Acta Geodyn. Geomater., Vol. 22, No. 2 (218), 233–244, 2025

DOI: 10.13168/AGG.2025.0016

journal homepage: https://www.irsm.cas.cz/acta

ORIGINAL PAPER

PETROGENETIC AND PETROGRAPHIC INVESTIGATION OF KUMRAT GRANITE, KOHISTAN ISLAND ARC, NORTHWESTERN PAKISTAN

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ARTICLE INFO

Article history:
Received 15 February 2025
Accepted 9 June 2025
Available online 2 September 2025

Keywords:
Granitic rocks
Kohistan Island Arc
Petrography
Petrogenesis

ABSTRACT

The granitic rocks in Kumrat Valley of Kohistan Island Arc have been studied in terms of their petrographic and geochemical characteristics. Field relationship and petrographic studies display coarse-grained to porphyritic texture and classifying it as a two-mica granite. Alkali feldspar, quartz, plagioclase and biotite make the essential minerals whereas muscovite apatite, zircon, titanite and chlorite are the accessory contributions. The modal mineralogy and colour index plots depict calc-alkaline and leucocratic character of the studied rocks. The CaO/(FeO+MgO+TiO2) versus CaO+FeO+MgO+TiO2 and Al2O3/TiO2 versus CaO/Na2O plots show per-aluminous nature and pelitic to psamtic source for this granite. SiO2 versus A/CNK discrimination diagram depicts its S-type origin. Haplogranite system plot also suggests that this granite is formed by partial melting of sedimentary rocks under water deficient conditions. The Harker plots of major element reveal early fractionation of feldspars and biotite from the system The tectonic discrimination plots predict collisional island arc type of tectonic environment during the formation and emplacement of Kumrat Granite.

1. INTRODUCTION

The granitic rocks are distributed over wide areas in the continental crust and are abundant basement rocks with thick overburden of sediments. Presently, the exposed granitic rocks at the surface are due to the process of uplifting and erosion of overlying rocks. The granites form in many different ways; they may be derived from melts exclusively from crustal components, differentiated melts derived from mantle, and mixture of both mantle and crustal derived melts (Justyna et al., 2002). A large volume of granitic rocks can be produced by subduction magmatism forming island arc and large plutonic complexes in continental mountain ranges. For example, the Coastal Range plutonic complex of western Canada (Castro, 2014).

The granitic rocks are exposed in many localities of Pakistan. In the north-western part of Pakistan granitic rocks are present either in the form of batholith or intrusions such as Kohistan Island Arc (Tahirkheli, 1997). The Kohistan Island Arc was generated due to intra-oceanic subduction. The length of KIA is 30000 km^2 and the geological timing of growth and crustal accretion is Early to Late Cretaceous (Petterson, 1984). The KIA consists of several geological units including the Kohistan Batholith. In Kohistan Batholith three stages of magmatism can be recognized. The bimodal series of high -K and Low-K high SiO_2 plutons represent stage-1 plutonism. The collision of the Kohistan Arc with Asian Continental Plate along the Northern Suture (Main Karakoram Thrust) resulted in the deformation of the stage-1 plutons (Bignold et al., 2006). The second stage of plutons are undeformed and consist of diorite, gabbros and granites. It is believed that these plutons have intruded between 85 and 40 Ma with a general mafic to acidic trend. The stage-3 plutons have intruded in the south eastern part of Gilgit with a layered leucogranite aplite-pegmatite sheet network (Petterson, 1984). The Jaglot Group, Kamila Amphibolite, and Chalt volcanics are the three different volcano-sedimentary sequences exposed in the Kohistan Island Arc (KIA) from North to South (Bignold et al., 2006).

Cite this article as: Ullah I, Siyar SM, Khan MA, Zafar M, Jalil R, Orakzai AU, Ali TUH, Ullah F, Kontakiotis G, Khan SF, Shams K: Petrogenetic and petrographic investigation of Kumrat Granite, Kohistan Island arc, Northwestern Pakistan. Acta Geodyn. Geomater., 22, No. 2 (218), 233–244, 2025. DOI: 10.13168/AGG.2025.0016

In 1993, Sullivan et al. described that Kumrat valley (Dir Group) is a part of Kohistan Batholith. The Kohistan Batholith has a length of 280 km North to South while having a width of 20 to 80 km. It is stretched in an accurate linear belt from Kalam, Dir and Chitral in the West to Gilgit and Nanga Parbat in the East (Petterson, 1984). The Kohistan Batholith is comprised of calc-alkaline granitoids with a large spectrum of age, size, shape and mineralogical composition intruded into older plutonic, volcanic and sedimentary formations. The gabbro, diorite, granodiorite, granite and tonalities make up the batholith, generally derived from the mantle melts and gradually changed over the time through amphibole dominated fractionation and assimilation of the arc crust (Jagoutz et al., 2009).

2. GEOLOGY AND TECTONICS

The study Kumrat area is sitituated witin the northwestern part of the Kohistan Isand Arc. The Kohistan Island Arc is sandwiched between the Karakoram and Indian plates, covering an area of 36000 km^2 in northern Pakistan. The Kohistan-Ladakh Arc developed as a part of the Neotethyan oceanic lithosphere's northerly subduction during Late Jurassic to Cretaceous time (Honnegar et al., 1982; Tahirkheli, 1979).

The Nanga Parbat dome, formed during the last 10 Ma, separates the Kohistan Island Arc from the Ladakh Arc (Zeitler, 1985). The East Ladakh Arc has tremendous geochemical and lithological similarity with the Kohistan Island Arc, suggesting their joint continuity in the geological record. The Main-Karakoram Thrust (MKT) in the north separate Kohistan Arc from Karakoram Plate, Main Mantle Thrust (MMT) in the South separates it from the Indian Plate and Raikot Fault in the East separates it from Nanga Parbat.

The MKT is also known as northern suture zone (Pudsey, 1986) or Shyok Suture Zone (Searle and Cox, 1991). The MKT is around 4 km wide melange zone and comprised of hundreds of meter scale beds of limestones, conglomerates, marble, serpentinized metavolcanics and ultramafic set in a matrix of slate. The Indian plate's subduction beneath the Kohistan arc terrane represents MMT. According to Shams (1980) and Arif and Jan (1993) the presence of glaucophane schist in a significant oceanic basin suggests that the subduction zone is closer. It has an acute bend at the Jijal, where the Kohistan Island Arc ultramafic unit is in direct contact with Indain Plate gneisses. Several hundred's meter large-scale melange zone represents the MMT in other places too such as Mingora and Allai, which comprised of ophiolite, ultramafic and gabbroic rocks, greenschist metavolcanics and glaucophane bearing pelitic melange (Kazmi et al., 1984; Shah and Majid, 1985). The local geology of the study area is a granitic body extending from Lamutai to near Lawari Tunnel in the northwestern direction. These courses grained hard massive and white color granites having quartz, plagioclase and biotite easily recognized. The weathering is noticed along the joints and fractures representing unloading physical weathering. The weathering is noticed along these joints and fractures showing grey color stains. The fresh outcrops surfaces look like milky-white due to the abundance of quartz and feldspar.

