samples is due to the alteration effect in the rocks, whereas the Khanak samples shows clustering in the Syno-granite field.

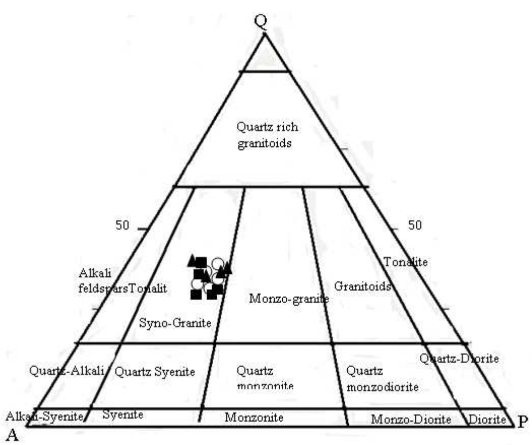

Fig. 4. Q-A-P classification diagram for Tosham and Khanak igneous bodies (Field after Streckeisen, 1973).

K-feldspars porphyry: This granite variety of the Tosham area is weathered. It also shows pervasive post-magmatic hydrothermal alteration effect. The phenocrysts of orthoclase and microcline with corroded margin are embedded within the cryptocrystalline to finely crystalline groundmass, whereas the phenocrysts of quartz are rare. The microcline phenocrysts show kaolinization effect. Along the margin of the biotite flakes chlorotization effect is observed. The modal composition of this rock is quartz, 1- 6%, k-feldspar 24-30%, plagioclase 3-5%, and muscovite and biotite, 0-1% with ground mass 62-72%. Tourmaline, allanite (Fig. 5a) and fluorite are important accessories present with rare occurrence of apatite. The ground mass is composed of quartz and feldspars, sericite and muscovite. The granite shows intergrowth between quartz and orthoclase (graphic texture) (Fig. 5b).

The K- feldspar granite of the Khanak is fresh without any alteration effect and consists phenocrysts of microcline occasionally orthoclase. There is little difference in its mineralogy from the Tosham variety. It contains quartz phenocrysts (1-2%), k-feldspars (24-26%), plagioclase (0-1%), biotite and muscovite less than 1%, and important accessories like zinnwaldite, zircon and beryl**.**

Quartz-feldspar porphyry: In the field quartz porphyry shows sharp contact with felsite and rhyolite. In the hand specimen it contains phenocrysts of quartz and plagioclase feldspars embedded in the medium to fine-grained matrix of quartz, feldspars, muscovite and biotite. The modal composition comprises the quartz 14-18%, plagioclase feldspars 2-3%, alkali-feldspars 14-18%, muscovite, 4-5%, and biotite 0.1-6% and ground mass 49-50%. The feldspars phenocrysts show oscillatory zoning (Fig. 5c). The plagioclase feldspars are altered and sericitised. Zircon which shows compositional zoning (Fig. 5d) and apatite are the important accessory mineral content present.

The quartz porphyry of the Khanak is composed of quartz and plagioclase feldspars phenocrysts. These phenocrysts are embedded into the medium to fine grained matrix of quartz, feldspars, muscovite and biotite. The quartz phenocrysts shows corroded margin. The modal composition of the different mineral shows quatz 19-20%, plagioclase feldspars 2-3%, alkali-feldspars 18-19, muscovite, 1-2%, and biotite 6-7% and groundmass 49-50%. The plagioclase feldspars are much altered than highly altered into sericite and kaolinite. The important accessory minerals are zircon, tourmaline.

Coarse to medium grained granite: The coarse-grained granite variety is hypersolves two-mica granite containing equigranular grains of the quartz, muscovite, biotite, microcline and plagioclase. The modal composition is quartz (27-31.5%), alkali feldspars (30.1-35.2%), plagioclase (5.1-7%), biotite (3.2-10%) and muscovite (3.1-11.2%) with groundmass (10.2-14.3%). Biotite flaks are corroded and decomposed to a green chloritic pseudomorphs and secondary magnetite is developed along the cleavage planes. Mirmekite texture is the important feature of this granite (Fig. 5e).

In the Khanak area the coarse to medium grained granite constitutes the major portion the Khanak igneous body. It is hard compact and fresh without weather and postmagmatic alteration effects. It contains orthopyroxenes and amphiboles, which are absent or rare in the Tosham granites. It is composed of quartz (30-32.7%), k-feldspars (microcline with minor orthoclase) (29-34.6%), plagioclase (5-6%), biotite (3-4%), muscovite (10-11%), orthopyroxene (Fig. 5f), and amphiboles (1-3%).

