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PETROGENETIC MODELING OF THE GRANITIC ROCKS IN AND AROUND LODHMA, DIST RANCHI, JHARKHAND, INDIA

Dr. Jayant Sinha
Associate Professor and Head, Department of Geology, St. Xavier's College, Ranchi-834001

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ABSTRACT

The Lodhma area, in the Ranchi district, constitutes the central segment of Chotanagpur Granite Gneissic Complex (CGGC) and falls in the northeastern segment of Survey of India toposheet number 73E/4.

The CGGC is mainly composed of variants of granitic rocks, amphibolites and metasedimentaries. The granitic rocks find good exposure in the area. They comprise predominantly of granite gneisses, crystalline massive granites and migmatites showing noticeable variations in mineralogy, texture, structure and associations. The regional strike of the lithounits of the area show almost E-W trend. However ambient structural controls have brought about local changes in the strike direction. The area has witnessed at least three phases of deformations which is reflected by three generations of folds, which are generally isoclinals.

Petrogenetic characterization of granitic rocks and its variants in the area has been attempted using various geochemical tools involving major/ trace element studies and Niggli values. S –type parentage of these Granites have been established on the basis of distribution behavior of various chemical components present in it, thereby indicating role of pelitic schists in the generation of anatectic melt, which ultimately crystallized into granites. S-type lineage of these granites has also been further cemented with the help of several well established binary and ternary variation diagrams.

The area under investigation lies in the Ranchi district of Jharkhand state. Lodhma is approximately 24 km from the Ranchi town and it lies to the south-west of Ranchi town. The Lodhma area falls in the northeastern segment of Survey of India topo sheet number 73E/4.

The Lodhma area constitutes the central segment of Chotanagpur Granite Gneissic Complex (CGGC). The CGGC is mainly composed of variants of granitic rocks, amphibolites and metasedimentaries. The predominance of granite gneisses has imparted the name CGGC to this region. A comparison between the disposition of structural signatures and nature of lithounits between the CGGC and Singhbhum Craton indicate the collision of these two microplates leading to their suturing and triggering a sequence of deformational, magmatic and metamorphic activities.

The Lodhma area is a depository of almost all representative lithounits of this region. The nature of these rocks presents an insight regarding palaeo-source material responsible for their generation. The multiplicity of deformational episodes has led to lithological and structural complexities in the rocks of this area.

The present work is a holistic attempt to explore the petrogenetic characterization of granitic rocks and its variants present in the area.

GEOLOGY OF THE AREA

The Lodhma area is a geologically complex terrain embracing signatures of multiphase deformations, magmatism, metamorphism and subaerial transformations. Granitic rocks, amphibolites and the metasedimentaries dominate the present area, all belonging to Precambrian age. The granitic rocks find good exposure in the area, showing variations not only in mineral composition but also in their fabric. The important variants are granite, granite gneisses and migmatites. Numerous inclusions of quartzo-felspathic veins have been encountered in the area. The pelitic, calcareous, psammitic metasedimentaries and amphibolites are the important metamorphic constituents in the area. Among the metasedimentaries the biotite schists, biotite-muscovite schists, quartz-garnet-sericite schists, calc-silicate rocks and diopside as well as hornblende quartzites are very prominent.

The regional strike of the lithounits of the area show almost E-W trend. However ambient structural controls have brought about local changes in the strike direction, as a result some of the lithounits have acquired a NW-SE strike. The metamorphites display strong planar structures, which is represented by the foliations and schistosity planes. The area has witnessed at least three phases of deformations which is reflected by three generations of folds, which are generally isoclinals.

Ghose(1983), Sarkar and Jha(1985), Banerji(1991), Tiwary et.al.(1992), Sinha(1998) and others have conducted geological investigation of different segments of CGGC. A detail study of the Lodhma area has revealed that pelitic, psammitic and calcareous sediments were the earliest lithounits deposited in the epicontinental basin. At present they are represented by their metamorphic equivalents. The regional metamorphism of the entire CGGC coincided with the culmination of third phase of deformation. The pelitic schists represent the first phase of sedimentation, which occur mainly as bands and enclaves of diverse shapes and sizes within the granitic rocks. Arenaceous sediments represent the next phase of sedimentation in the area, which are being represented by quartzites of diverse mineralogy. The cal-silicate rocks are the youngest sedimentary representatives in the area. They occur as small outcrops in the granitic country.