The Kohistan Island Arc (KIA) is a key tectonic unit within the Himalayan orogenic system of northern Pakistan, forming a distinct crustal block sandwiched between two major suture zones: The Main Mantle Thrust (MMT) to the north, which demarcates its boundary with the Asian (Karakoram) Plate, and the Indus Suture Zone (ISZ) to the south, marking the collision zone with the Indian Plate. Geographically, the KIA extends from the Swat Valley in the east to the Dir and Chitral regions in the west, representing the remnants of an intra-oceanic volcanic arc that developed above the northward-subducting Neo-Tethys Ocean during the Cretaceous period (Tahirkheli, 1979; Burg et al., 2006; Treloar et al., 1996). Within the northwestern margin of the KIA specifically the Dir Valley and Bibior area, the crystalline basement comprises meta-sedimentary sequences, amphibolites, and a variety of plutonic intrusions. Granitic rocks in this region occur as both localized and regionally extensive intrusions into older metamorphic assemblages, including amphibolites of the Kamila Belt and the Barawal Banda meta-sediments (Bignold et al., 2006; Haq et al., 2013). These intrusions range from coarse-grained granites and granodiorites to finer-grained aplite and pegmatite dykes, and reflect multiple pulses of arc-related magmatism and crustal reworking (Ullah et al., 2025; Khan et al., 2025). The Bibior Diorite Complex, intruding the meta-sedimentary sequences of quartzite, phyllite, and slate, includes a range of lithologies such as granodiorite, granite, tonalite, and hornblendite, with associated quartzofeldspathic and pegmatitic veins (Sullivan et al., 1993; Bakr and Jackson, 1964). These granitic intrusions are typically emplaced along major structural trends and shear zones and are often accompanied by contact metamorphic features such as hornfels and recrystallized schists, suggesting syn- to post-tectonic emplacement during the arc's accretionary and collisional phases (Chaudhry et al., 1974; Chaudhry et al., 1987; Hyden, 1915). In the Bibior area, the spatial distribution and petrographic diversity of these granitoids suggest prolonged and multi-stage magmatic activity within an evolving arc crustal section. The region also includes complex mafic to felsic associations such as the Norite Complex and Chilas Complex, which further document the deep crustal differentiation processes during arc maturation (Chaudhry and Chaudhry, 1974; Treloar et al., 1996). Thus, the granites in the northwestern KIA occupy a structurally complex transition zone between mafic-ultramafic arc roots and metasedimentary cover sequences. Their occurrence reflects both arc plutonism and later crustal anatexis associated with

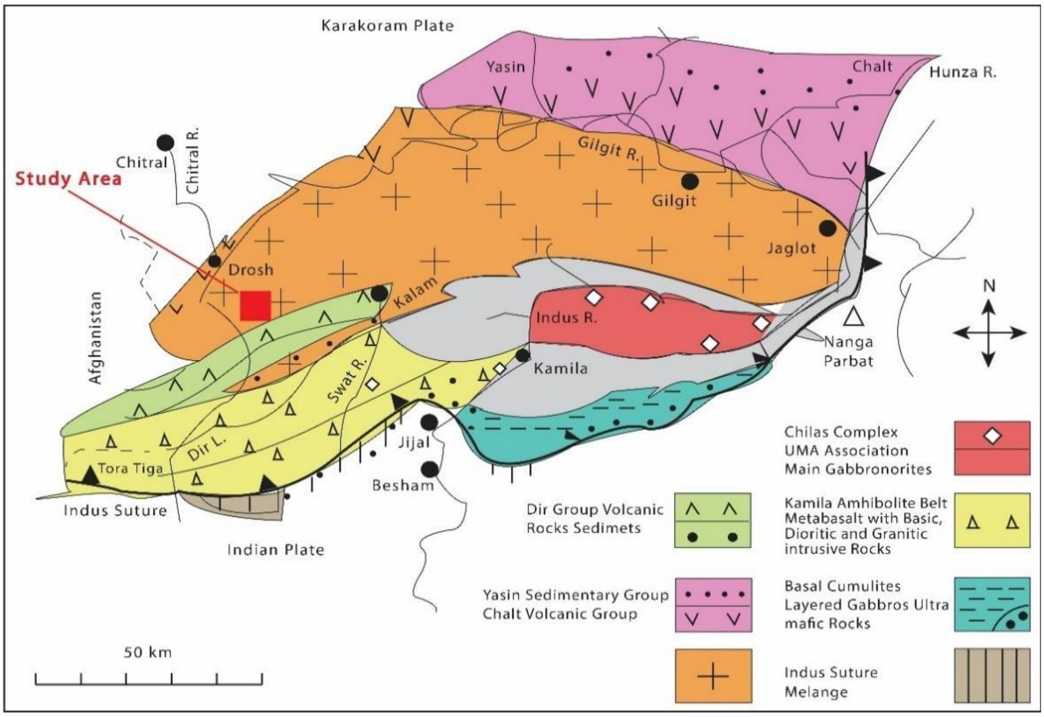


Fig. 1 The detailed geological map of Kohistan Island arc having the study area of Kumrat Granite (Khan et al., 1993).

continental collision. The KIA, as a whole, represents a geologically critical segment of the Pakistan Himalaya, documenting the arc–continent convergence and the tectono-magmatic evolution of the India-Asia collision zone (Ullah et al., 2025; Tahirkheli, 1979; Burg et al., 2006; Treloar et al., 1996).

3. METHODOLOGY

The collected twelve samples were subjected thin sections preparation in the laboratory of the National Centre of Excellence in Geology (NCEG), University of Peshawar, Pakistan. The details petrographic study was performed through petrographic microscope facility available at Geomatics Lab, Department of Earth and Environmental Sciences, Bahria University Islamabad. A petrographic microscope (Olympus SZ61) was used for taking microphotographs at Sedimentology Lab, NCEG University of Peshawar.

Among the field samples ten samples were analyzed major elements. The elements contents were determined through wave energy dispersive X-ray fluorescence spectrometry (XRF) facility available in National Physical & Standards Laboratory (NPSL), Islamabad one of the units of PCSIR (Pakistan Council of Scientific and Industrial Research). Glass beads were used for XRF analysis. About 5 gm of sample were dried at 110 ℃ in order to remove the absorbed moister content, if present and then 0.5 gm of each of the samples was mixed with 7 grams of flux (mixture of lithium metaborate and lithium tetraborate) after cooling in desiccators. 2-3 drops of lithium iodide (releasing agent) were added to the mixture and the resulting sample-flux mixture was fused in platinum (95 %) - gold (5 %) crucible at 1100 ℃ for 10-15 minutes. During this period the crucible was periodically swirled over a burner to eliminate the gas bubbles and ensure the thorough mixing and homogeneity of the melt. The melt was hurl in a platinum mould of 30 mm diameter and each bead was analysed for major elements (TiO_2, Al_2O_3, Fe_2O_3, MnO, MgO, CaO, Na_2O, K_2O and P_2O_5). The PANalaytical PW4400/24 spectrometer equipped with a rhodium anode X-ray tube was used, and the standards, WROXI-1, WROXI-2, WROXI-3, DT-N, SDC-1, PG-1, G-2 was alternately run with each batch of 5 samples for accuracy and precision.