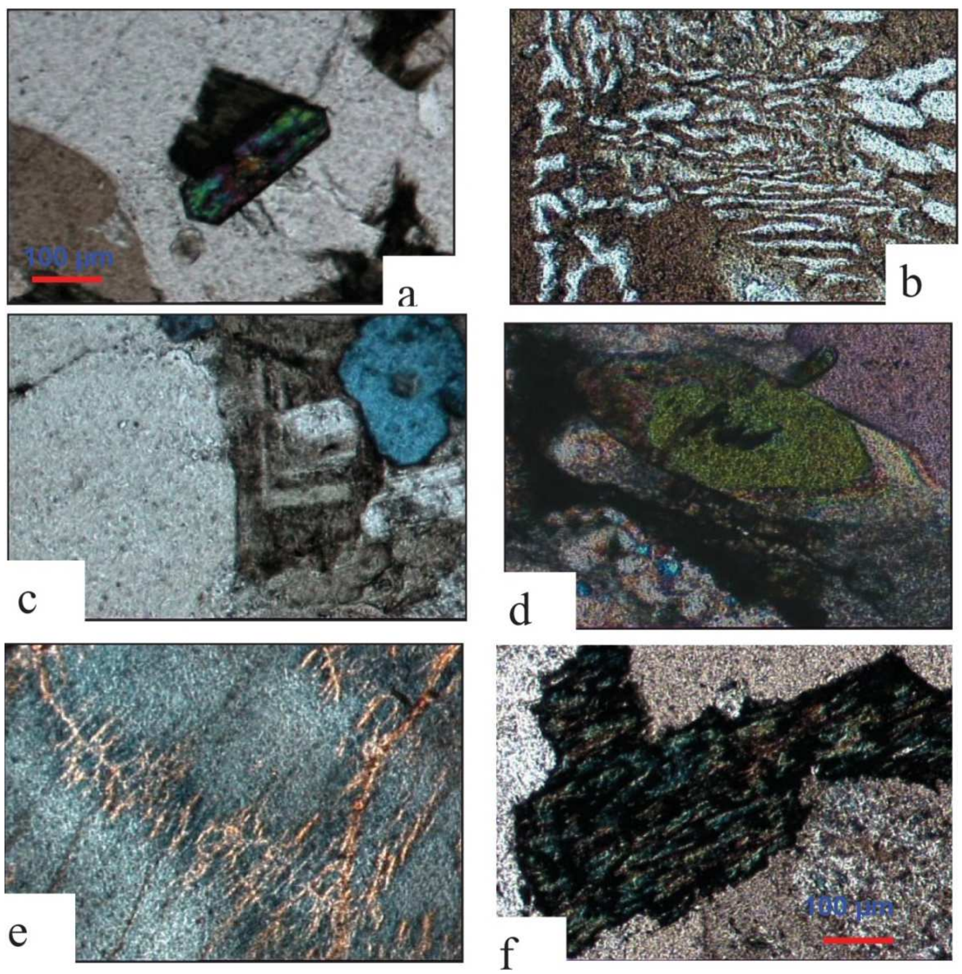

Fig. 5. Photomicrographs show the Petrographic characteristics of the Tosham and Khanak igneous bodies. **(a)** Allanite crystal within the untwined feldspar crystal, **(b)** photographs showing graphic intergrowth of quartz and k-feldspar of the k-feldspar porphyry **(c)** Presence of zoning within the feldspar crystal, **(d)** Shows typical zoning in zircon crystal, **(e)**, Mirmetic texture of the coarse grained granite of the Tosham area. **(f)**, Pyroxene crystal in the coarse to medium grained granite of the Khanak area.

Biotite granite: A small patch of this granite variety, which is hard compact, is present on the northwestern slope of the Tosham hillock. The mineralogy of the biotite granite is same as muscovite granite but the distinction between the two granite varieties is that former contains more biotite content than later, more over the plagioclase feldspars are untwined in the muscovite granite. Also in the field coarse-grained granite shows more weathering and alteration affect whereas the biotite granite is medium grained hard compact melanocratic with least weathering and alteration effect. Zircon and tourmaline (Fig. 6a) is major accessory mineral present.

In the Khanak area this granite variety also occupies the small portion and texturally appears the same but mineralogically it shows some difference from the Tosham. Some pyroxene and amphibole minerals have been observed in good proportion in the Khanak. It is composed of quartz (29-30%), k-feldspars (microcline with minor orthoclase) (27-32%), plagioclase (4-7%), biotite (11-13%), muscovite (2.5-3%), orthoprroxene**,** and amphiboles (3-4%) (Riebeckite Fig. 6b), with important accessories like sphene (Fig. 6c), zircon and beryl (Fig.6d) which is present in the orthopyroxene**.**

Rhyolite/felsites: Rhyolite constitutes the major rock units in the Tosham igneous body. It occupies the central and apical portion of this hillock and shows sharp contact with adjacent rock types. It contains fragments of the plutonic rocks indicating its younger age than plutonic phase in the area. Rhyolite contains quartz (3-5%), clasts 13-15% and k-feldspars (6-7%) phenocrysts embedded in a groundmass (69-70%), which is glassy to cryptocrystalline showing spherulitic texture (Fig. 6e).