The amphibolites of diverse mineralogical composition as well as textural configuration occur in the area. They mainly occur as large circular or elliptical masses and in narrow strips intercalated with other metamorphites. They seem to have originated as a result of basic magmatism followed by amphibolisation (Sinha, 1998). Medium grained amphibolites occurring as inclusions within the granitic country is also found in the area.

The granitic rocks are the dominant lithounit in the area and are the representatives of the CGGC. The granitic rocks in the area comprise predominantly of granite gneisses, granites and migmatites showing noticeable variations in mineralogy, texture, structure and associations. These granitic rocks crop out as huge rounded domes showing the effects of spheroidal weathering in them. Geologically these granitic rocks in particular and the CGGC in general is an extension of the Satpura range of central India judged from the continuation of the ENE-WSW strike (Mahadevan, 2002). However, in the Lodhma area, due to local adjustments the granitic rocks exhibit a strike which varies from E-W to NW-SE. inclusions of various sizes and shapes of older metasedimentaries and amphibolites have been noticed within the granitic country.

PETROGRAPHY OF GRANITIC ROCKS

The granitic rocks of Lodhma area display following petrographical characteristics:

- The granitic rocks in general are coarse grained showing both massive as well as foliated habit.
- The granite gneisses are characterized by typical gneissose structure showing alternate mafic and felsic bands.
- The massive granites display typical holocystalline, hypidiomorphic and interlocking textute.
- Quartz and Alkali felspar, in the form of orthoclase, microcline, albite and perthite form the essential minerals whereas biotite, muscovite, garnet, hornblende, apatite, sphene, opaques and epidote constitute the accessory minerals of the granitic rocks.
- Plagioclase felspars are one of the dominant constituents in these rocks and it usually occurs as subhedral grains and often exhibits polysynthetic twinning with { 010} and {101} as the twin planes.
- Myrmekites are quite common in them, the quartz occurs as blebs, drops and vermicules within the felspar plates.
- Sericitisation of plagioclases and chloritization of biotite is very often observed.
- One of the important variation in the mineralogy of the granites is in the nature and amount of the felspars present and also in the type of ferromagnesian constituent present in them.
- Based on mineralogy, fabric and field associations, three broad types of granitic rocks have been identified in the area, viz. the granite gneisses, the massive granites and the migmatites.
- Based on dominance of ferromagnesian minerals, the granite gneisses have been

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categorized as biotite granite gneisses, hornblende granite gneisses and garnetiferous granite gneisses. However, on the basis of field observations and fabric studies following types of granite gneiises have been identified; the banded gneissse, the streaky gneisses, the augen gneisses and the porphyroblastic gneisses.

- Massive granites have been identified as Gray granites, and migmatites as biotite and hornblende bearing migmatites.

GEOCHEMISTRY OF GRANITIC ROCKS

The major element, trace element chemical analyses and Niggli values of the granitic rocks of Lodhma area has been shown in the Table 1, table 2 and Table 3 respectively.

Sample numbers used in the chemical analyses

Sample Nos BL1 ----BL5 = Massive Granites.
BL6 ----BL10 = Foliated Granites.
BL11 ----BL12 = Migmatites.

The silica content of the granites varies between 68.95% - 74.01%, thereby establishing their persilic nature. This also confirms their oversaturated character and is reflected in the occurrence of quartz as essential mineral. The Al_2O_3 percentage varies between 13.25% - 15.12%. Their Al_2O_3 / (Na_2O + K_2O+CaO) ratio is greater than 1.1, which classifies these granites into peraluminous category as well as suggests S type affinity to them. The average value of CaO is 1.66 wt%, which is another evidence in support of pelitic lineage for these granites. (Chappell and White,, 1974).

The Feo(t) and MgO content is almost uniform in all the samples. The interrelationship between the mafic and felsic components has been demonstrated in the (K_2O + Na_2O) – (MgO + FeO(t)) variation diagram (Fig. 1). The points show a weak negative correlation, a chemical behavior supporting the magmatic origin of granites. It also indicates that alkali silicates are far more common than the mafic silicates in them.