4. RESULTS AND DISCUSSIONS

4.1. PETROGRAPHY

The Kumrat Granite, located in the Kohistan Island Arc at the northwestern margin of Pakistan, is a petrographically homogeneous igneous body. It does not display lithofacies variation based on mineral assemblages, although it shows noticeable textural diversity, ranging from coarse-grained to porphyritic forms. The rock is generally equigranular to subgranular in texture. Field samples collected for this study appeared greenish and whitish in hand specimen; however, petrographic analysis confirms a consistent mineralogy and texture across all samples. Both essential and accessory minerals, along with some secondary phases, have been identified. Modal mineralogical compositions were estimated visually and, when plotted on the IUGS classification diagram, all samples fell within the granite field (Fig. 2).

Among the essential minerals, alkali feldspar is the most abundant, making up 41 % to 47 % of the total composition. The crystals are typically subhedral to anhedral and appear grey under cross-polarized light. Myrmekitic intergrowths are observed at the

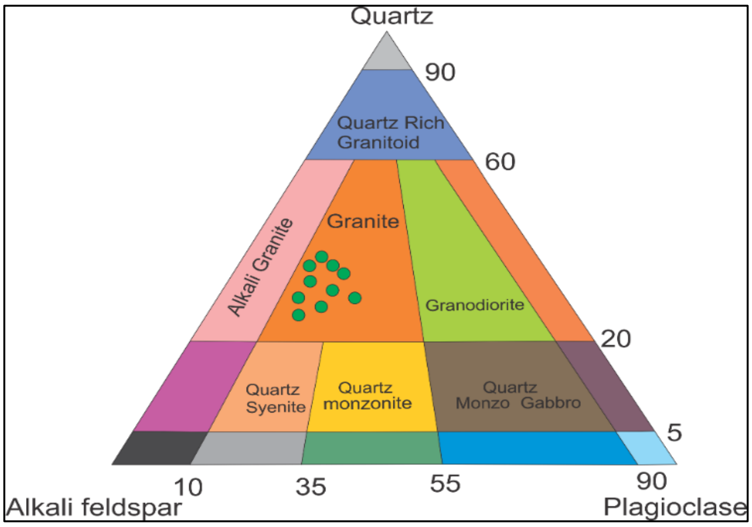


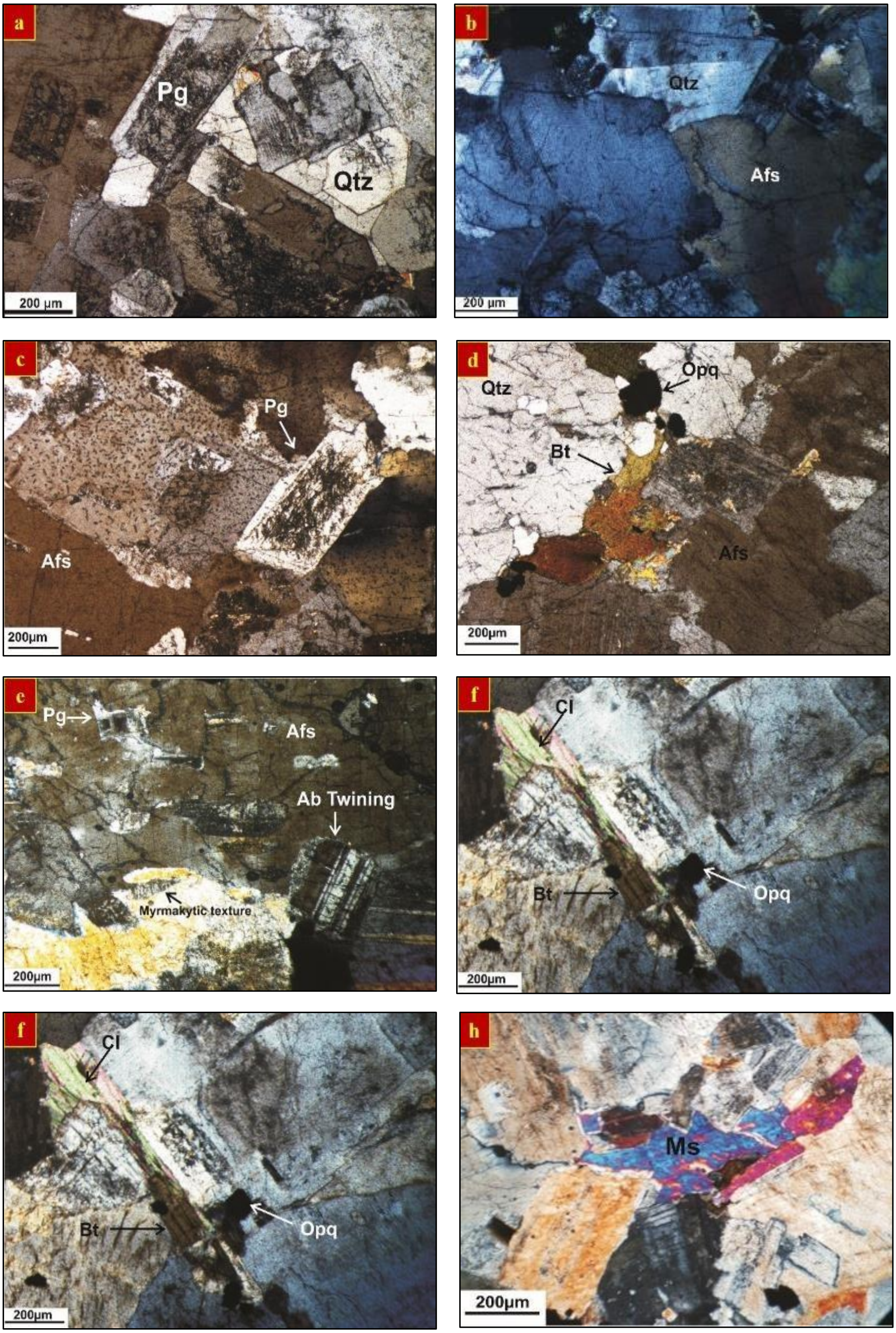
Fig. 2 Modal composition of Kumrat Granite plotted on IUGS classification diagram (Le Maitre, 2002).

boundaries between alkali feldspar and plagioclase, and cross-hatched twinning, characteristic of microcline, is visible in several grains (Figs. 3a, b). Quartz, the second most abundant mineral, accounts for 30 % to 35 % of the rock. It is usually colorless in thin section but may display interference colors in thicker sections. Quartz occurs both as phenocrysts and in the groundmass, where it encloses grains of feldspar and biotite. Most quartz grains exhibit undulose extinction, a feature indicative of crystal strain and post-crystallization deformation, pointing to tectonic stress on the granite body (Figs. 3c, d). Plagioclase makes up 10 % to 19 % of the rock and generally appears as euhedral to subhedral grains. It occurs both as phenocrysts and as part of the groundmass, in association with alkali feldspar, quartz, and biotite. Plagioclase grains often show a cloudy appearance due to partial alteration, with sericite and muscovite forming as alteration products. Albite polysynthetic twinning is commonly observed in thin sections (Fig. 3e), and some grains are zoned, with sericitized cores. Inclusions of muscovite, biotite, and zircon are also present within plagioclase, reflecting a complex crystallization history. Biotite, the fourth essential mineral, contributes 6 % to 14 % of the total composition. It exhibits strong pleochroism from light to dark brown and typically occurs as well-formed flakes, either isolated or in clusters associated with other minerals. Several biotite grains show embayed or "eaten" edges, indicating magmatic or post-magmatic reaction textures. Inclusions of zircon, titanite, and opaque minerals are frequently found within biotite. Many biotite crystals are partially or completely altered to chlorite (Fig. 3f). Additionally, in zones close to intrusive contacts, biotite and muscovite flakes may show weak to moderate preferred orientation and bending, suggesting localized deformation during or after emplacement.

