

GEOCHEMISTRY: TRACE ELEMENTS

Abundances and ratios of various trace elements have not only been used to determine the parentage of rock types and minerals but, in basaltic rocks, they have especially been widely utilized to reveal characteristics of specific magma types and the results in turn extrapolated to get information about the magma source and lateral inhomogeneity or vertical zoning in trace element chemistry of the mantle. Such studies have also been found to reflect on the behaviour of various minerals involved in the basalt generation during their partial melting and also give information on the nature and amount of partial melting.

Some elements have been used individually for such studies and others in pairs. For instance, on the basis of absolute concentration of Cr, Evans and Leak (1960) established the igneous parentage of striped amphibolites from Connemera, Ireland, and Faust et al. (1956) distinguished serpentines of igneous origin from those derived from metamorphism of limestones and dolomites. Similarly, quartz-normative tholeiites have been shown to have lower Cr content than olivine-normative tholeiites and Cu and V concentration of tholeiites is higher than in alkali basalts (Prinz, 1967). The two similar divalent elements, Ni^{+2} and Co^{+2} , show diverse geochemical behaviour during the fractionation of the basaltic magma. Ni goes to the structure of early olivine and orthopyroxene and is rapidly

depleted whereas Co, also fractionated by olivine and pyroxene, shows a gradual decrease. The Ni/Co ratio has been found to vary from 2.2 to 7.6 in primary magmas generating at different depths during the partial melting of mantle; values approaching 1 are found in the alkali magmas of ijolite and nepheline-syenite types that are produced by differentiation of primary magmas (Kogarko, 1973). Similarly, Rb/Sr ratio of alkali basalts is lower than tholeiites indicating a high pressure origin of the former (Prinz, 1967). Roe (1964) suggested that the initial-abundance variation of Sr in basaltic rocks is related to the Rb/Sr ratio of differing depths in the upper mantle; accurate measurements of Rb/Sr ratio may be used to determine the depth of magma generation. Trace elements have also been used to determine the tectonic setting of the lava eruption (Pearce and Cann, 1971, 1973; Winchester and Floyd, 1975). However, the use of trace elements for such types of studies, especially on volcanic rocks of older geological ages, is strongly limited by the alteration of these rocks. *Not M...*

Studies on chemical changes during various types of alteration processes, such as epidotization, chloritization, carbonization, ocean floor weathering, and green-schist facies metamorphism of basaltic rocks, have been done by many workers (e.g., Melson and Van Andel, 1966; Cann, 1969, 1970; Hart, 1970; Condie, 1977). Cann (1970) found that Ti, Zr, Y, and Nb are relatively insensitive to secondary processes.

Cr, from its geochemical behaviour should also be fairly stable (Bloxam and Lewis, 1972). K and Rb are too mobile during alteration processes. Sr, however, can be used with care (Pearce and Cann, 1973). Introduction of alkalis leads to an increase in K/Sr ratio (Condie et al. 1969). In a recent study on the effects of alteration on element distribution in Archaean tholeiites, Condie (1977) found that upto about 10% carbonization and 60% epidotization of tholeiite, the interpretation of trace element models for magma generation are not appreciably affected.

Since the Panjal Traps have not suffered carbonization (carbonates are very rarely observed in these rocks) and epidotization is far too less than 60%, it can reasonably be argued that the trace element data on these rocks may represent fairly primary nature. However, the concentration of trace elements affected by the alkali enrichment may be anomalous as the Panjal Traps show evidence of alkali metasomatism presumably by the liquids from nearby exposed granitic intrusion.

In the preceding chapters it was suggested that the Panjal Traps are tholeiite basalts, relatively less basic in character, and have been subjected to alkali metasomatism after their solidification. To substantiate this inference and also to determine tectonic setting of lava eruption, trace element analysis of these rocks was carried out. The trace elements

TABLE IV
Trace element composition of the Panjal Traps. (Values given in ppm)