The Na_2O / K_2O ratio in general is less than 1. In the binary diagram Na_2O vs K_2O (Fig. 2) , the granitic rocks of the area are placed in the K_2O field, an observation matching well with the major oxide analysis and dominance of K-felspars in them.

The higher percentage of Na_2O may be due to the replacement of Ca^{++} by Na^{+}. The Na_2O / CaO ratio varies from 1.23 to 3.43, substantiating the fact that plagioclases are enriched in Na.

The MgO / CaO ratio is less than 1, which is manifested in the absence of camafic minerals in them.

The impoverishment of CaO and its manifestation in the mineral formation of silicate affinity is illustrated in the CaO - Na_2O - K_2O ternary diagram (Fig. 3). The granitic rocks of the area are placed far away from the CaO end. Abundance of Na_2O / K_2O in them is clear indication of preponderance of late differentiate minerals. There is progressive enrichment of alkalies, which is clearly reflected in the mineral composition. Presence of Na rich and Ca poor plagioclases also cements this conjecture.

The role of anatexis has been established in the generation of granitic melt and ultimately crystallizing into granite. Experimental studies have indicated that in presence of adequate water, partial melting of a variety of rocks can produce granitic melt which kinetically tends to move towards shallower level, i. e. , low pressure region. The movement of granitic melt, however may be arrested by loss of water and small granitic segregations can be formed (Bose, 1997). Niggli c vs mg variation diagram (Fig. 4) is very useful in identification of the primary source material, which underwent partial melting, followed by melt segregation and finally emplacement at shallower levels with distinct magmatic signatures. The compositional points are placed within the pelitic and semipelitic field, thus indications are that the metapelites of the area had their contributions, if not entirely, at least substantially, in the generation of granitic melt. Occasional presence of enclaves of biotite schist in the granitic country further establishes its lineage to metapelites.

One of the most popular classifications used in recent studies is the I- and S- type granitoid classification. These two contrasting granite types have been recognized by Chappell and White (1974) and White and Chappell (1977) in the plutonic rocks of southeastern Australia. They proposed a genetic subdivision of the granitic rocks into those derived from igneous source rocks as I – type and those extracted from sedimentary protoliths as S – type.

Chappell and White (1974) proposed several chemical parameters to distinguish S-type and I- type granites. I-type granites have Al_2O_3 / (Na_2O+ K_2O K_2O+CaO) ratio less than 1.1 while S-type have more than 1.1. The granitic rocks of the present area are peraluminous; its average value has been found to be 1.42, an indication towards the S-type affinity for them. CaO percentage in S-type should be less than 3.7 wt%. the average value of CaO for these granites is 1.66, supporting the pelitic parentage for these granites.

The distribution behavior of certain trace elements has proved its efficacy in the distinction of I- / S- type granites. Cr, Co and Zr are present in higher amounts in S-type varieties. In such granites, their amount should be more than 45, 16 and 15 ppm respectively. The average value of Cr, Co and Zr for the granites of study area has been found to be 371.95, 92.81 and 162.48 respectively. It gives the indication that these granites owe their origin the metapelites.

Chappell and White suggest that S-type granites are restricted in composition to high SiO_2 types, while I-type granites have a wide composition from felsic to mafic. These characteristics are a consequence of S-type granites having been derived from a more SiO_2 rich source. Therefore granitoids containing less than 65% SiO_2 can assumed to be I-type. This is consistent with the work done by Hine et.al. (1978). The average value of SiO_2 for granites of the study area is more than 70%, thus matching with the standards of S-type granites.

S-type affiliation of these granites is further cemented with the help of FeO – Fe_2O_3 (Fig. 5 8.31) and Na_2O vs K_2O (Fig. 6 .32) variation diagrams. The compositional points religiously occupy the field assigned for S-type granites.

CONCLUSION

The granitic rocks are the most widely distributed lithounits in the area. The granites appear younger than the older metasedimentaries, as they are intrusive into them, a feature observed at many places. The granitic rocks of the study area consist of different variants and they differ in colour, texture, structure, mineral composition and field association. Broadly two types of granites have been identified, viz., the strongly to weakly foliated and lineated types and the massive, equigranular and crystalline varieties.