Accessory and secondary minerals are present in minor amounts but provide significant insights into the rock's evolutionary history. Chlorite is observed in concentrations ranging from 0.5 % to 1.2 %, appearing in various green hues under the microscope. It is typically formed through the alteration of biotite, as suggested by their frequent association. Muscovite is present in amounts of approximately 2 % and displays pleochroism from light blue to pink. It is commonly found in close association with biotite and appears as fine flakes. In certain thin sections, muscovite exhibits bird's eye extinction, a distinguishing optical property (Fig. 3h). Titanite (sphene) is occasionally seen as small subhedral to euhedral crystals. These grains are generally found in association with biotite and opaque minerals (Fig. 3i). Though rare, apatite can be identified as inclusions within feldspar and biotite, indicating early crystallization stages. Additionally, minor opaque minerals, likely metallic in nature, occur sporadically throughout the rock, representing residual ore-bearing phases.

The Modal abundance of plagioclase in Kumrat Granite is ranging from 11 % to 16 %. Petrographically, it occurs as euhedral to subhedral grains. The plagioclase in the Kumrat Granite showing polysynthetic albite twining (Fig. 3e), indicative of magmatic crystallization. Based on CIPW Normative mineral calculation, plagioclase show a very low anorthite content (0 to 7.6) (Table 3) suggest highly sodic while fall with-in the field of albite and showing low basicity. The low anorthite content also support the per-aluminous character of Kumrat Granite later discussed in geochemistry part with full details.

Two samples of schist (biotite-schist) were also collected during field. Biotite mineral shows dark brown to light brown pleochroism. Muscovite display variety of colours (blue, pink and green). Both biotite and muscovite flakes exhibit bending due to stress and strain condition. The quartz is in euhedral to subhedral shape, as ground mass and is coarse to fine grained. Alkali feldspar is present as both phenocrysts and ground mass. Plagioclase occurs as ground mass and shows albite twining (Figs. 3k, l).


a
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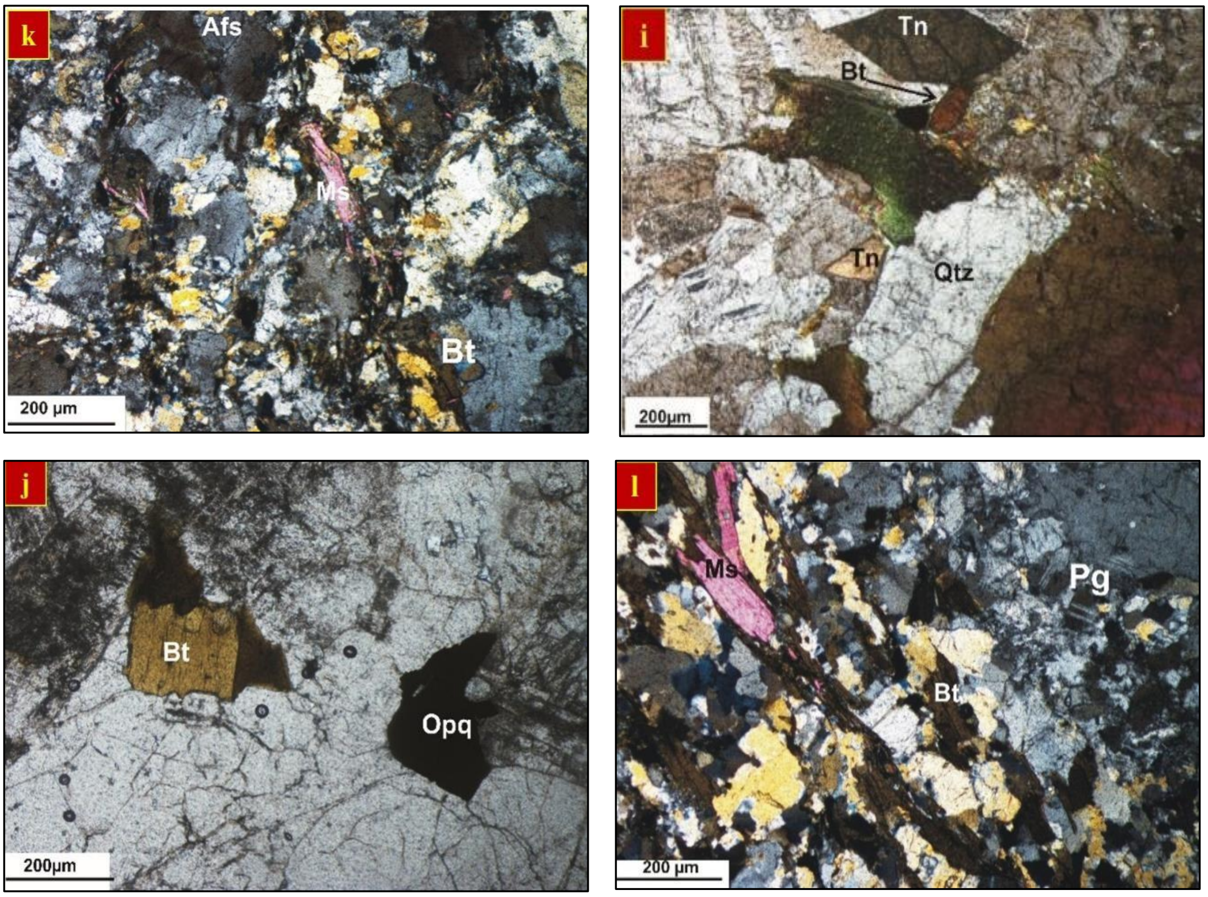

Fig. 3 Photomicrographs showing; (**a**) Alkali feldspar with abundant quartz (**b**) Quartz and alkali feldspar. (**c**) Zoned plagioclase and alkali feldspar (**d**) Quartz, biotite and opaque mineral. (**e**) Plagioclase, alkali feldspar and polysynthetic albite twining. (**f**) Biotite, chlorite and opaque mineral association, (**g**) Cloritization of biotite, (**h**) Muscovite (**i**) Titanite, biotite and quartz. (**j**) Biotite and opaque mineral. (**k**) Showing the ground mass of biotite, muscovite and alkali feldspar. (**l**) Showing the ground mass of plagioclase, biotite and muscovite.

Table 1 Modal mineralogical composition of Kumrat Granite.