Flow No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Mg	20	23	62	56	38	22	35	30	42	60	19	27	29	24	33	7	15
Co	8	5	12	18	12	18	17	10	10	25	25	20	13	19	15	17	3
Cr	45	52	75	71	70	75	95	95	70	63	65	58	60	70	49	53	42
Cu	264	280	245	222	238	100	203	196	116	177	310	180	165	170	274	103	180
V	245	283	357	384	395	386	356	355	432	450	358	412	467	378	498	365	480
Y	52	34	41	44	61	59	18	16	71	73	38	38	50	58	38	44	61
Zr	100	73	86	146	106	94	99	132	154	162	139	150	146	125	117	142	164
3a	39	35	26	30	28	25	21	24	22	27	25	30	27	31	24	28	11
3b	6	5	12	12	9	10	13	8	14	18	5	11	6	11	13	7	11
Rb	22	52	46	48	36	61	147	127	133	127	95	126	116	95	146	143	117
Ba	278	320	227	170	255	449	619	585	692	528	647	563	536	566	621	547	2158
Sr	197	201	194	232	221	71	96	117	126	103	142	197	492	235	149	108	556
Y/Rb	8.7	6.8	3.4	3.7	6.8	5.9	3.7	5.7	5.1	4.1	7.6	3.5	8.3	3.3	2.9	6.3	6.1
K/Rb	232	128	153	207	180	24	13	70	118	78	136	79	82	128	69	82	67
K/Ba	24	21	31	58	25	26	19	15	23	19	20	18	18	21	16	21	4
K/Sr	26	33	36	43	29	20	20	76	125	97	91	50	19	52	68	109	14
Ba/Rb	5.5	6.2	4.9	3.5	7.1	7.4	4.2	4.6	5.2	4.2	6.8	4.5	4.2	6.0	4.3	3.8	18.4
Sr/Ba	0.35	0.63	0.85	1.36	0.87	0.16	0.16	0.20	0.18	0.20	0.22	0.35	0.92	0.42	0.24	0.20	0.26
Ca/Sr	473	426	379	320	325	976	728	654	618	781	426	304	119	315	453	548	144

TABLE IV - Continued

Flow No.	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34
Mg	40	35	50	15	5	22	20	47	35	35	16	42	55	25	21	32	88-90
Co	11	19	20	13	12	7	15	26	17	15	58	15	33	40	15	15	40
Cr	94	100	85	49	50	60	60	112	94	72	58	65	52	60	25	68	162-168
Cu	195	266	188	97	90	346	285	195	167	100	184	172	98	187	196	177	119-123
V	422	460	375	345	473	505	360	314	201	336	365	447	260	353	281	380	247
Y	49	44	52	43	55	48	59	36	38	48	31	49	30	46	42	48	28-31
Zr	105	93	108	94	117	97	121	90	79	96	96	106	80	97	85	113	116
3a	25	17	23	19	28	22	36	20	15	25	30	24	20	22	35	26	20
3b	10	12	5	13	9	9	7	5	11	10	10	6	15	8	10	10	19
Rb	60	95	42	44	57	17	44	35	56	27	117	83	32	42	53	76	18-33
Ba	416	433	134	186	439	157	262	274	329	443	490	492	265	182	378	400	303
Sr	190	191	115	163	95	226	125	80	156	146	127	133	66	198	174	173	544
Y/Rb	4.9	3.7	10.4	3.3	6.1	5.3	8.4	7.2	3.5	2.4	3.1	8.1	2.0	5.7	4.2		
K/Rb	156	66	207	258	175	288	126	161	170	363	120	145	391	142	167	167	
K/Ba	22	14	65	61	23	31	21	20	29	22	29	24	47	33	23	23	
K/Sr	49	62	76	70	104	22	44	70	61	67	110	90	190	30	51	51	
Ba/Rb	6.3	4.6	3.2	4.2	7.7	9.2	6.0	7.8	5.9	16.4	1.2	5.9	8.3	4.3	7.1		
Sr/Ba	0.46	0.23	0.86	0.98	0.22	1.44	0.48	0.29	0.47	0.33	0.26	0.27	0.25	1.09	0.46		
Ca/Sr	257	592	700	539	702	279	570	880	456	457	452	536	1052	319	429		

Column 33 shows the average trace element composition of the Panjal Traps.
 Column 34 shows the average trace element composition of basalts.
 Data source for trace elements in column 34 except Nb: Prinz, M. (1967).
 Data source for Nb: Pearce and Cann (1973).

determined were accordingly selected to suit the purpose. The determination of trace elements was made on the same powders that were used for major oxide analyses. However, for trace element analysis, instead of analyzing different samples from a single flow and then deriving an average, as in the case of major oxides, equal portion of samples powders from various locations on a flow were thoroughly mixed in a mixer mill to obtain a representative sample powder of a particular flow for the analysis. In all thirty-two samples, representing equivalent number of flows that were sampled on Mount Kayol, were analysed for Ni, Co, Cr, Cu, V, Zr, Y, Nb, Ga, Ba, and Sr.