A careful scan of the various chemical components and their behavior has clearly indicated towards the contribution of pelitic schists in the generation of anatectic melt, which formed granites in the area. S-type parentage of these granites has also been established on the basis of distribution behavior of certain trace elements like Cr, Co and Zr. S-type affiliation of the granites of the present area has been further cemented with the help of several well established binary and ternary variation diagrams.

An amalgamation of all these observations is a clear indication towards the contribution of pelitic schists in the generation of anatectic melt, which formed granites in the Lodhma area.

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	BL1	BL2	BL3	BL4	BL5	BL6	BL7	BL8	BL9	BL10	BL11	BL12
SiO_2	70.89	71.23	71.30	71.89	70.70	74.01	72.98	71.27	69.75	68.95	71.64	71.16
TiO_2	0.21	0.20	00.13	0.09	0.20	0.11	0.13	0.62	0.74	0.65	0.80	0.45
Al_2O_3	14.37	14.44	14.52	14.42	13.99	14.14	14.25	13.25	14.80	15.44	14.15	15.12
Fe_2O_3	0.33	0.29	0.23	0.26	00.38	0.22	0.25	0.66	0.76	0.82	0.71	0.62
FeO	1.53	1.48	1.22	1.48	1.53	1.41	1.37	1.85	2.05	1.96	1.25	1.13
MnO	0.05	0.08	0.03	0.03	0.05	0.03	0.04	0.03	0.18	0.20	0.02	0.04
MgO	0.59	0.60	0.48	0.60	0.59	0.22	0.22	1.42	1.56	1.65	1.12	0.48
CaO	1.82	1.79	1.34	1.61	1.82	1.32	1.29	1.74	1.85	2.08	1.66	1.61
Na_2O	3.81	4.1	4.6	4.26	3.8	3.69	4.34	2.20	2.42	2.55	2.34	3.29
K_2O	4.93	4.88	4.66	4.87	4.93	4.68	4.97	5.54	4.83	4.76	5.60	5.34
P_2O_5	0.07	0.07	0.04	0.02	0.07	0.03	0.03	0.10	0.07	0.03	0.09	0.03
LOI	0.98	1.21	0.98	0.82	1.11	1.01	1.27	1.222	1.01	0.98	0.76	0.82
Total	99.58	100.37	99.53	100.35	99.17	100.87	101.15	99.90	100.02	100.07	100.14	100.09

Table 1.Major Oxides Wt% of Granites of Lodhma area

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	BL1	BL2	BL3	BL4	BL5	BL6	BL7	BL8	BL9	BL10	BL11	BL12
Co	35	40	20	25	52	21	90	30	45	60	15	25
Cr	120	75	82	114	110	50	240	130	255	310	135	80
Ba	315	150	180	295	325	360	315	175	200	95	98	130
Sc	-	-	60	55	46	30	42	-	25	-	18	-
Ni	54	72	-	90	-	31	94	-	-	76	65	54
Sr	165	200	114	185	160	440	420	330	-	390	250	225
V	10	14	12	20	-	15	-	-	-	25	30	18
Y	35	25	40	55	35	-	41	40	20	35	30	-
Zr	107	210	155	80	94	220	210	140	235	150	140	107

Table2.Trace Element composition (in ppm) of Granites of Lodhma area

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	BL1	BL2	BL3	BL4	BL5	BL6	BL7	BL8	BL9	BL10	BL11	BL12
Al	42.94	42.66	44.17	42.86	42.22	46.24	44.51	39.94	41.69	41.84	43.32	45.91
Fm	12.44	12.14	10.00	11.89	12.76	9.44	9.00	21.48	22.84	22.54	17.03	11.15
C	9.91	9.63	7.42	8.72	10.00	7.86	7.34	9.55	9.49	10.27	9.26	8.90
Alk	34.71	35.57	38.40	36.54	35.01	36.46	39.15	29.03	25.98	25.36	30.39	34.03
Mg	0.38	0.39	0.39	0.40	0.38	0.20	0.21	0.54	0.52	0.54	0.56	0.37
K	0.46	0.44	0.40	0.43	0.46	0.46	0.43	0.62	0.57	0.55	0.61	0.52
Si	360.09	357.71	368.71	363.23	362.72	411.42	387.52	365.19	334.00	317.61	372.89	367.33
Ti	0.80	0.75	2.75	1.66	0.77	0.46	0.52	2.38	2.66	2.25	3.12	1.74