Sample ID	Quartz	Alkali feldspar	Plagioclase	Biotite	Sericite	Opaque	Chlorite	Muscovite	Titanite
K-1	32.5	41.4	10.5	14	1	0.6	0	-	-
K-3	33	42	12.5	8	1.5	0.5	1	1.5	-
K-5	30	47	15	7	0	0.5	0.5	-	-
K-8	31	42	16	8	2	1	1	-	-
K-12	35	41	11	10	1	1	0.5	0.5	-
K-15	30	41	18	5	2	1.3	0.7	1	1
K-18	31.5	44	16.4	4	1.4	0.7	1	1	-
K-19	32	45	12	6	2	1	0.5	1	0.5
K-20	31	41	14	10.5	2	0.5	0.5	0.5	-

4.2. GEOCHEMISTRY

During present study, 10 samples were analysed geochemically to perform nomenclature, classification, and petrogenesis of Kumrat Granite. The major elements data is listed in Table 2. GCDkit Tool (Geochemical Data Tool Kit) software, introduced by Janousek et al. in 2006 was used to calculate CIPW norm (Table 3). According to Middlemost (1994) classification of igneous rocks based on SiO_2 concentration and degree of alkalinity (Na_2O+K_2O), the investigated samples occupy the place with in the field of Granitic rocks (Fig. 4). This is in agreement with the modal mineral classification of IUGS.

The FeOt/MgO Versus SiO_2 Diagram of Miyashiro (1974) is used to differentiate the tholeiitic and calc-alkaline series. All the samples represent high potash and calc-alkaline nature (Fig. 5). The Shand (SiO_2 Versus A/CNK) discrimination plot shows mildly per-aluminous and metaluminous nature while Chappell and White (1974, 1992, 2001) proposed that S-type Granite or peraluminous leucogranites are

Table 2 Major elements composition of representative samples.

SPECIMEN	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5	LOI	Total
K-1	75.0	0.19	14.60	0.14	0.16	1.61	1.56	4.56	3.06	0.05	0.06	100.93
K-3	74.3	0.24	15.70	0.77	0.09	-	1.88	3.56	3.81	0.07	0.05	100.11
K-5	77.2	0.14	12.90	0.56	-	0.26	1.45	2.73	3.09	0.05	0.14	98.29
K-8	76.0	0.18	13.50	0.43	-	0.63	1.61	3.53	3.00	0.07	0.04	98.96
K-12	73.0	0.51	13.08	0.56	0.01	1.23	1.50	3.01	5.32	0.23	0.03	98.07
K-13	72.2	0.25	16.50	0.58	0.07	0.57	2.16	3.21	4.06	0.09	0.02	99.50
K-15	72.5	0.21	17.09	0.99	0.06	0.28	1.82	3.05	3.62	0.08	0.05	99.61
K-18	74.1	0.15	16.34	0.87	0.06	0.37	1.41	3.55	3.40	0.06	0.06	99.88
K-19	75.3	0.15	15.09	0.33	0.41	0.28	1.51	2.50	3.83	0.06	0.03	99.10
K-20	75.1	0.21	14.50	0.19	-	0.83	1.6	4.00	3.38	0.07	0.14	99.92

Table 3 CIPW norms calculated for Kumrat Granite.

Norms	K-1	k-3	K-5	K-8	K-12	K-13	K-15	K-18	K-19	K-20
Q	31.992	31.87	40.292	35.054	26.777	27.353	32.445	37.193	37.412	30.612
C	0.000	0.678	0.939	0.000	0.000	0.000	0.000	2.287	1.235	0.000
Or	18.084	19.65	18.261	17.729	29.549	23.993	21.393	20.093	22.634	19.975
Ab	38.078	32.67	31.308	38.078	33.847	35.539	29.616	29.616	28.262	40.230
An	5.225	5.234	6.902	3.356	2.749	7.602	4.976	6.697	7.162	0.000
Hy	3.459	1.560	0.648	0.276	2.357	0.810	0.000	0.922	0.698	0.000
Hm	2.160	1.567	1.730	1.950	1.560	2.730	2.050	1.550	1.740	1.437
Tn	0.466	0.345	0.000	0.442	1.252	0.614	0.516	0.000	0.000	0.516
Ap	0.117	0.105	0.106	0.152	0.347	0.201	0.154	0.108	0.119	0.164
Py	0.271	0.058	0.000	0.000	0.000	0.114	0.092	0.000	0.693	0.000

Q-Quartz, C-Corundum, Or-Orthoclase, Ab-Albite, An-Anorthite, Tn-Titanite, Ap-Apatite, Py- Pyrite, Hy- Hypersthene, Hm- Hematite

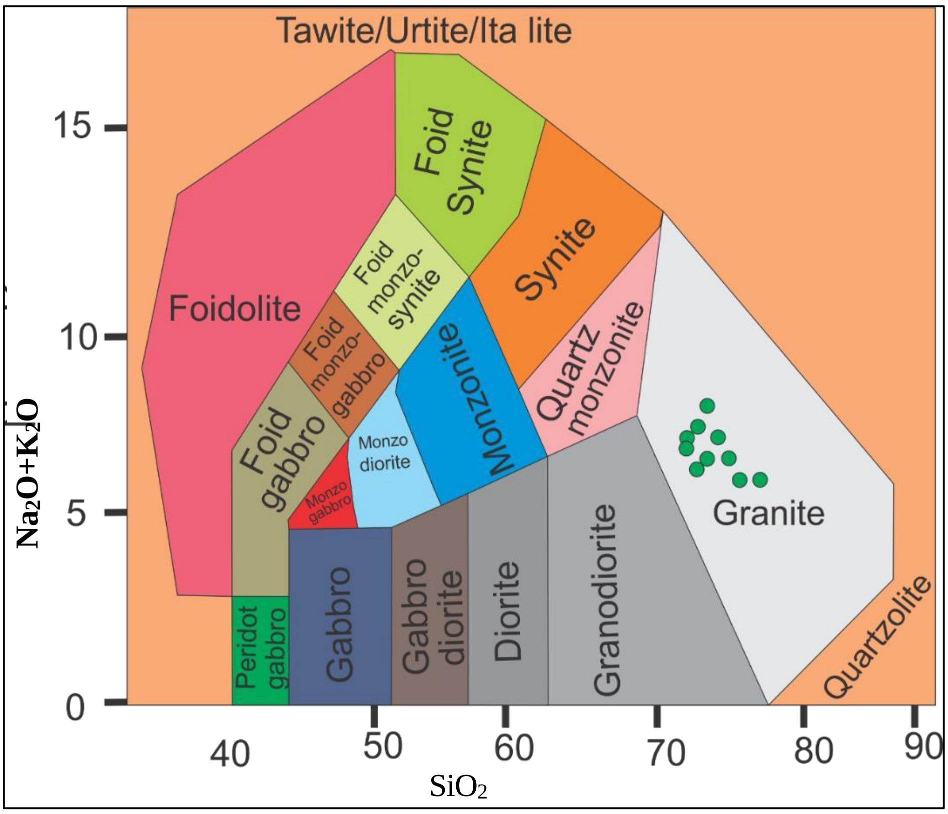

Fig. 4 TAS classification (Middlemost, 1994).