Table IV shows the trace element composition of the Panjal Traps. Also included in this Table is the average trace element composition of basalts (column 34) for comparison with the trace element composition of the Panjal Traps. *no meaningful average can be computed*

It is evident from Table IV that Ni, Co, and Sr values of the Panjal Traps are much lower than the average for these elements in the basalts. Cr is also lower than the average for basalts but not to the extent of Ni, Co, or Sr. Zr, Cu, and Ba are higher whereas Y is much higher. Rb has exceptionally very high concentration. The elements which shows close similarity are Zr and Ga.

The amount of Ni in the Panjal Traps ranges from 7-56 ppm with a mean value of 32 ppm. Ni in basaltic rocks is mainly

fractionated by olivine and to a lesser extent by early pyroxene (Vogt, 1923; Wager and Mitchell, 1951; Storm and Holland, 1957; Turekian, 1963). Co, which also enters the same minerals as Ni, has a range from 0 - 40 ppm and a mean value of 15 ppm. Since olivine is absent in the Panjal Traps of Lidderwat area, both Ni and Co may then be present in the pyroxene phase of these rocks. The lower values of these elements may suggest that the magma was impoverished in these elements at the time of eruption; same may be true for Cr. Olivine do not incorporate Cr in its structure (Turekian, 1963). It is largely fractionated by early pyroxenes (Wager and Mitchell, 1951; Turekian, 1963; McDougall and Lovering, 1963). Thus, lower Cr content in the Panjal Traps indicate that not only olivine, but some amount of pyroxene may as well have separated from the liquid before its eruption occurred. Such a suggestion goes well with the lower magnesium content and relatively evolved mineral assemblage of these rocks. Ga in basaltic rocks is present in the highest amount in the feldspars, mainly plagioclases (Heier, 1962; Wager and Mitchell, 1951). In plagioclase Ga replaces Al, an increase in Ga content in late plagioclases would be expected (Wager and Mitchell, 1951). However, Prinz (1967) found that Ga increase little with fractionation. The relatively higher values of Ga in Panjal Traps, especially Flow Nos. 1, 2, 24, 28, and 32 which are relatively rich in plagioclase, is consistent with their composition. Zr enters early and middle

pyroxenes (Wager and Mitchell, 1951; Rose and Cornwall, 1957; Wilkinson, 1959) and increases with the fractionation (Rose and Cornwall, 1957; Prinz, 1967). The Zr content of the Panjal Traps ranges from 73 to 164 ppm with an average value of 113 ppm. Zr, in the Panjal Traps is probably largely concentrated in the apatite crystals because this mineral contains considerable amount of Zr (Prinz, 1967). The high content of Y may be explained by its tendency to increase with differentiation; quartz-normative tholeiites contain more Y than early stage olivine-normative tholeiites (Prinz, 1967). Y in the Panjal Traps may be concentrated in apatite crystals since apatite contains 10 times more Y than clinopyroxenes (Wilkinson, 1959). Y is also abundant in magnetite and ilmenite (Rose and Cornwall, 1957).

Wager and Mitchell (1951) found that the amount of Cu that enters olivine, pyroxene, plagioclase and iron ores is less than in the liquid. It, therefore, accumulates in the residual magma till the sulphide phase develops (Ringwood, 1955 a). At this stage Cu gets strongly fractionated and the concentration starts to decline. Plagioclase and iron ores of late fractionation stages contain highest amounts of Cu possibly due to earlier separation of sulphide phase in the middle stage (Prinz, 1967). In the Panjal Traps, Cu content ranges from 90 - 346 ppm with a mean value of 197 ppm. Such high values indicate relatively evolved nature of the magma. The often observed pyrite cubes in the Panjal Traps suggest that

the fractionation of magma had reached the early stage of separation of sulphide phase at the time of eruption.