Table 3.Niggli values of Granites of Lodhma area

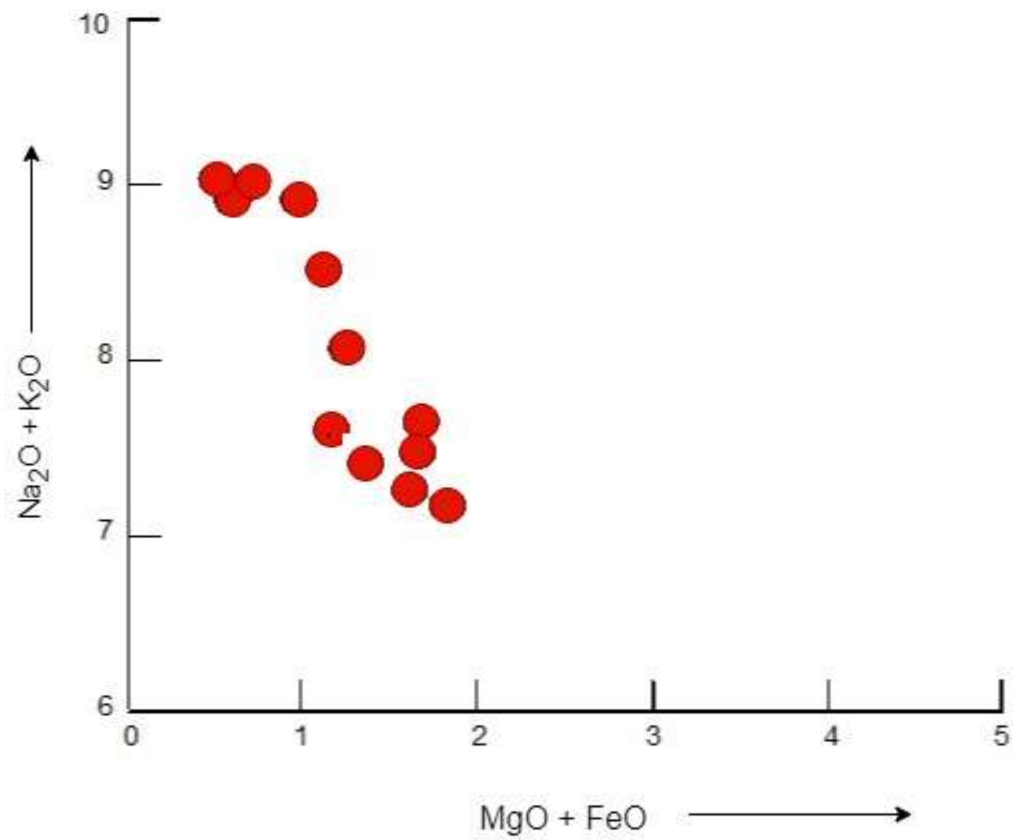

Fig.1 Mafic vs alkali binary plot for Granitic rocks of Lodhma area

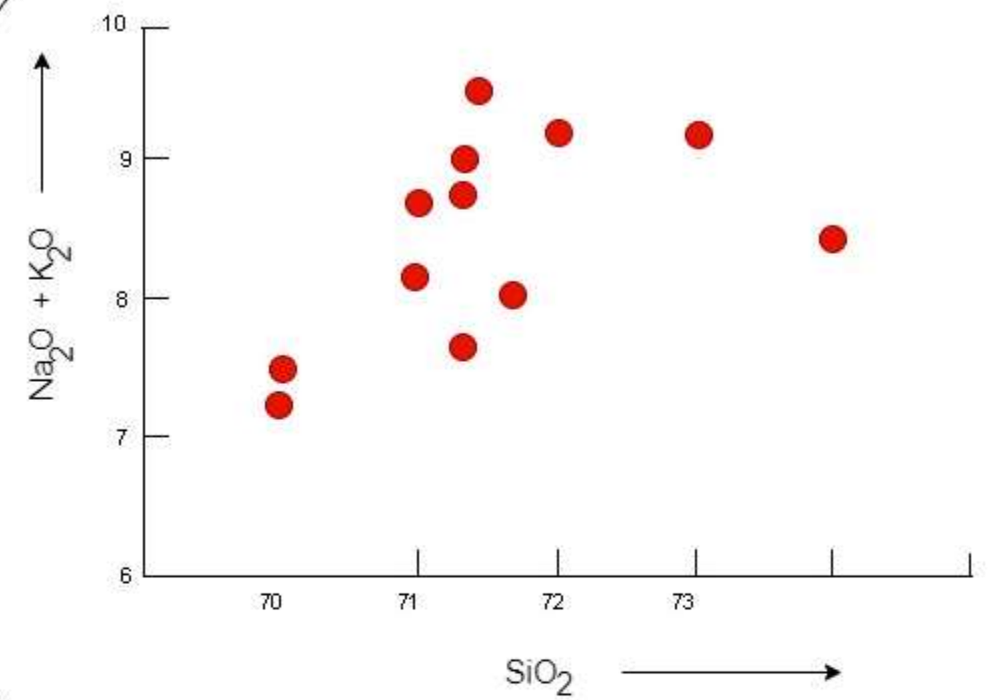