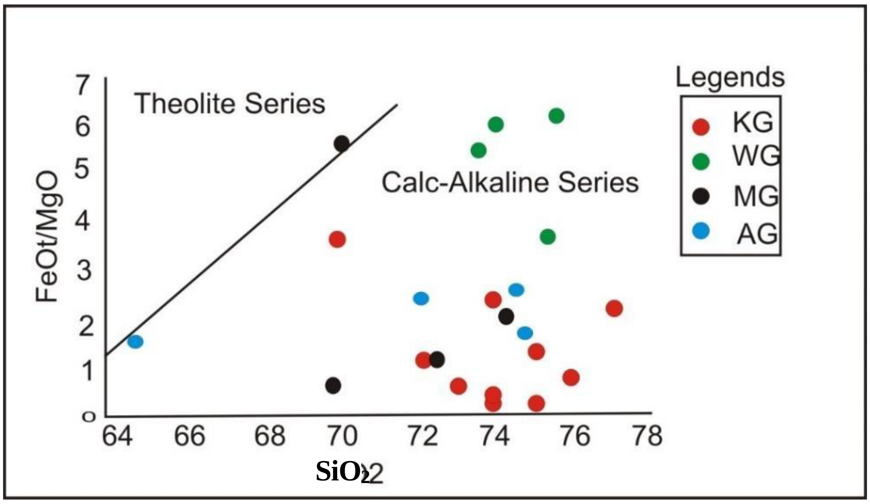

Fig. 5 FeOt/MgO versus SiO_2 Miyashiro (1974). Kumrat Granite (KG) shown by red colour while Wadhrai Granite (WG) by green circle, Mansehra Granite (MG) by black color, Ambela Granite (AG) by bue color.

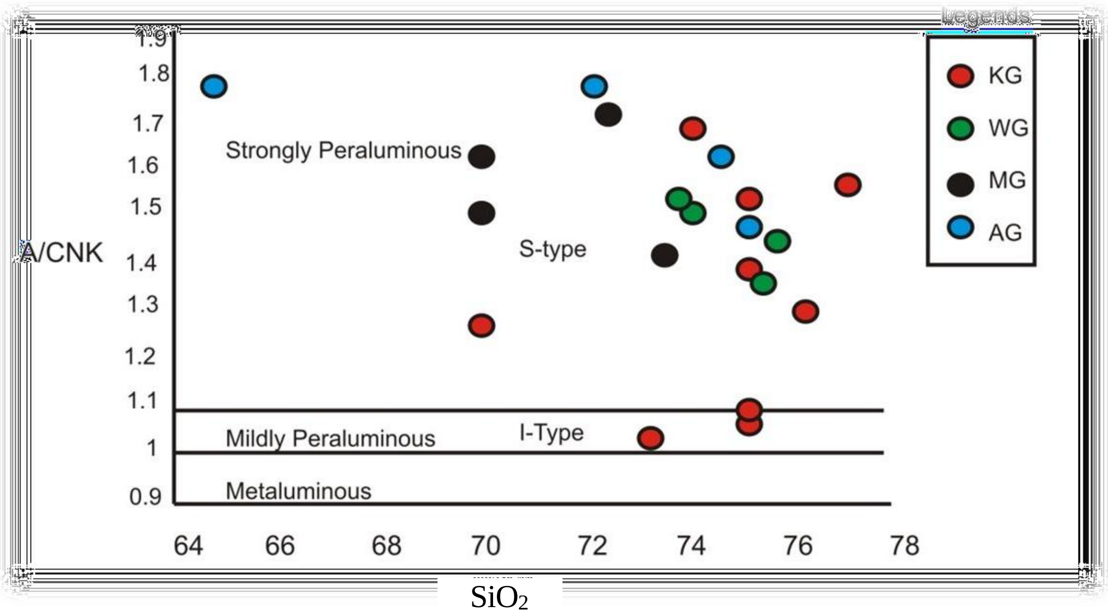

Fig. 6 SiO_2 versus A/CNK discrimination diagram. Division between strong per-aluminous, mildly per-aluminous and metaluminous (Shand, 1951), and between I & S-type after Chappel and White (1974) for studied samples, Kumrat Granite (KG), WG represent (Wadhrai Granite), MG (Mansehra Granite), AG (Ambela Granite).

originated from the melting of upper crustal elements (Fig. 6).

For the formation of leucogranites number of methods have been proposed among which most important is the metapelites and metagreywackes melting, including basalt magma admixture cases (Sylvester, 1998; Patino Douce, 1999). Some possible melt's source information can be obtained by using Patino Douce (1999) diagram ($CaO+FeO+MgO+TiO_2$ versus CaO/ ($FeO+MgO+TiO_2$) which describes the correlation link of granite constituents with melt's constituents originated by experimental dehydration of different type of crustal rocks. By using these that diagram the investigated samples fall within the field of melts originated from dehydration of melting of felsic pelites and greywackes rocks (Fig. 7). Moreover, Sylvester (1998) described that the low ratios of CaO/Na_2O reflect clay rich, plagioclase poor pelitic and clay poor plagioclase rich psammitic (greywackes) sources for granitic rocks. Based on these observations the CaO/Na_2O ratio of Kumrat Granite is averagely from 0.34 to 0.60. Furthermore, Sylvester (1998) described that Al_2O_3/TiO_2 versus CaO/Na_2O diagram might be used for identifying source composition for melts parental to per-aluminous granite. By using these parameters of Sylvester (1998), the polygon demarcate compositionally field of strong peraluminous granite, with lower portion of the field describing pelitic sources while psamtic sources upper portion of the

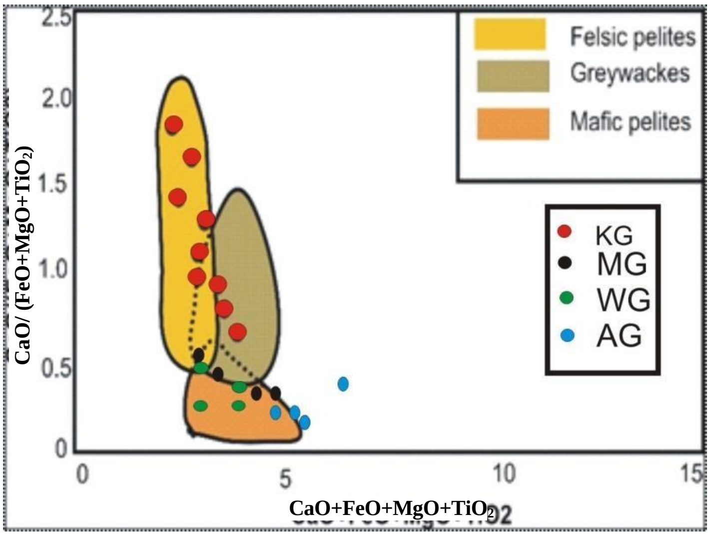

Fig. 7 The $CaO+FeO+MgO+TiO_2$ versus $CaO/ (FeO+MgO+TiO_2)$ plot showing the melts composition of Kumrat Granite obtained in experimental dehydration of meta-sedimentary rocks (after Patino Douce, 1999). Kumrat Granite (KG), WG represent (Wadhrai Granite), MG (Mansehra Granite), AG (Ambela Granite).