V mainly goes to the structure of magnetite and to a lesser extent pyroxenes (Prinz, 1967). The concentration of V increases with fractionation in tholeiite magmas whereas it decreases in calc-alkaline rock series (Miyashiro, 1974). The Panjal Traps contain an average of 378 ppm V with a range of 201 - 505 ppm. Such a high value may also suggest differentiated character of the magma.

Nockolds and Allen (1953), Liebenberg (1960), Heier and Taylor (1964), Taubeneck (1965), Gast (1965), and Prinz (1967) found that Rb increases with differentiation of basaltic magma. Rb prefers K-feldspar to plagioclase (Heier, 1962) and both Rb and K being incompatible elements, are enriched in the residual liquid during the fractionation of basic magma. Ba, like Rb, shows a similar behaviour with fractionation but the increase is low (Wager and Mitchell, 1951; Nockolds and Allen, 1953; Wilkinson, 1959; Prinz, 1967). It is mainly concentrated in feldspars, feldspathoids, and to a small extent, in apatite. Cornwall and Rose (1957) found a significant amount of Ba in clinopyroxenes and chlorites. Highly calcic plagioclases (anorthite and bytownite) and highly sodic plagioclase (albite) have considerably less Ba. Oligoclase through labradorite, i.e., plagioclases with high K-content, have high Ba concentration (Heier, 1962) which indicates strong

mutual coherence of these elements.

Wagar and Mitchell (1951) suggested that Sr behaves as an incompatible element until about 60% solidification of basaltic magma and then the concentration decreases. Turekian and Kulp (1956) supported this inference on the evidence of decreasing Ca/Sr ratio in the residual liquid. Butler and Skiba (1962) showed that intermediate plagioclases, which have high K and Ba contents, also have highest Sr contents. This may be due to the substitution of Sr for K as well as for Ca, a pattern similar to Ba. Sen (1960) suggested that this substitution occurs at high temperatures. Prinz (1967) after reviewing the data on Sr in various basaltic mineral phases, suggested that relatively low values of Sr in highly calcic and sodic plagioclases may be related to the availability of Sr in the liquid. Heier and Taylor (1964) noted high Sr values in many alkaline rocks.

In the light of the above inferences of various authors regarding the concentration of Rb, Ba, and Sr in different types of basalts and various mineral phases of basalt, and also their behaviour during fractionation, it may be suggested that, considering tholeiitic lineage, the high contents of Rb (mean = 76 ppm) and Ba (mean = 396 ppm) found in the Panjal Traps are most likely associated with alkali metasomatism of these rocks for which there are ample petrographic and chemical evidence. Liquids from granitic intrusion that have invaded

