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Geology and Geochemistry of Granites Around Jaswantpura, Jalore District, Southwestern Rajasthan, India

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Abstract

The Neoproterozoic granite plutons around Jaswantpura, western India, form a large complex of granitic rocks and, at least, four distinct granite types, based on cross-cutting relationships, have been found: coarse- to medium-grained biotite granites; medium- to fine-grained two- mica granites; coarse- to medium-grained porphyritic hornblende granites and fine-grained biotite granites with accessory hornblende. Younger acidic and basic dykes cut these granites. The Jaswantpura granites show a narrow range of variation in terms of their chemistry. The hornblende granites are hypersolvus with mild peralkaline character as reflected by the enrichment in incompatible trace elements including Zr, Nb, La and REE but are characterized by relatively low Sr and Al_2O_3. The biotite granites are subsolvus, mildly to moderately peraluminous and are characterized by relatively high SiO_2, Al_2O_3, Rb and low Zr, Nb and REE contents compared to the hornblende granites. The mineralogical and chemical characteristics of the different granite types exposed in the Jaswantpura area point to a continental crust source.

Key words: Granite, Neoproterozoic, geochemistry, petrogenesis, crust.

Introduction

The West Indian craton in Rajasthan has a well-documented magmatic history between 900 to 700 Ma and it is mainly represented by widespread felsic magmatism. The late Proterozoic felsic magmatism commenced with the intrusion of syn-tectonic Erinpura granite/granodiorite and the late orogenic granitoid of Mt. Abu batholith. The culminating phase of magmatism is indicated by anorogenic bimodal volcanism and plutonism of Malani Suite during 750–730 Ma (Bhushan, 1989). The Malani plutonism is represented by Jalore (alkali feldspar granite) and Siwana granite (alkali granite).

A number of granitic plutons occur in western and southwestern Rajasthan, India, whose geochemistry has not been studied in detail. In this study, field setting and chemical variants of one such granitic occurrence exposed around Jaswantpura and Dorra, Jalore district, are given and the possible source for the investigated granites also discussed. Garhia and Ravi (1995) have provided the field observations of the area around Jaswantpura, Jalore district, India, and correlated the granites with the Erinpura and Malani magmatism of Neoproterozoic age, western Rajasthan, India. No geochronological data are presently available for the granites.

Geology and Petrography

The geological map of the Jaswantpura region is shown in figure 1. The area is characterized by the presence of multiple granitic activities and younger dyke swarm of basic and felsic dykes of different generations. Three granite types are noticed and identified as biotite granites, hornblende granites and biotite granites with accessory hornblende. The earliest biotite granites and hornblende granites are characterized by the presence of metasediments and basic enclaves. On the basis of mutual cross-cutting relationships, abutting nature of primary structures and other field and microscopic characteristics, the following magmatic sequence has been proposed for the area (from the oldest to the youngest): (a) Roof