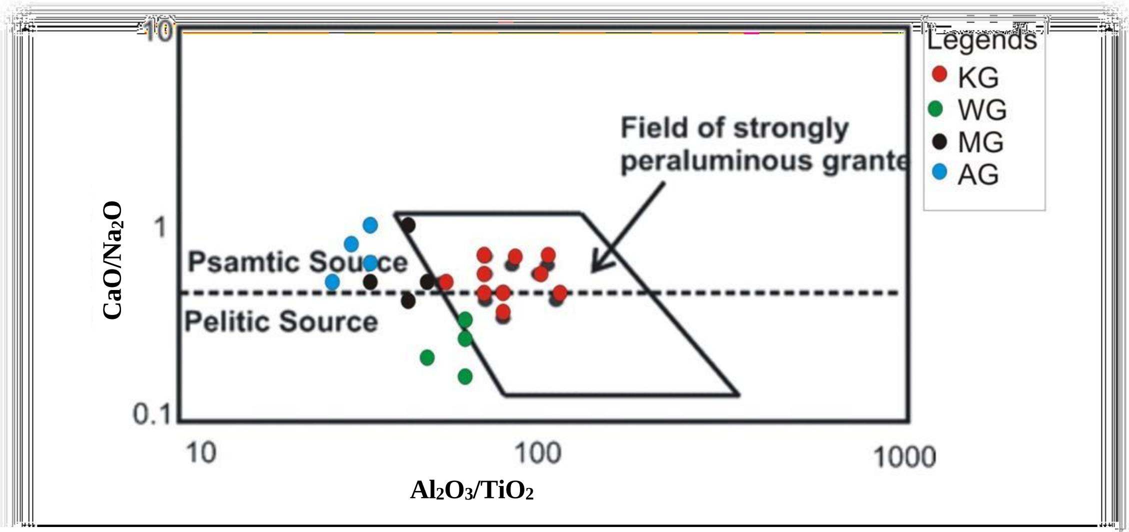

Fig. 8 Al_2O_3/TiO_2 versus CaO/Na_2O diagram of Sylvester (1998). Kumrat Granite (KG), WG represent (Wadhrai Granite), MG (Mansehra Granite), AG (Ambela Granite).

field (Fig. 8). Thus, the major elements composition of investigated samples indicates pelitic to psamtic sources for Kumrat Granite.

Batchelor and Bowden (1985) showed a bivariate graph to describe granitic rocks related tectono-magmatic division by using the R1[(4Si – 11 (Na +k) -2 (Fe + Ti)] and R2 (Al + 2Mg + 6Ca) parameters. By using these parameters, the Kumrat rocks fall in syn-collisional field (Fig. 9). Moreover, Maniar and Piccoli (1989) categorised a tectonic setting environment for granitoid rocks on the basis of modal analysis and major element geochemistry data. By using the M/AFM versus F/AFM and C/ACF versus F/AFM parameter, the cluster forms in Island Arc Granite (IAG) field for the studies samples (Fig. 10).

The chemical analysis show that these rocks have a narrow range (72-77 wt %) of SiO_2 content and have a variable relation with other oxides (Fig. 11). Harker variation diagrams of Al_2O_3, TiO_2, CaO, and K_2O show a well-defined decreasing trend representing early fractionation of feldspars (both the alkali and plagioclase) and biotite from the melt. The plots of Na_2O against SiO_2 are more or less flat depicting loss of volatiles during alteration of the rocks (Chappell and White, 2001). The negative trends of TiO_2 and P_2O_2 versus SiO_2 may represent the fractionation of titanite and apatite, respectively.

The Kumrat Granite were compared with other Granitic bodies which includes Wadhrai Granite (WG) Stock of the Malani Igneous Suite in Nagar Parkar Area from the work of Jan et al., in 2022 from SE Pakistan. Mansehra granitic complex, Hazara area, Northwestern Himalaya, Pakistan by Naeem in 2012 and Ambela Granitic Complex by Rafiq, 1989 research work. By putting FeOt/MgO versus SiO_2 values in plot after Miyashiro (1974) all the Granite

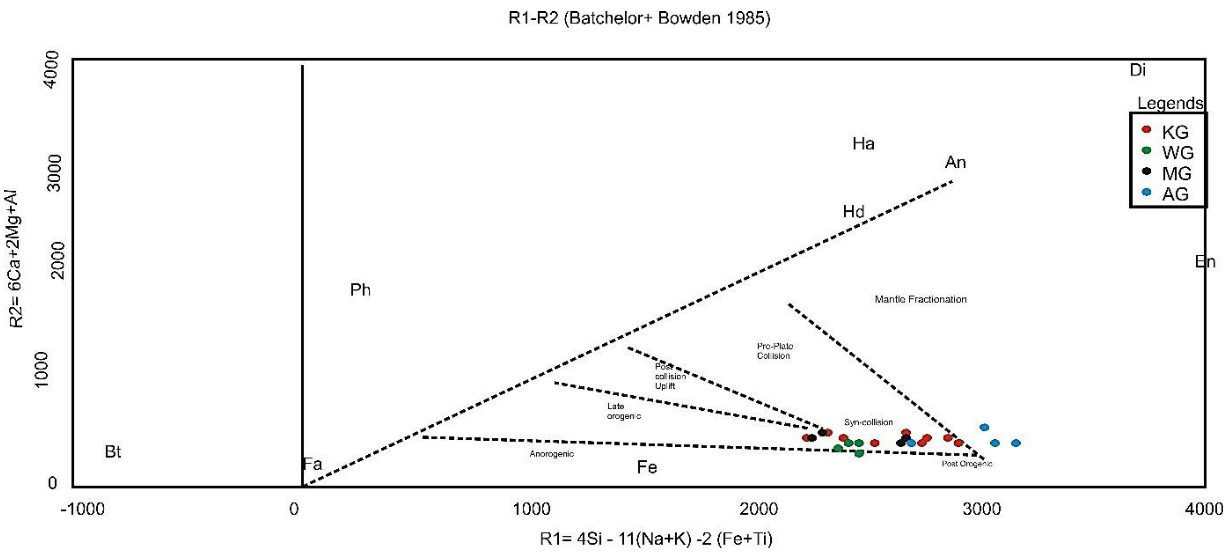

Fig. 9 Tectono-magmatic parameter diagram (Batchelor and Bowden, 1985). Kumrat Granite (KG), WG represent (Wadhrai Granite), MG (Mansehra Granite), AG (Ambela Granite).