Fig.2 Silica vs Alkalies biaxial diagram of Lodhma Granitic rocks

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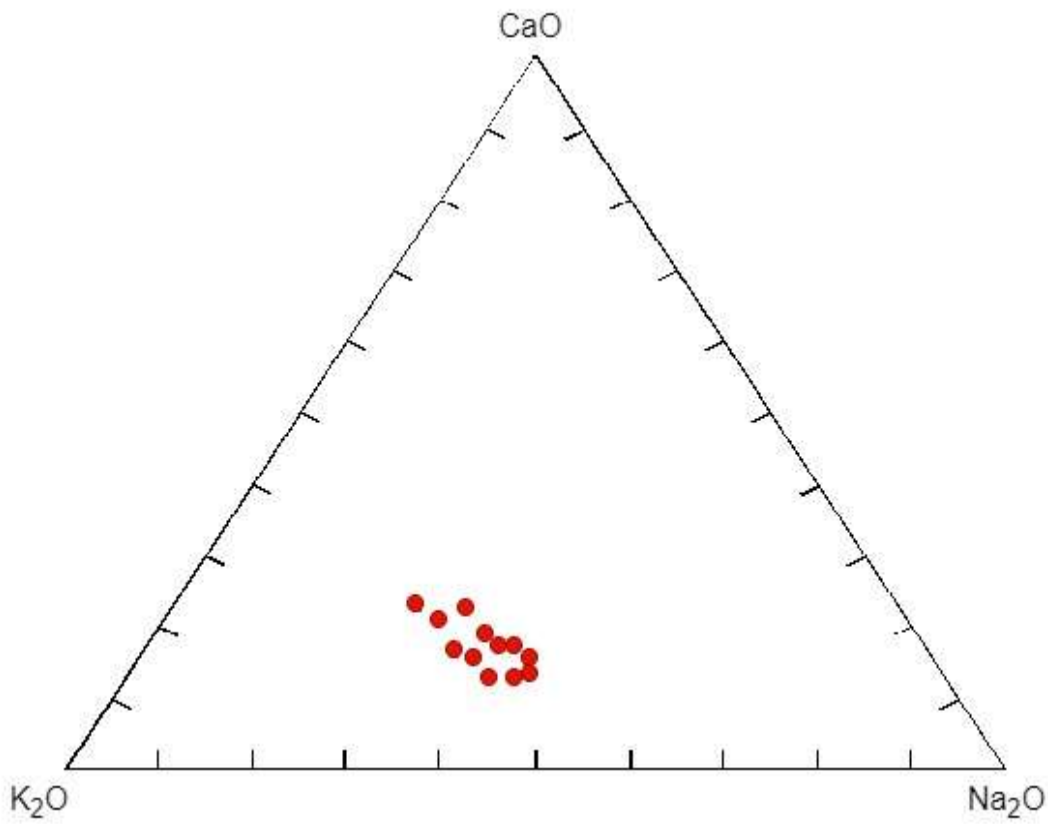