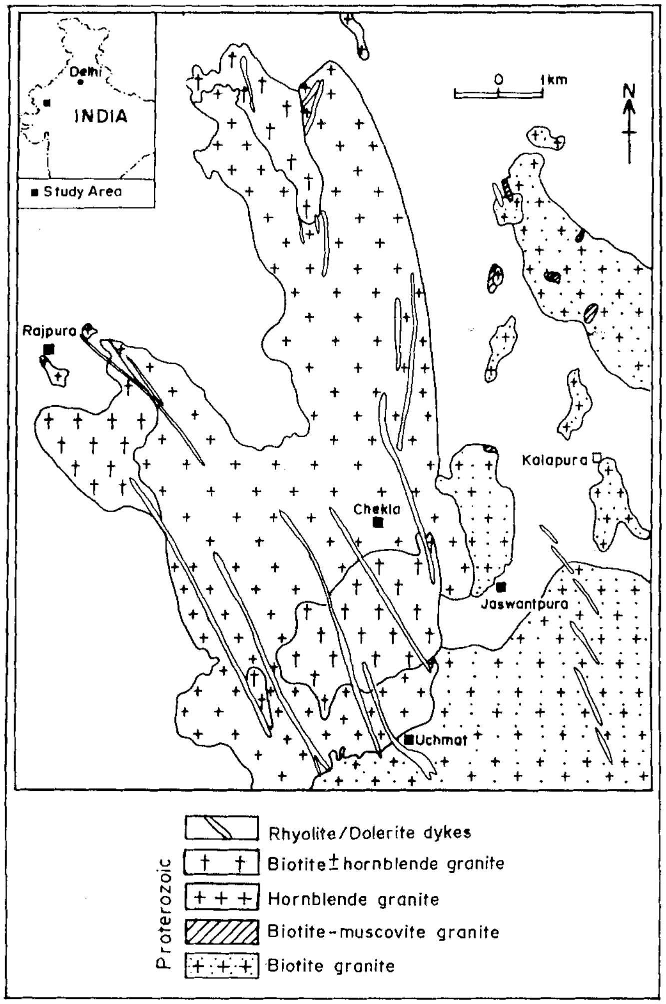

Fig. 1. Geological map of Jaswantpura, Jalore district, Rajasthan, India (modified after Garhia and Ravi, 1995).

pendants of micaceous quartzite, limestone and dolerite dykes/sills; (b) coarse- to medium- grained biotite granites; (c) homophanous two-mica granite; (d) coarse to medium porphyritic hornblende granites, with pegmatites, quartz veins, aplites; (e) fine-grained porphyritic to non-porphyritic biotite and granites with accessory hornblende; (f) dolerite dykes/pegmatites/aplites; (g) rhyolite porphyry/rhyolite dykes and (h) dolerite/basaltic dykes.

The brief details of geology, petrography and mineral probe analyses of the different granites are discussed below.

Biotite Granite

The biotite granites are exposed in the low lying areas and have been classified into two distinct types, on the basis of cross-cutting relationships with each other, the presence of enclaves of older phases in younger granite, and discordant relationship of primary magmatic structures noticed in them. The two granite types are represented by (i) coarse, porphyritic to non-porphyritic ferromagnesian-rich (10–15%) to poor (2–5 %) biotite granites and (ii) fine-to medium-grained, homophanous two-mica granites at places displaying porphyritic texture.

The biotite granites are the most extensively developed rock-type, showing mineralogical and textural variations within short distances, which are abrupt as well as gradational. The coarse porphyritic type is exposed in the Pavti-Golua section and contains enclaves of diorite, micaceous quartzite and basic rocks. The biotite granites consist of quartz, plagioclase, K-feldspar and biotite as major minerals in order of decreasing abundance. The accessory phases are muscovite, sericite, apatite, zircon, rutile and iron oxides. Plagioclase occurs as euhedral, tabular crystals randomly distributed in the coarse- to medium-grained granitic groundmass. The high modal contents of plagioclase in a few samples of these granites indicate their granodioritic affinity. The biotite occurs as flakes and inclusions in feldspar. Most of the biotite flakes have corroded margins.

The younger biotite-muscovite granites are found intruding the earlier ones and have been observed at several locations, viz., SSW and SE of Pavti, SE of Golna. The intrusive nature of this granite into the older biotite granite has been established on the basis of cross-cutting relationships and presence of enclaves of biotite granite. The concentration of enclaves is more near the contact but gradually diminishes towards the central part of the granitic body. Mineralogically the younger biotite-muscovite granites contain quartz, plagioclase, biotite and muscovite in decreasing abundance and zircon, apatite, tourmaline and opaques as accessories. In general, the rock is fine-grained and hypidiomorphic in texture, but at places it also exhibits porphyritic texture, with phenocrysts of feldspar and quartz set in an equigranular, fine-grained granitic mass.