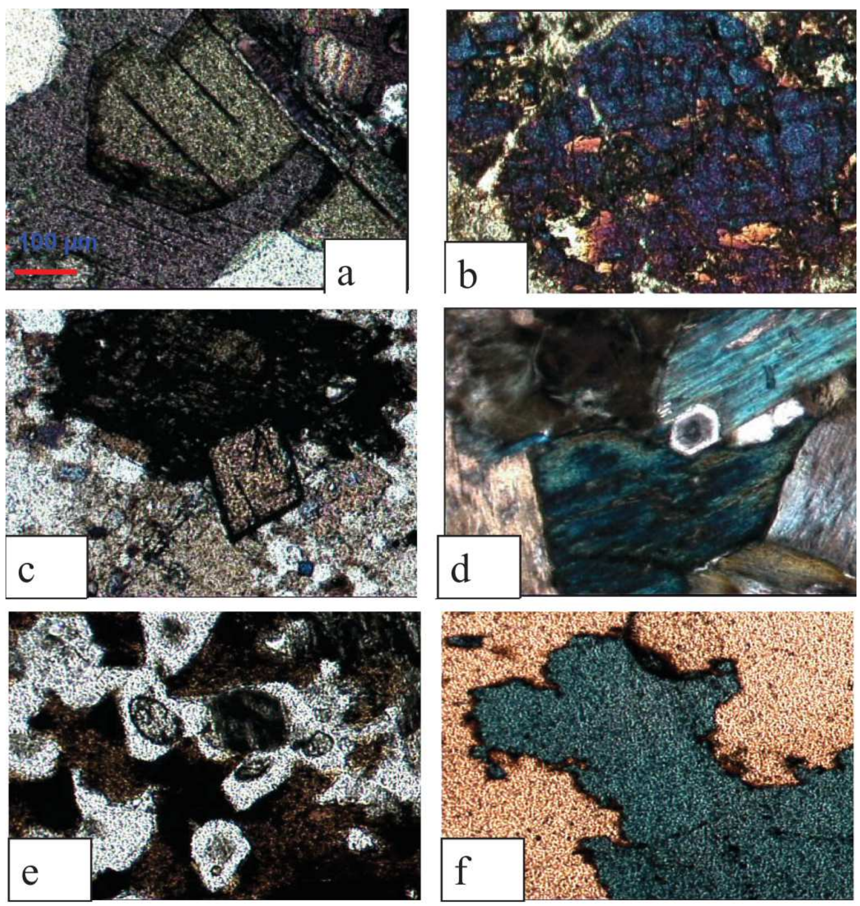

Fig. 6. Photomicrographs show the Petrographic characteristics of the Tosham and Khanak igneous bodies. **(a)** Zonning in the tourmaline, **(b)** rebeckite in the Khanak coarse to medium grained granite, **(c)** presence of sphene, **(d)** presence of beryl in the pyroxene, **(e)** Spherulitic texture of rhyolite, and **(f)** Corroded margin of quartz in rhyolite.

The quartz phenocrysts are sub idiomorphic to idiomorphic in shape sometimes with corroded margin (Fig. 6f). Micas are very less (1-4%).

Volcanic Ash and Tuffs: These volcanics occurs in small bodies in the rhyolite phase are soft and friable consisting angular to sub-rounded quartz (3-5%) which are corroded and cracked, k- feldspars (3-6%), plagioclase >1, micas (4-6%) and sub rounded glass shards (7-8%) embedded in fine grained groundmass (75-76%) which is composed of quartz and feldspathic material.

Explosion breccia: The volcanic breccia is important rock variety in the area, which contains the fragments and clasts of both the granitic and volcanic phase. The clasts are angular to sub-round in shape and are of different size of quartzite, mica granite, k-feldspars porphyry, quartz-feldspars porphyry and rhyolite. The volume percent of the clasts and ranges from (15-22%). The matrix contains the phenocrysts of quartz, k-feldspar. The blocks of the different rock types show sharp contact with the matrix. The sub- rounded shape of blocks is due to fluid activity.

In the Tosham igneous body mineralization is present in form of quartz-biotite- sulphide veinlets and small networks of quartz-cassiterite veins intruded in the quartz feldspar porphyry and mica granite and associated intense hydrothermal alteration effect indicated the evolution of the hydrothermal fluid in the late stage of the magmatic evolution. The physical association of the Sn-W mineralization with the granite porphyry and rhyolite indicates the evolution of the mineralizing fluids from the granitic magma. This evidence is well supported by the presence of the three types of the fluid inclusions in the quartz of the granites as well as of the mineralized quartz veins and their high homogenizing temperature. The mineralogical and geochemical difference in the rocks of the Tosham and Khanak area indicates that rocks of the Tosham area are more magmatically differentiated than the rocks of the Khanak area. This might be the reason of the presence of the mineralization in the Tosham and devoid of any mineralization in the Khanak area.

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