

Magmatic Evolution of the Fresh Basalts from the Ridge Axis near Egaria Fracture Zone, Central Indian Ridge

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Abstract: Fresh Mid-Ocean Ridge Basalts (MORBs) from the Central Indian Ridge (CIR) (20° 12'S; 66°53'E), located north of the Rodriguez Triple Junction (RTJ) are studied for their petrography and bulk composition along with mineral chemistry of plagioclase, olivine and spinels. Melt inclusions from plagioclases and olivines show post-entrapment depletion of oxides with the host mineral. Plagioclases and olivines show gradual changes in the anorthitic and forsteritic content ($An = 89$ to 78 ; $Fo = 90$ to 85) from the basalts under study. These gradual changes in the olivines and plagioclase point to a simple evolution of the basaltic magma by differentiating mineral phases from the parental basalt. The resorption features observed in high forsteritic olivines ($\sim 89,90$) and zoning in the high anorthitic plagioclases ($\sim 90, 94$) in fractionated host basalt indicate that these olivines and the plagioclases are xenocrystic to the host viz., evolved basalts. One basalt sample from a set of the basalts has a near primitive composition ($MgO \sim 9.50\%$) and from this the remaining basalts seem to have fractionated. Major and trace element data reveal low-pressure crystal fractionation in a shallow level magma chamber within the crust.

The chemical data of the basalts under study was run through a computer programme of the least square and mass balance calculations for understanding the evolutionary path by differentiating minerals present in these basalts. The results indicate that the basalts under study represent a set of basalts, with a parental basalt which is near primitive in its composition, and remaining have differentiated from this parental basalts. The chemical data of basalts under study has been compared with two published basalt data sets from the CIR for understanding the possible evolutionary sequences of basalts from CIR.

Keywords: Mid-Ocean Ridge Basalts (MORBs), Central Indian Ridge (CIR), Magmatic processes, Evolution of basalts.

INTRODUCTION

Detailed studies related to the tectonics and structure of the Central Indian Ridge (CIR) have been reported by Parson et al. (1993), Briaies (1995), Chaubey et al. (1990) and Kamesh Raju et al. (1997). However, studies on basalts recovered from this ridge with medium spreading rate (~ 2 cm/yr halfspreading rate, Schlich, 1982) are not many (Dmitriev, 1974; Frey et al. 1980) as compared to the Mid-Atlantic Ridge (MAR) or East Pacific Rise (EPR) basalts. The evolution of basalts along the CIR is, therefore, not well understood. Studies on the basalts from the Indian Ridge (Natland, 1989, 1990a; Price et al. 1986; Fisk et al. 1989) and drilling of the ocean crust during Leg 115 of the Ocean Drilling Program (ODP) (Duncan, 1990) has given a thrust to the petrological studies (Fisk and Howard, 1990; Baxter, 1990). Price et al. (1986) reported glass inclusions, from the basalts from a location close to Rodriguez Triple

Junction (RTJ), with primitive chemical composition within a calcic plagioclase phenocryst ($An 89-90$) with high MgO/FeO^* and low TiO_2 . Detailed study by Humler and Whitechurch (1988) on olivines and plagioclases led to two groups of different composition, from a site just north of RTJ. They put forward a two-layered magma reservoir model for the evolution of the Central Indian Ridge (CIR) basalts.

In the present study, MORB samples were collected from single site along the CIR and were studied for their geochemical and mineralogical characteristics. The major element and trace element data from other CIR basalt database of Price et al. (1986) and Humler and Whitechurch (1988) were used for comparative study. The evolutionary sequence of the basalts under study has been worked out through least square and mass balance calculations.

SAMPLING AND ANALYSIS

During the Ocean Research Vessel Sagar Kanya Cruise No. 16, fresh basalts of different macroscopic characters were recovered, from a depth of ~3675 m in the axial valley bounded by the steep scarps, by a chain-bag dredge from the CIR (20°12'S; 66°53'E). The sampling location is on the northern side of the Ridge Axial Discontinuity (RAD) B-1 of the Egaria fracture zone (Parson et al. 1993) with a left lateral movement, which is about 550 km north of RTJ (Fig.1). The basalts are fresh with quenched glassy zone, exhibiting conchoidal fracture of varying thickness. Macroscopically, two types of basalts viz., aphyric and moderately plagioclase phyric basalt, (MPPB; Hekinian, 1982) have been identified on the basis of their macroscopic characters and are summarised in Table 1.

Detailed petrography and microprobe analyses of minerals were carried out on the polished thin sections of basalts. For microprobe analyses, scanning electron microscope (Hitachi make) attached with the KEVEX micro-analyser (at the Earthquake Research Institute, University

of Tokyo, Tokyo), with an accelerating voltage of 15 kV and beam current of 0.8 mA, was used. The whole rock analyses (SiO_2 , TiO_2 , Al_2O_3 , FeO^* , MnO , MgO , CaO , Na_2O and K_2O) of basalts was carried out with X-Ray fluorescence spectrometer by making fused pellets, while compressed powder pellets were prepared for trace element determination. Different rock standards (JB-1 and JP-1) were analysed along with the samples for the accuracy of the results and the error was found to be $\pm 3-5\%$.