Hornblende Granite

The hornblende granites are exposed in two major hills located to the west of Jaswantpura and Dorra and are quite variable in terms of mineralogical and textural parameters. Mineralogically, the rock is ferromagnesian-rich to poor, whereas texturally it is porphyritic in addition to coarse- to medium-grained. The coarse porphyritic variety is exposed along the peripheral parts of pluton. In general, these granites are grey to pink in colour and characterized by the presence of dark greenish to dark greyish coloured ferromagnesian minerals. They also contain elliptical to elongated enclaves, mostly of diorites or schists with sharp outlines.

The hornblende granites are mainly composed of potash feldspar, quartz, hornblende and a few grains of aegirine and riebeckite (?). Zircon, sphene, rutile and magnetite are found as accessory minerals. Phases potash feldspar is the most abundant mineral constituent and occurs as perthite and microcline. Perthites show variation in texture from braided-vein-platy-flame type and form euhedral laths. In general, the perthites are coarse in texture but meso- to micro-perthites are also noticed as inclusions in the former type, suggesting the presence of two generations of potash feldspar.

Due to extreme shearing and stretching, the main constituent minerals of these granites have been converted into fine aggregates. The porphyroclasts of more resistant minerals occur in a fine-grained quartz-feldspathic matrix. The matrix minerals show the effects of dynamic recrystallization and a strong preferred orientation. Retrograde products such as fine-grained aggregates of epidote and flakes and elongated needles of sericite are common.

Biotite (± Hornblende) Granite

The rocks are texturally fine- to medium-grained and light grey to pink in colour. Its porphyritic types are well developed to the south of Rajpura, whereas the medium- to coarse-grained varieties occur to the west of Dorra. They show intrusive relationships with the earlier biotite granites. In the porphyritic types, rectangular to euhedral phenocrysts of potash feldspar, plagioclase and quartz, randomly oriented, occur in a fine-grained granitic groundmass. At places, rapakivi texture has been noticed, where the pink ovoid shape potash feldspar phenocrysts are mantled by light yellowish to white coloured plagioclase rim.

The biotite granites are mainly composed of quartz, plagioclase, K-feldspar, biotite and hornblende. The accessory minerals include zircon, apatite, sphene and magnetite. Plagioclase (An_{31-37}) forms small euhedral crystals displaying polysynthetic lamellar twinning. The core of the normally zoned grains is highly sericitized. Potash feldspar occurs as euhedral to subhedral laths. In order of abundance it is present as microcline and microperthite.

Younger Dykes

All the granite types described above have been intruded extensively by younger acidic dykes viz., granite porphyries, rhyolite porphyries and rhyolite. On the basis of their cross-cutting relationships and mineralogical parameters, these acidic dykes may represent two generation phases. Granite porphyry dykes constitute the older phase, whereas the other acidic dykes seem to correspond to a more younger phase.

The studied granites have been intruded by many pulses of dolerite dykes as indicated by cross-cutting relationships. The first pulse of basic activity is represented by the NNW-trending doleritic dykes. Numerous enclaves of dolerites are observed in acidic dykes, suggesting the emplacement of dolerite dykes prior to the acidic activity. The second pulse regards the emplacement along the

Table 1. Electron microprobe analyses of the minerals of Jaswantpura granites.