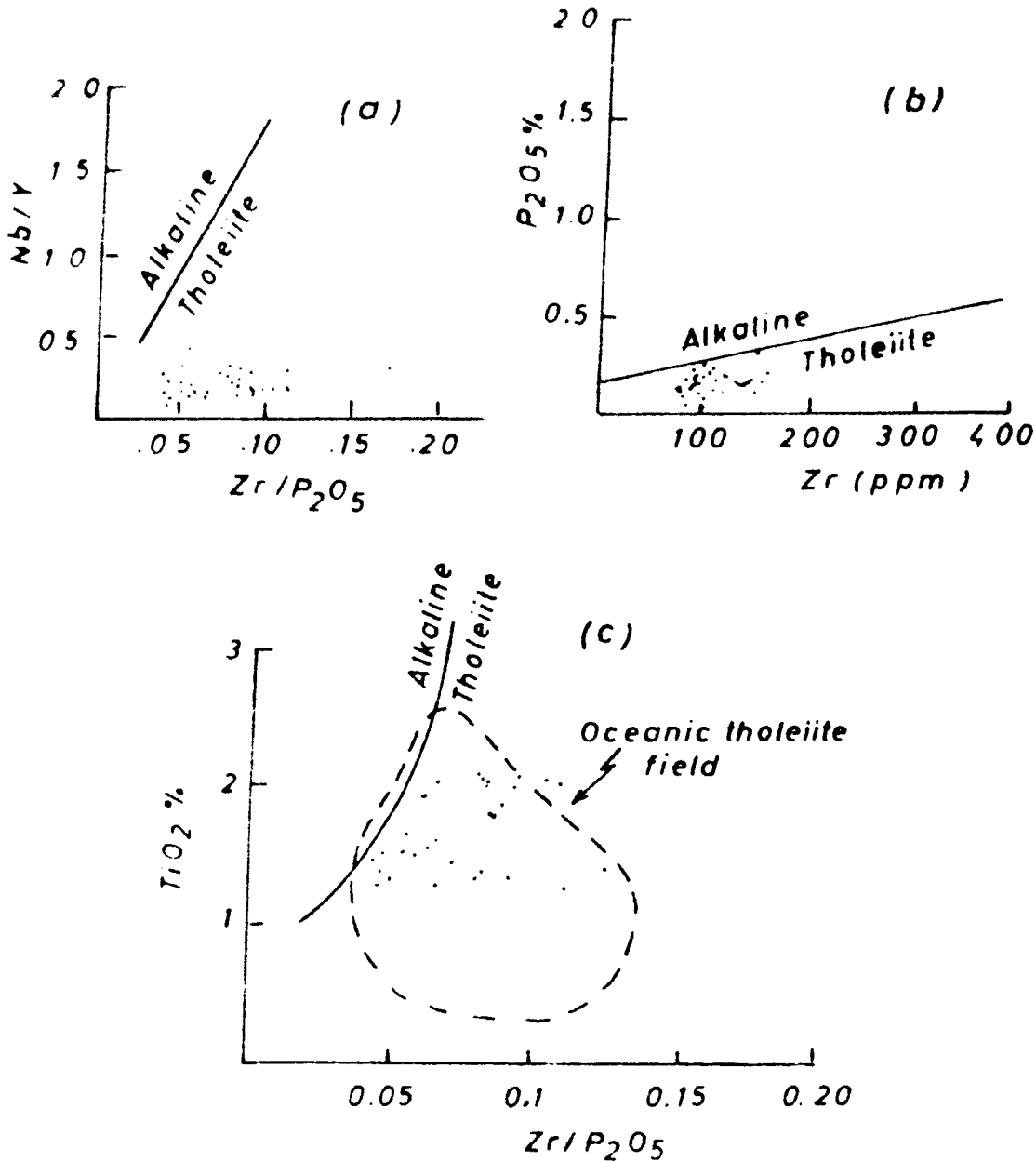


Figure 15 Distribution of the Panjal Traps shown on (a) Nb/Y — Zr/P₂O₅, (b) P₂O₅ — Zr, and (c) TiO₂ — Zr/P₂O₅ diagrams of Winchester and Floyed (1975). The division line in the diagram separates alkali-olivine and tholeiite basalts.

these rocks at a later stage after their solidification may have carried significant amounts of Rb and Ba. Like random enrichment of Na and K, both Rb and Ba have also been concentrated unsystematically since there is no regular pattern in the increase or decrease of these two elements with successive flows from the base to the top of the lava sequence. Further, support to the view that Rb and Ba along with Na and K, have been added from extraneous source is provided by the increase in such ratios as K/Sr and Rb/Sr in these rocks. Sr being much lower than Rb and Ba in the granitic liquids may not have enriched the Panjal Traps (mean Sr = 173 ppm); this explains high K/Sr and Rb/Sr ratios (Table IV).

Nature of Magma

Since Ni, Co, and Cr have been shown to represent depleted concentration in the Panjal Traps due to early separation of olivine and a part of pyroxene, these elements may not give reliable information about the nature of the primary magma of these lava rocks. However, high values of Cu, V, and lower Sr contents suggest that these rocks are tholeiitic. Same is suggested by high Y/Nb ratio which is more than 8 (Table IV).