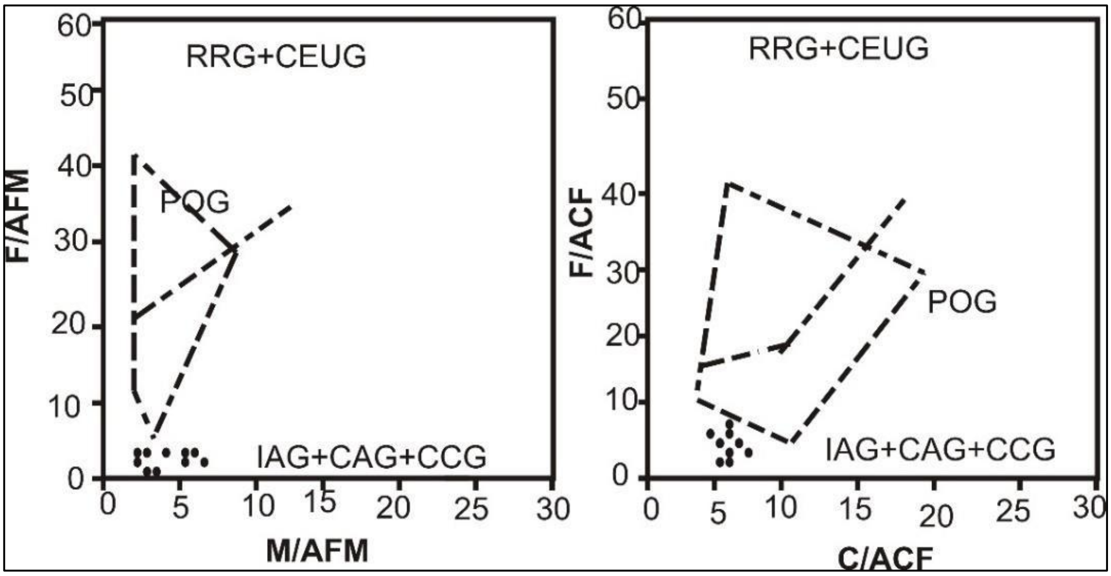

Fig. 10 Granite tectonic discrimination (Maniar and Piccoli, 1989).

bodies majorly show Calc-Alkaline Nature. However, one sample from both the Mansehra Granite and Ambela Granite Suite moving towards Theolite series (Fig. 5). The compared granitic bodies show similar strongly peraluminous nature as Kumrat Granite according to Shand (SiO_2 versus A/CNK) discrimination diagram while S-type leucogranite (Fig. 6). The $CaO+FeO+MgO+TiO_2$ versus CaO/ ($FeO+MgO+TiO_2$) plot showing that Mansehra Granite has Mafic to felsic Pelites melts composition, Wadhrai Granite also mafic to felsic while Ambela Granite is showing the same mafic where the melt composition trends for Kumrat Granite is moving form felsic towards greywackes (Fig. 7). According to Sylvester (1998) the Al_2O_3/TiO_2 versus CaO/Na_2O diagram the Ambela Granite showing psamtic source, Mansehra Granite depicts politic to psamtic source while Wadhrai Granite from Nagar parker region shows pelitic magma source where as Kumrat Granite showing politic to psamtic source (Fig. 8). Batchelor and Bowden (1985) bivariate graph to describe granitic rocks related tectono-magmatic division by using the R1[(4Si – 11 (Na +k) -2 (Fe + Ti)] and R2 (Al + 2Mg + 6Ca) parameters. According to these parameters, the Kumrat rocks fall in syn-collisional field, the Ambela Granite trends moving towards the post orogenic however its very close to syn-colliosional tectonic setting. The Mansehra Granite Wadhrai Granite from Nagar Parker region fall in the field of syn-collisions (Fig. 9).

5. CONCLUSIONS

The petrographic and geochemical analyses of Kumrat Granite indicate its classification as a coarse-grained leucogranite with a calc-alkaline and peraluminous character. Mineralogical composition and geochemical discrimination diagrams suggest an S-type affinity, likely derived from the partial melting

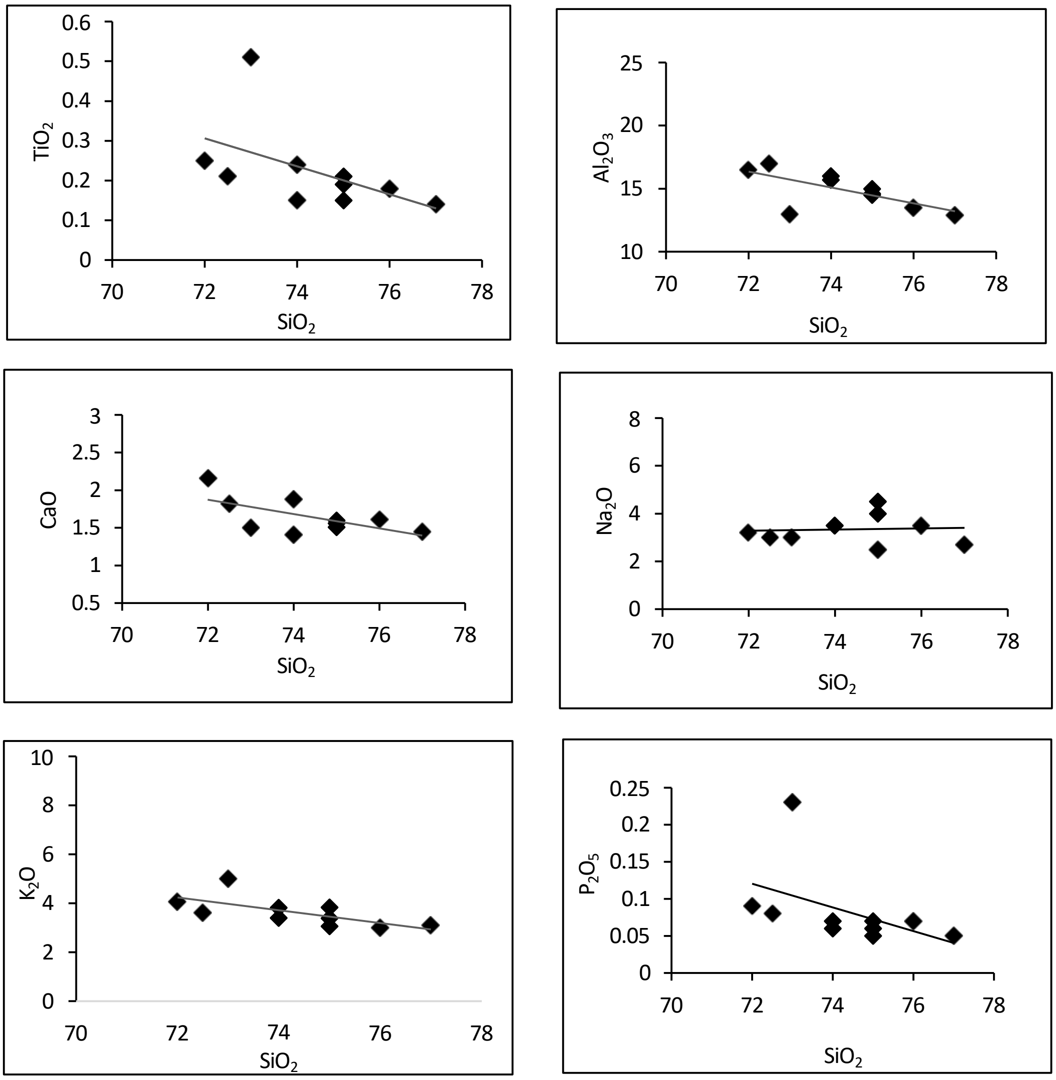

Fig. 11 Major elements versus SiO_2 Harker Variation diagram of Kumrat Granite.

of sedimentary protoliths under water-deficient conditions. Major element trends highlight early fractionation of feldspars and biotite, while tectonic discrimination plots place Kumrat Granite within a syn-collisional and island arc setting, consistent with magmatism in a convergent margin environment.

Further investigation through trace element geochemistry, rare earth element analysis, and radiometric dating is recommended to refine the petrogenetic history and tectonic significance of Kumrat Granite.

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