	Feldspar							Biotite					
	Biotite granite				Biotite+hornblende granites			Biotite granites			Biotite+hornblende granites		
SiO_2	68.27	68.75	65.57	63.69	66.69	66.3	60.36	32.88	34.09	32.65	34.04	35.18	36.73
TiO_2	0	0	0.03	0	0	0	0.02	2.45	2.41	2.32	3.32	3.1	2.99
Al_2O_3	20.11	19.59	18.69	18.23	22.52	21.47	19.74	14.01	14.52	14.68	13.84	14.64	12.97
FeO	0.06	0.04	0.05	0	0.1	0.06	0.12	29.53	29.35	31.72	34.74	32.49	33.07
MnO	0	0.01	0.03	0	0	0	0	0.03	0.04	0.09	0.55	0.46	0.51
CaO	0.49	0.29	1.21	0	3.13	2.57	3.16	0.03	0.03	0.03	0.01	0.07	0.02
MgO	0	0	0	0	0	0	0.02	3.07	3.31	2.7	1.02	1.25	0.97
Na_2O	11.87	11.87	11.32	0.43	9.22	9.9	8.48	0.08	0.07	0.05	0.12	0.12	0.05
K_2O	0.09	0.07	0.09	16.49	0.26	0.48	0.33	8.98	9.13	9.13	9.09	8.01	8.48
Total	100.94	100.71	98.47	98.96	101.94	100.79	92.23	95.12	96.98	97.42	100.92	99.45	100.03
Si	11.85	11.95	11.7	11.95	11.48	11.57	11.52	5.52	5.59	5.41	5.51	5.66	5.89
Ti	0	0	0	0	0	0	0	0.31	0.29	0.29	0.4	0.37	0.36
Al	4.11	4.01	4.23	4.03	4.57	4.41	4.44	2.77	2.81	2.87	2.64	2.77	2.45
Fe^{2+}	0.01	0.01	0.01	0	0.01	0.01	0.02	4.15	4.02	4.4	4.71	4.37	4.44
Mn	0	0	0	0	0	0	0	0	0.01	0.01	0.07	0.06	0.06
Mg	0	0	0	0	0	0	0.01	0.77	0.81	0.66	0.24	0.3	0.23
Ca	0.09	0.05	0.23	0	0.57	0.48	0.64	0.01	0.01	0.01	0	0.01	0
Na	3.99	4	3.92	0.15	3.08	3.35	3.14	0.03	0.02	0.02	0.04	0.04	0.02
K	0.02	0.02	0.02	3.94	0.05	0.1	0.08	1.93	1.91	1.93	1.88	1.64	1.73
Scat	20.09	20.05	20.13	20.08	19.79	19.94	19.86	19.99	19.86	20.04	19.86	19.55	19.52
O × Num	32	32	32	32	32	32	32	24	24	24	24	24	24

faults which have displaced the first generation of dolerite dykes as well as granite porphyry dykes. Another generation of NE-trending dolerite dykes is found NE of Jaswantpura and West of Dorra.

Microprobe analyses of feldspar and biotite of the different granite types are provided in table 1. The microprobe analyses were carried out using a CAMECA SX50 machine, with a beam current of 20 μA and an acceleration potential of 15 kv. Counting time was 5 seconds and routine corrections were done using a ZAF program. The phenocrysts of alkali feldspar and plagioclase feldspar are observed. Some phenocrysts show compositional zoning which was also observed under the microscope. The alkali feldspars are Or-rich (X_{Or}= 0.97 with X_{Ab}= 0.03) and plagioclase are albitic in composition. The extreme composition of the feldspar pairs seem to have been acquired from the melt rather than from a post-magmatic process. In the biotite discrimination diagrams of Abdel-Fattah and Abdel Rahman, 1994) not shown here, the biotite composition of the studied granites plots into the alkaline or along the border between the alkaline and peraluminous fields.

Geochemistry

Selected samples of granites from different parts of the studied plutons around Jaswantpura and Dorra, Jalore district, have been analysed for geochemical variants. Major and trace element analyses were carried out on a RIX-3000 Rigaku XRF unit on fused pellets at the NEG-LABISE, UFPE, Recife, Brazil. REE analyses were performed by ICP at Geosol, Belo Horizonte, Brazil, and the results are provided in tables 2 and 3.