Fig.3 CaO - K_2O - Na_2O diagram for granitic rocks of study area

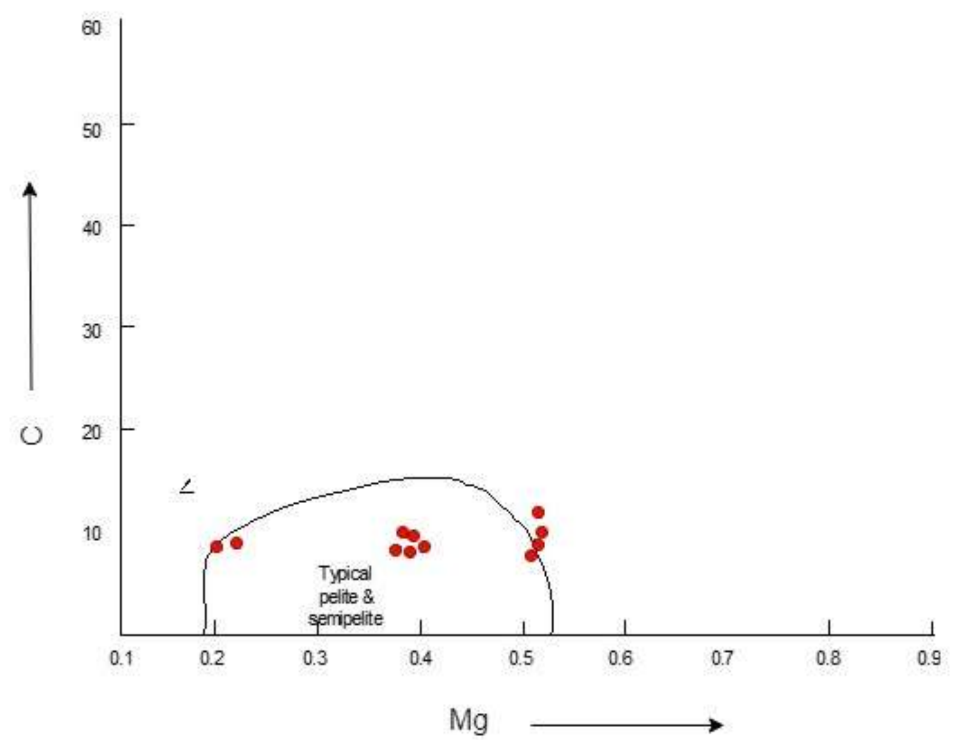

Fig.4 Niggli c-mg plot of Lodhma area showing genetic linkage with meta=pelites(after Leake,1969)