Winchester and Floyd (1975, 1976) found that the plots of abundances and ratio of Ti, P, Zr, Y, and Nb, known to be chemically stable during alteration and low grade metamorphism, can be used to distinguish tholeiites from alkali basalts. Figure 15 shows the plots of (a) Nb/Y against Zr/P_{2O_5} , (b) P_{2O_5}

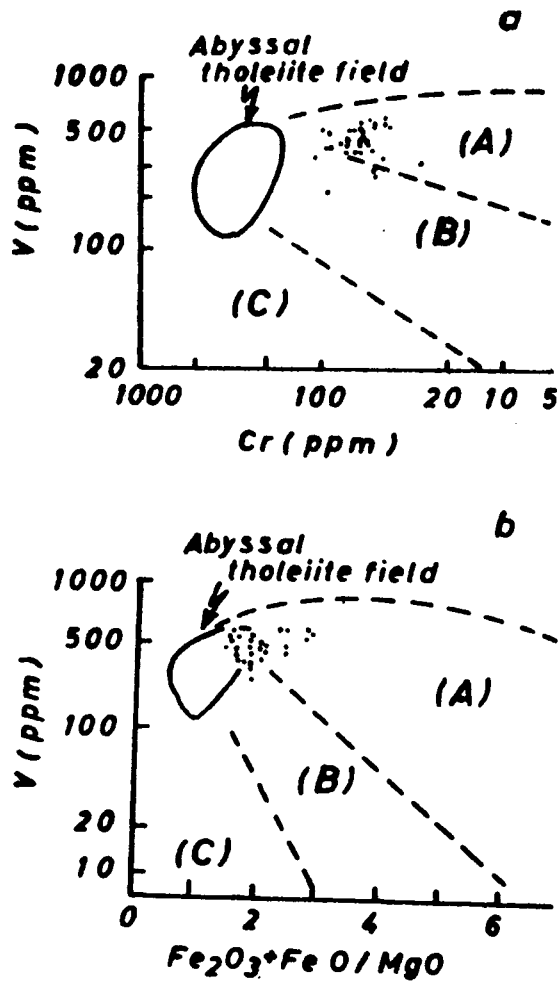


Figure 16. Plots of the V against (a) and V against $Fe_2O_3 + FeO / MgO$ ratio (b) for the Panjal Traps. The boundary lines separate the three regions: (A) calc-alkali, (B) mixed region, and (C) tholeiite as outlined by Miyashiro and Shido (1975). Encircled area shows abyssal tholeiite region.

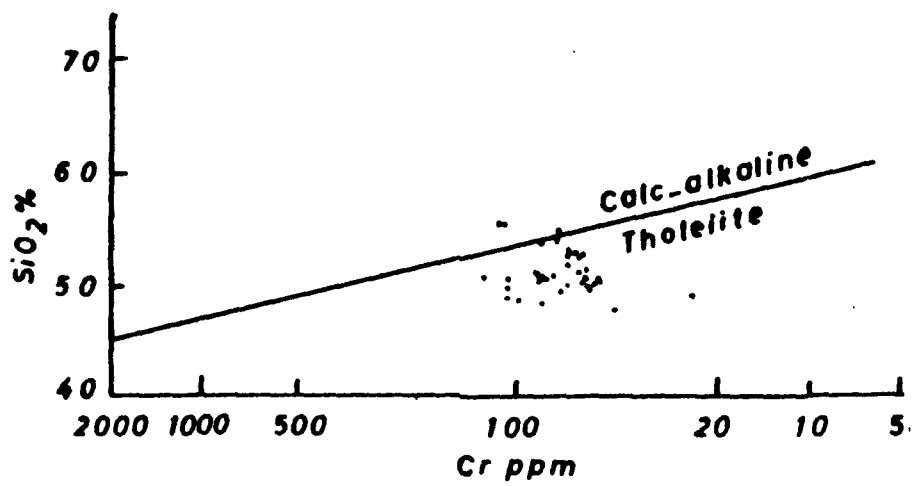


Figure.17 Plots of the Panjal Traps on SiO₂ Versus Cr diagram of Miyashiro and Shido (1975)

against Zr, and (c) TiO_2 against Zr/P_2O_5 for the Panjal Traps. On all these diagrams the Panjal Traps lie distinctly in tholeiitic field.