The granites show a narrow range of variation in terms of their chemistry. The biotite granites are enriched in SiO_2, MgO, FeO and CaO, with a few of these samples pointing to granodioritic composition. The hornblende granites have higher alkalis, Zr, Nb and Ba contents compared to the biotite granites and are mostly plotted into the metaluminous field of Maniar and Piccoli (1989, figure not provided). The hornblende granites are significantly enriched in incompatible trace elements including Zr, Nb and La but are characterized by relatively low Rb, Sr and Al_2O_3. In the Zr/TiO_2 vs. SiO_2 plot (Winchester and Floyd, 1977; Fig. 2), they fall dominantly in the commendite/pantellerite field. The Zr/TiO_2 vs. SiO_2 plot is commonly applied for the classification of volcanic rocks. However, in the present study it is used to indicate the mildly peralkaline character of the hornblende granites, as reflected by the high Zr content, also a characteristic feature of commendite/pantellerites. The biotite granites with accessory hornblende are however, characterised by relatively high SiO_2, Al_2O_3, Rb and low Zr, Nb contents compared to the hornblende granites.

Alumina saturation with respect to alkalis and lime is one of the most important factors recognized since long and has been most extensively used by many workers (e.g., Zen, 1986; Chappell and White, 1974, 1984, 1992) for genetic classification. The alumina saturation index (ASI = molar $Al_2O_3/Na_2O + K_2O + CaO$) for the biotite granites ranges between 1 and 1.27. As a result, these rocks are weakly to moderately peraluminous and may

Table 2. Major and trace element composition of granites from Jaswantpura, Jalore district, southwestern Rajasthan, India.

Sample No.	1	2	3	4	6	8	9	10	11	13	14	15	16	17
Major elements (wt. %)														
SiO_2	69.3	67.93	71.28	66.95	71.19	77.09	72.82	69.73	67.25	70.69	72.6	74.54	74.72	74.12
TiO_2	0.24	0.43	0.32	0.35	0.23	0.05	0.3	0.36	0.39	0.03	0.2	0.18	0.12	0.16
Al_2O_3	14.1	13.72	12.34	14.23	12.79	12.76	13.1	14.06	13.36	14.96	12.9	13.32	13.2	13.37
MgO	0.37	0.27	0.21	0.34	0.23	0.22	0.35	0.25	0.23	0.21	0.28	0.25	0.23	0.24
MnO	0.05	0.2	0.14	0.13	0.08	0.01	0.04	0.15	0.16	0.15	0.04	0.03	0.02	0.05
CaO	0.98	1.68	1.17	1.83	0.74	0.35	1.13	1.35	1.62	0.36	1	0.91	0.72	0.95
Na_2O	4.3	4.16	5.01	3.88	3.85	4.45	3.07	4.3	4.13	3.28	3.3	3.32	3.56	3.87
K_2O	4.7	4.78	3	4.67	4.95	3.89	5.59	5.24	4.94	7.02	5.5	5.33	5.08	4.83
P_2O_5	0.07	0.06	0.04	0.05	0.02	0.01	0.06	0.05	0.06	0.02	0.03	0.03	0.02	0.03
Fe_2O_3(t)	3.5	6.59	5.13	6.44	3.2	0.95	3.12	5.26	5.88	1.66	2.3	1.9	2.05	2.21
Total	97.61	99.82	98.64	98.87	97.28	99.78	99.58	100.75	98.02	98.38	98.15	99.81	99.72	99.83
A/CNK	1.015	0.912	0.903	0.959	0.977	1.05	0.992	0.926	0.885	1.065	0.984	1.031	1.04	1.008
Trace elements (ppm)														
Cr	50	251	239	202	120	132	219	241	213	150	50	137	385	249
Ni	n.d	12	20	14	21	26	24	26	17	22	n.d	14	19	15
Ba	n.d	472	313	413	233	62	500	493	478	148	n.d	301	105	578
Rb	117	118	113	111	167	138	232	129	146	1393	333	344	466	224
Sr	38	63	43	48	13	10	77	48	45	10	45	53	10	51
Zr	694	1175	1071	1277	649	107	415	955	1343	32	417	355	266	445
Nb	35	61	52	51	44	11	24	51	59	26	28	21	32	26