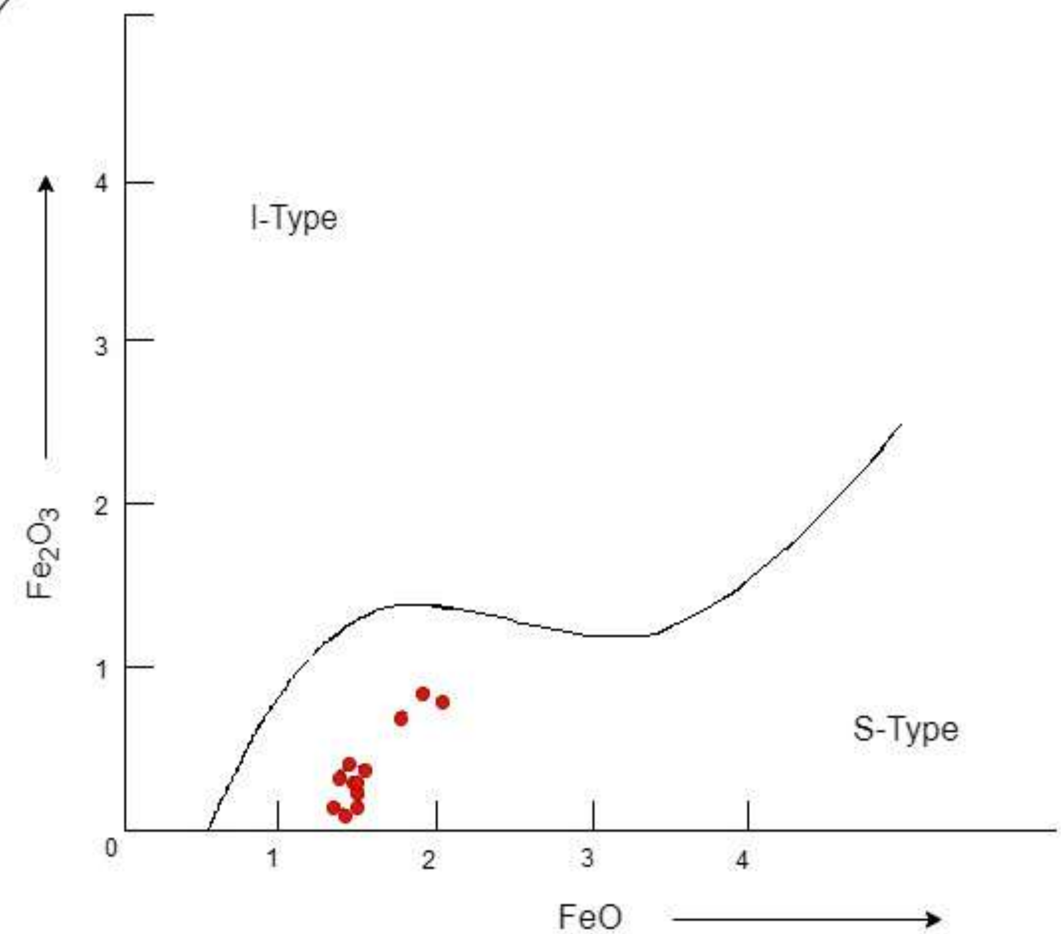

Fig. 5 Biaxial diagram of Fe_2O_3 and FeO of Lodhma Granites for I/S- Type Categorisation

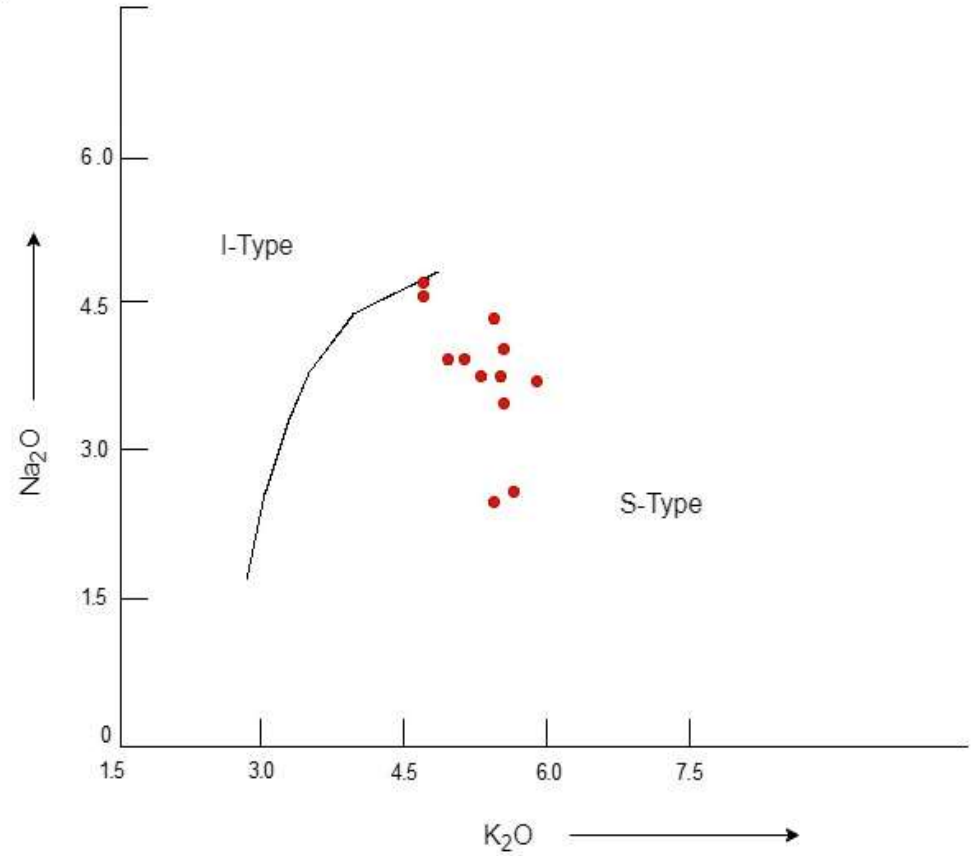

Fig.6 Biaxial diagram of K_2O and Na_2O of Lodhma Granites for I/S-Type Categorisation(after Chappell and White ,1974)