Bulk chemical data of CIR basalts from Price et al. (1986) and Humler and Whitechurch (1988) (Fig. 1) were used to compare the geochemical trends of the basalts under study. The computer programme developed by Stormer and Nicholls (1978), which uses the mass balance calculations to carry out different magmatic processes mathematically was used for the present study to understand the petrogenetic evolution of the basalts under study.

PETROGRAPHY AND MINERAL CHEMISTRY

Basalts under study (herein after called as SK basalts)

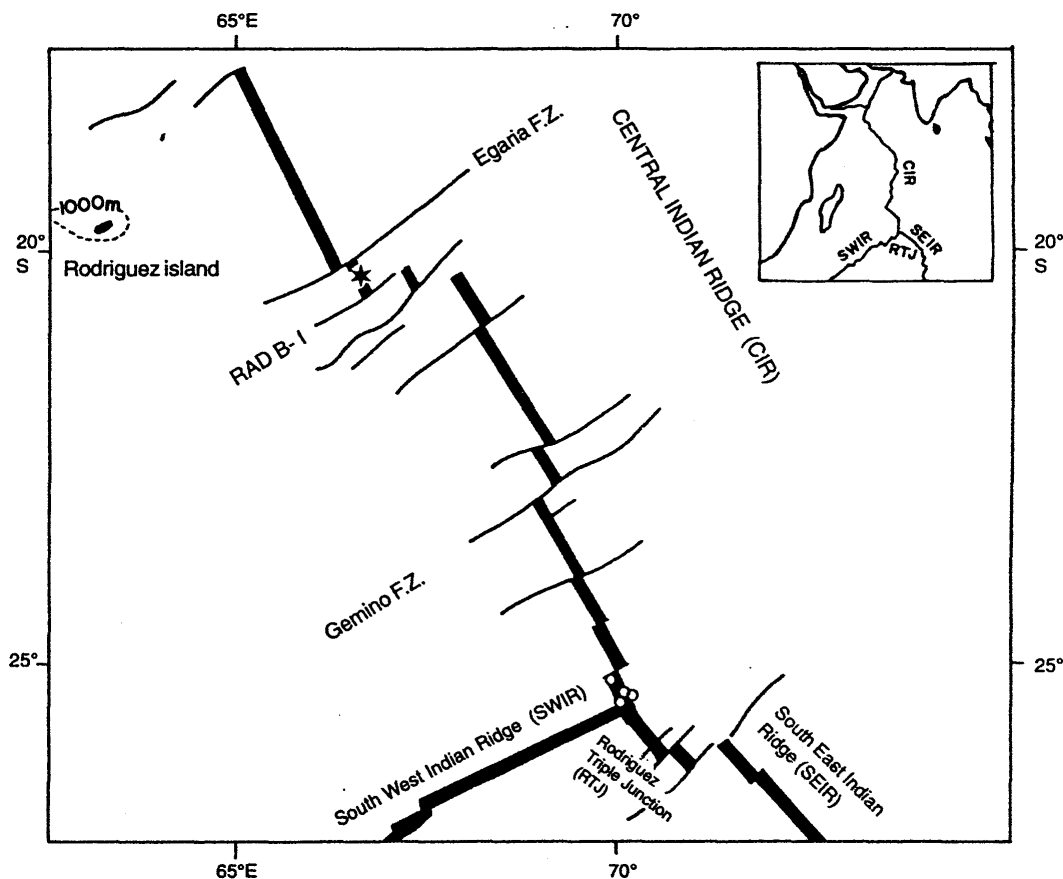


Fig.1. Map showing the present dredge site (*) and (O) sample locations from Price et al. (1986) and Humler and Whitechurch (1988).

Table 1. Description of ridge basalts under study

Sample No.	Phyric / Aphyric	Thickness of glass margin	Other typical characteristics	Remarks
B1	Phyric	~2mm	Plagioclase and olivine	Melt inclusion in both mineral phases
B2	Aphyric	3-4 mm	Thin lava flow like sheet Glass on both side of lava	Flow structure can be seen due to the acicular plagioclase
B3	Aphyric	1-2 mm	Block lava variolitic zone observed	Olivine and plagioclase in microcrysts form
B3A	Aphyric	1-2 mm	Block lava variolitic zone observed	Olivine and plagioclase in microcrysts form
B4	Aphyric	3-4 mm	Within glass zone small crystals of olivine and plagioclase	Modally Glass is main component
B5	Aphyric	4-5mm	Tongue of lava. Glass shows conchoidal fracture	Fine 0.5 mm olivine crystals within the glass. Acicular plagioclase is absent
B7	Aphyric	3-4 mm	Similar to B4	Modally glass is the main

have varying modal composition with plagioclase as the most abundant mineral, while olivine is comparatively less abundant. Glass constitutes the maximum volume percentage (~60 - 70) in all basalts while spinels are present as accessories (< 1 %). Pyroxenes are not present in the basalts under study. Detailed petrography is described below:

Plagioclase

B1 basalt is the only plagioclase phyric basalt among the basalts under study. Plagioclase in basalt B1 (~15 % modal) occurs in different size, from ~1-2 mm to microphenocrysts (> 1mm) to thin acicular laths, while in other basalts, plagioclase occurs mostly as acicular laths. Few plagioclase phenocrysts show resorption features, such as fritted margins, rounding off of the crystalline shapes, etc., which are indicative of corrosion by the host melt. Many plagioclase phenocrysts contain melt/glass inclusions. Plagioclases of varied size, from microcrysts (~200 µm) to phenocrysts are present within the top transparent yellow glass. Microcrysts, within the glass are in early stage of crystallisation.