Table 2. *Contd.*

Sample No.	18	20	21	22	23	24	25	26	27	28	29	30	31
SiO_2	69.02	76.82	71.52	74.94	67.8	77.62	64.2	67.46	71.22	74.67	66.9	73.37	70.07
TiO_2	0.5	0.07	0.12	0.12	0.54	0.06	0.73	0.47	0.5	0.05	0.7	0.1	0.27
Al_2O_3	14.04	13.19	11.68	13.08	14.1	13.07	16.2	14.96	14.23	15.1	14.77	15.07	14.35
MgO	0.77	0.2	0.31	0.39	0.76	0.23	0.48	0.78	1.37	0.27	1.24	0.26	0.21
MnO	0.06	0.01	0.13	0.02	0.07	0.03	0.06	0.07	0.07	0.09	0.09	0.04	0.06
CaO	1.71	0.9	9.4	1.36	1.6	0.74	5.8	1.69	2.42	0.45	2.91	0.58	0.44
Na_2O	2.42	4.18	1.69	2.63	2.2	4.17	2.7	2.51	3.71	4.08	3.13	3.13	3.28
K_2O	5.34	3.86	1.19	4.98	6.3	4.15	4.9	6.07	2.25	4.21	3.07	5.57	6.76
P_2O_5	0.14	0.02	0.05	0.03	0.22	0.01	0.25	0.19	0.1	0.07	0.21	0.16	0.02
Fe_2O_3(t)	4.96	0.57	3.63	1.15	5	0.93	3.8	4.52	4.1	0.97	5.16	0.81	2.3
Total	98.96	99.82	99.72	98.7	98.59	101.01	99.12	98.72	99.97	99.96	98.18	99.09	97.76
A/CNK	1.095	1.04	0.553	1.076	1.053	1.056	0.799	1.097	1.102	1.244	1.066	1.233	1.06
Trace elements (ppm)													
Cr	187	127	163	225	228	118	50	207	109	208	142	180	199
Ni	25	14	20	23	33	12	n.d	15	26	23	20	12	16
Ba	704	109	195	561	878	233	n.d	767	325	57	365	33	1015
Rb	209	141	66	193	253	213	175	291	227	435	181	267	133
Sr	146	37	183	127	126	14	346	121	125	10	131	11	70
Zr	389	124	71	90	535	104	622	489	160	53	355	37	619
Nb	15	11	10	10	24	25	30	21	12	22	14	10	10

Sample No. 1-11–Hornblende granite, 13-20–Biotite+ hornblende granite, 21-27–Biotite granite, 28-31–Two mica granite.

Table 3. REE analyses of Jaswantpura granites.

Sample No.	2	3	15	24	28
La	212	146	50.7	83	2.9
Ce	522	352	127	183	9.5
Nd	267	167	53.6	83	4
Sm	47	24	9	13.5	1
Eu	5	2.57	0.68	1.8	0.01
Gd	37	14.4	7.8	10.5	1
Tb	0	0	0	0	0
Dy	43	10.42	9.61	10.5	1.36
Ho	9.5	2.26	2.01	2.2	0.3
Er	27	5.79	5.64	5.6	0.85
Yb	24	4.28	4.69	4.7	0.9
Lu	3	0.54	0.63	0.6	0.1

2 and 3–Hornblende granite, 15–Biotite + hornblende granite, 24–Biotite granite, 28–Two-mica granite.