Miyashiro and Shido (1975) discussed the behaviour of Ti, V, Cr, and Ni during the fractionation of tholeiitic and calc-alkaline series and found that the two rock series can be distinguished by these elements. In tholeiite series V behaves like iron and titanium; it first increases and then, after attaining a maximum, starts to decline. In calc-alkaline series V continues to decrease rapidly with the progress of differentiation. Cr and Ni show almost similar decrease in both tholeiite and calc-alkaline series. However, both Ni and Cr contents of tholeiite series are higher than that of calc-alkaline series.

V - Cr, V - $Fe_2O_3 + FeO/MgO$ and $TiO_2 - Fe_2O_3 + FeO/MgO$ diagrams for the Panjal Traps are plotted on Figure 16a, 16b, and 16 c respectively. In these diagrams the majority of the points fall in tholeiite region (c). Some points that lie in mixed field of tholeiite and calc-alkaline rocks represent rocks with less than 2.5 $Fe_2O_3 + FeO/MgO$ ratio. For this range of $Fe_2O_3 + FeO/MgO$ ratio, the two rock types are indistinguishable on these diagrams (Miyashiro and Shido, 1975). However, in Figure 16b, a trend tending towards an increase is discernible which is a characteristic feature of tholeiitic rocks (Miyashiro and Shido, op.cit.). Distinctive tholeiitic nature of the Panjal Traps is also shown by SiO_2 -Cr diagram in Figure 17.

Table V shows a comparison of Rb, Ba, and Sr values of the Panjal Traps with the tholeiites of various tectonic

TABLE V

Rb, Ba and Sr values of the Panjal Traps compared with these elements in tholeiitic rocks of different tectonic environments and alkali basalts.

	A	B	C	D	E	F
Rb	76	36	5	10	2	51
Ba	400	352	148	100	12	649
Sr	173	428	397	353	125	761

A. Panjal Traps

B. Continental Tholeiites

C. Island Arc Tholeiites

D. Island Tholeiites

E. Submarine (Dredge hauls) Tholeiites

F. Alkali Basalts.

Data source:

Column A: Panjal Traps (Present study). The average value for Ba does not include concentration of Ba in Flow No. 26 because of its too high content.

Columns B to F: Adopted from Condie et al. (1969, Table 3).

environments and alkali basalts. It is seen that Ba content of the Panjal Traps is higher than all the tholeiites but lower than alkali basalts; Rb is much higher than all basalts whereas Sr shows resemblance only with submarine tholeiites. However, Rb and Ba contents of the Panjal Traps may be anomalous as these elements are likely to have been enriched during alkali metasomatism, and hence these elements may not be useful in deciphering the nature of the magma. These rocks show significantly higher Ca/Sr, Rb/Sr, and K/Sr ratios than the continental tholeiites.

Table V shows that the Panjal Traps are low in Sr values when compared to continental tholeiites. Similar low Sr values are observed in Jurassic tholeiites from Antarctic (the Ferrar dolerites) and Tasmania (Heier et al., 1965; Gunn, 1966; Compston et al., 1968) and Wyoming Precambrian diabase dikes (Condie et al., 1969).

Green and Ringwood (1967c) suggested that basalts fractionate along two trends relative to Sr. Condie et al. (1969), based on the available data in the literature and their work on Wyoming diabbases, support the suggestion of Green and Ringwood and designated these two trends as "normal-Sr fractionation trend" which characterise most basalts, and "Sr-depletion fractionation trend" which is characteristic of the Jurassic tholeiites from Antarctica and Tasmania, and Precambrian tholeiites from Wyoming, and also all submarine

tholeiites. Comparison of the average Sr values for the Panjal Traps with other tholeiites (Table V) indicates that the Panjal Traps have Sr-depleted nature. Condie et al. (1969), who noted the similarity between Sr-depleted continental tholeiites and submarine tholeiites, suggested that the coincidence of the trends may indicate a genetic relationship between the two.