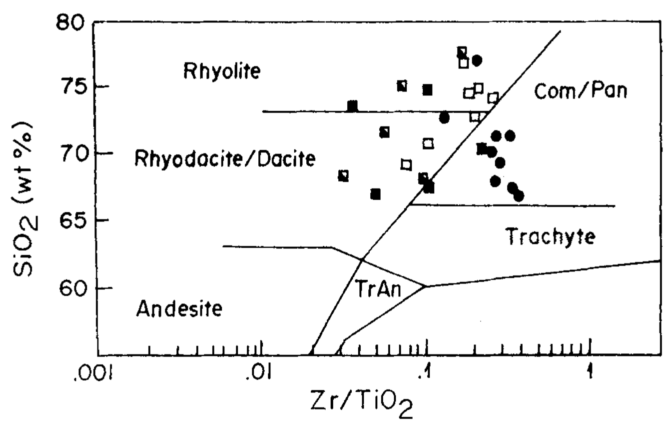

Fig. 2. Zr/TiO_2 vs. SiO_2 plot (Winchester and Floyd, 1977) for magmatic rocks of Jaswantpura. ● Hornblende granite, □ Biotite ± hornblende granite, ■ Biotite-muscovite granite, ◪ Biotite granite. Same symbols have been used in subsequent diagrams.

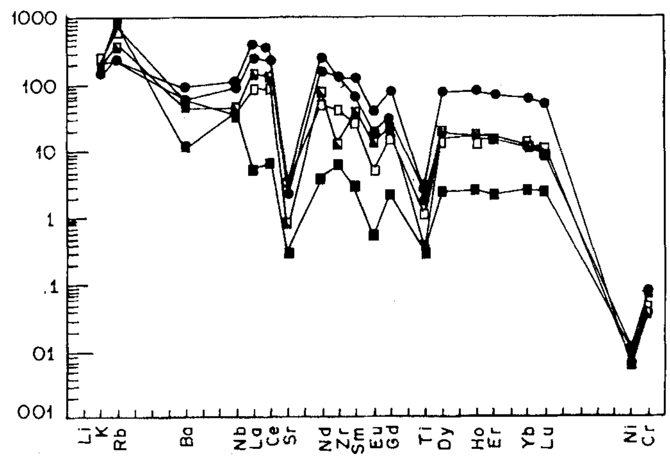

Fig. 3. Primordial mantle-normalized spiderdiagram for Jaswantpura granites (normalizing factors from Wood et al., 1979).

potentially be derived from a sedimentary source. The hornblende granites are characterized by ASI values <1 and fall into the metaluminous field of Maniar and Piccoli (1989).

The multi-element primitive mantle normalized spider diagram (Fig. 3) illustrates that the Jaswantpura granites are enriched in Rb, La and Ce and are strongly depleted in terms of Sr and Ti. Nb shows a mild negative anomaly which is typical of upper crust. Except for a few elements, the trends and level of abundance are remarkably similar to upper crustal averages (Taylor and McLennan, 1985). The chondrite-normalized REE patterns (Fig. 4) reveal that they are LREE enriched and show Eu anomaly. A wide variation in Eu/Eu* suggests feldspar fractionation (Norman et al., 1992). The flat HREE pattern might have

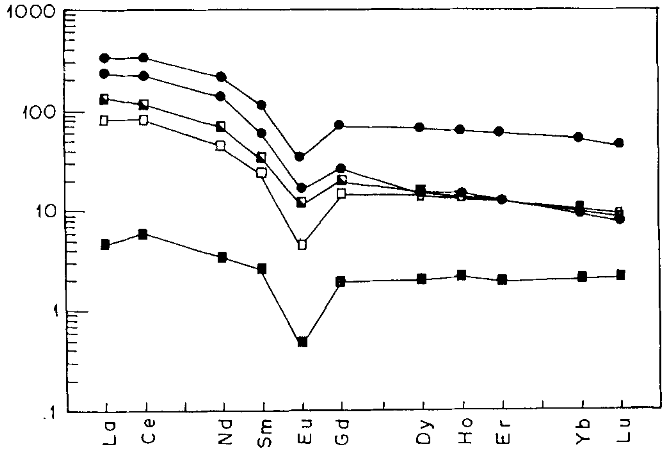

Fig. 4. Chondrite- normalized REE spiderplot for granite from Jaswantpura.

resulted due to the presence of apatite and zircon that are entrapped within large feldspar grain.