Green and Ringwood (1967c) accounted for the Sr-depleted character of Tasmanian and Antarctic tholeiites by shallow wall rock reaction of these magmas. Compston et al. (1968), on the basis of their study on Sr^{87}/Sr^{86} of these rocks, support the view of Green and Ringwood, Condie et al. (1969), however, pointed out that if shallow wall rock reaction is important to account for the Sr-depletion of Tasmanian and Antarctic tholeiites, it is necessary to account for the absence of Sr-depletion in most tholeiite suites since all tholeiites must fractionate at shallow depths to preserve their tholeiitic character (Green and Ringwood, 1967c; Kushiro, 1968). For significant shallow wall rock reaction, large amounts of heat must be supplied to the surrounding rocks; mass transfer of magma may provide a source for such heat (Gast, 1968). However, Condie et al. (1969) pointed out that chilled contacts of Wyoming diabase dikes do not favour shallow wall rock reaction model to explain Sr-depletion in these rocks.

Condie et al. (1969) invoked extensive plagioclase crystallization from a Ca - Al rich primary tholeiite magma to explain the Sr-depletion of the Wyoming diabases. The Ca - Al rich primary magmas envisage the existence of Ca - Al rich ultramafic source areas in the upper mantle (Condie et al., 1969). They noted the apparant convergence of the normal-Sr and Sr-depletion trends at low K which implies that the primary Ca - Al rich magmas possess similar Sr distribution to those of "normal" primary tholeiite magmas. They accounted this by the recent partition coefficient estimates of Gast (1968) and Stueber (1968). The data of Gast and Stueber indicate that although K, Rb, Ba and Sr are concentrated in clinopyroxenes relative to orthopyroxenes and olivine, these minerals do not appreciably fractionate K, Rb, Ba and Sr; hence, it should be possible to have approximately the same initial K/Sr and Rb/Sr ratios in the upper mantle source area that is clinopyroxene rich (Ca - Al rich) as in the one that is clinopyroxene poor.

Condie et al. (1969) suggested that more than 75% plagioclase must crystallize to produce noted K/Sr and Rb/Sr ratios in the Wyoming diabases. They opined that analysis of some of the Wyoming diabase dikes (leopard-reck dikes), containing as much as 75% large (2 - 5 cm) plagioclase phenocrysts, may offer some support for the model.

The model of plagioclase crystallization at first seems to offer a convincing explanation for the Sr-depleted character of the Panjal Traps since the lower two flows are porphyritic with as large as 1.75 cm plagioclase phenocrysts. Plagioclase is the sole phenocryst phase observed in these lower porphyritic flows. Accepting Condie et al. (1969) model, these lower two flows must show very high concentration of Sr relative to the rest of the flows, But, from Table IV, it is evident that instead of showing high values these two flows have lower Sr contents than many of the other flows in the sequence. This is probably due to the highly calcic ($An_{56}-An_{82}$) composition of the plagioclase phenocrysts which have been shown to incorporate less amount of Sr (Butler and Skiba, 1962). Thus, the extensive plagioclase crystallization model does not seem to explain the Sr-depleted character of the Panjal Traps. Also, the early crystallization of plagioclase in the Panjal Traps may be related to the polybaric evolution of these lava rocks, as discussed earlier, rather than due to an original Ca - Al rich parent magma.

Turekian and Kulp (1956), on the other hand, reported pronounced regional variation of Sr in basaltic rocks which they ascribed to small dispersion of Sr values in most provinces, marked differences in regional averages, lack of covariance of Sr and Ca, and lack of magmatic differentiation.

Plagioclase in the basaltic rocks contains most of the Sr, relatively large difference of Sr values in the plagioclase in different provinces indicates a regional variation of Sr in primary magma. Initial-abundance variation of Sr in basaltic rocks is better documented than for any other element (Prinz, 1967).

Thus, it appears that the Sr-depleted character of the Panjal Traps may reasonably be accounted by the Sr-depleted mantle source of these lavas. In view of the critical evaluation and failure of the shallow wall rock reaction model the possible cause for the Sr-depletion of Antarctic and Tasmanian tholeiites may be the original Sr-depleted nature of primary magmas. Also, unless the plagioclase porphyritic Leopard dikes of Wyoming do show higher Sr contents than the analysed non-plagioclase porphyritic rocks of these diabases, initial Sr-depletion model may apply to these rocks as well. If such an explanation proves satisfactory for the Sr-depleted tholeiites of both continental and submarine environments, the occurrence of such tholeiites may offer a direct method of mapping the distribution, both in space and time, of Sr-depleted ultramafic source areas in the upper mantle.