Discussion

Primary source and geotectonic setting are intimately related in the process of generation of granitic magma. In the R1-R2 diagram (De la Roche et al., 1980; Fig. 5), the studied granites fall into the late-orogenic and syn-collision fields. Few of the samples however, lie close to the anorogenic field. The presence of low normative corundum and the sub-rounded shape of zircon crystals suggest a possible continental crustal source. Field observations indicate that xenoliths of the two-mica granites are present in the hornblende granites. The fragments of hornblende granites are further found in younger biotite granites. This feature suggests that the two-mica granites and hornblende granites are older than the biotite± hornblende granites.

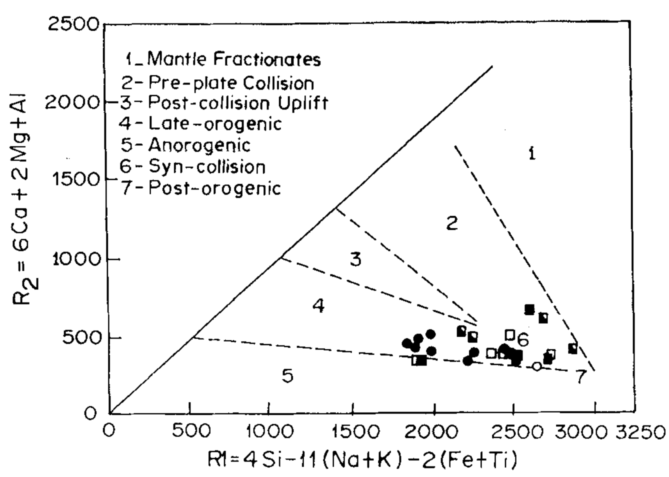

Fig. 5. R1-R2 diagram (De la Roche et al., 1980) for Jaswantpura granites.

The relatively narrow range of major elemental compositions of granites implies that there was not much variation in terms of degree of partial melting of the source. Alternatively, it may represent a minimum melt composition, and P_{H_2O} requirement was made available internally by dehydration or partial melting of hydrous phases, like biotite, muscovite etc., and intergranular water dissolved at grain boundaries (Pichavant et al., 1988 and Pichavant and Montel, 1988). Thus the activity of water (a_{H_2O}) during the melting was gradually increasing (sufficiently high). This is also reflected in the Q-A-P diagram (not provided) applied for the Jaswantpura granites. The high a_{H2O} would also lead to a higher degree of partial melting and less viscous melt that would facilitate easy homogenization resulting in a restricted compositional elemental variation. The haplogranitic system under variable a_{H_2O} and pressure predicts that the melting took place initially at deeper levels and subsequently emplaced at a shallower level where elaborate solidification took place under water-saturated conditions.

These granites have higher SiO_2 and total alkali and low normative corundum contents that reflect their moderately to weakly peraluminous nature. The biotite granites have low to moderate ASI, K_2O/Na_2O and slightly high normative corundum, suggesting an S-type affinity. The peraluminous nature of two mica granites of Jaswantpura herald their source from S-type material. Except for muscovite, absence of more peraluminous minerals suggest that they are not strongly peraluminous. It should be noted that according to White et al. (1986) the characterization of granites as S-type solely on the basis of high ASI and high normative corundum is unreliable. They suggest that the presence of cordierite is the most reliable mineralogical indicator of strongly peraluminous composition and, therefore, S-type affinity. The biotite granites representing the Jaswantpura suite do not have any cordierite. The Jaswantpura hornblende granites are metaluminous with no or little normative corundum and low K_2O/Na_2O ratios which are typical of I-type hornblende granites. Moreover, the younger biotite granites have minor hornblende, which according to Chappell and White (1984), never occurs in S-type granite and is diagnostic of I-type granites. Further, the presence of sphene, allanite and zircon is also consistent with the accessory mineralogy of the I-type granitoids (Sawka and Chappell, 1986; Cuney and Friedrich, 1987).

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