CaO content in plagioclase laths from B1 basalt varies from 12 to 18%, thereby anorthite content (An content = mole [CaO/CaO+Na₂O]) varies from 65 to 90 (Table 3). These plagioclases are comparatively more common than few plagioclase laths with high An content (90). Plagioclase phenocrysts with low An content (70-80) are comparatively more in this basalt (B1). Some large plagioclase laths exhibit

zoning on a minor scale with An content varying from 84 at core and 81 at rim which indicates the change in the composition of the host melt from less evolved to more evolved melt. The presence of the high and low anorthitic plagioclase in the same basalt indicates the ephemeral magma chambers (Nisbet and Fowler, 1978) beneath CIR and the high anorthitic plagioclase might have crystallised from the primitive basaltic melt and got attached to the magma chamber walls which were later scrapped by the ascending magma.

Acicular plagioclase laths show flow texture and form hetero-cumulate texture with olivine in basalts B3 and B3A. Plagioclases from samples B2, B3, B3A and B4 have uniformly low An content (68-78) with a maximum anorthitic content about 80 (Table 3) as compared to the B1 basalt. High anorthitic plagioclases are distinctly absent in these basalts.

Olivines

In B1 basalt, olivines occur in comparatively high modal percentage (~10%) than other basalts under study and are found in two forms: as phenocrysts (> 1 mm) and microcrysts (<1 mm). Olivine phenocrysts have forsterite content (Fo content = mole [MgO/(MgO+FeO*)]) varying from 88 to 89 (Table 2) while the Fo content of microcrysts is from 86 to 87. However, few microcrysts have still low forsterite content (85). In glomerophyric hetero-cumulate clots, globular olivine has low Fo (86). Melt inclusions are rarely observed in olivine phenocrysts.

Table 2. Major and trace element composition of SK Basalts

	B1	B2	B3	B3A	B4	B5	B7
SiO ₂	48.93	48.06	49.12	48.75	48.53	48.47	48.43
TiO ₂	0.97	1.06	1.21	1.22	1.07	1.07	1.07
Al ₂ O ₃	16.63	16.39	16.29	16.18	16.46	16.40	16.42
FeO*	8.62	9.85	9.26	9.37	9.47	9.72	9.88
MnO	0.13	0.15	0.14	0.15	0.10	0.15	0.15
MgO	8.18	9.43	8.74	8.71	9.46	9.52	9.45
CaO	12.71	11.39	11.70	11.69	11.48	11.45	11.44
Na ₂ O	2.07	2.58	2.79	2.73	2.61	2.58	2.63
K ₂ O	0.09	0.08	0.09	0.08	0.08	0.08	0.09
P ₂ O ₅	0.08	0.07	0.09	0.08	0.07	0.07	0.07
Total	98.41	99.06	99.43	98.96	99.33	99.51	99.63
Y	24	27	29	30	28	28	28
Zr	56	61	74	75	63	62	62
V	245	231	249	244	233	238	231
Cr	529	443	405	400	450	456	442
Ni	166	253	183	182	247	251	255
Cu	71	94	87	87	93	94	94

FeO* = Total iron is same in all tables

Other basalts (B2, B3, B3A & B4) have olivines with low forsterite content ranging between 85-86. Rarely some olivines show little higher Fo of about 87 (Table 2). However, small (< 1 mm) euhedral olivine crystals (~ 5 modal %) present in a aphyric basalt B5, have olivines with high forsterite content (90) (Table 2) indicative of a primary nature of the magma (Fujii and Bougault, 1983). In this basalt (B5), olivine is the only mineral phase that is observed apart from glass. These olivines are of uniform size and are little larger than microcrysts (0.5 mm).

Phenocrysts of olivine with Fo 88-89 exhibit resorption features, such as rounding off of the crystalline edges and embayment of the glass. The resorption features that are seen on these olivines demonstrate that corrosion features are due to the refractory nature (high Fo = 88-89) of olivine

getting corroded by the evolved basaltic melt to develop equilibrium between the crystal and the melt. Equilibrium calculations as per BVSP (1981, Ref. Table 1.4.2.1 on p.413) for the high Fo olivines with the host basalt with partition co-efficient 0.30 for Mg and Fe between olivine and melt (Roeder and Emslie, 1970) indicate that such high forsteritic olivines are not in equilibrium with the host basalt (Wilson, 2000). Therefore, these olivines are xenocrystic in nature. As per the calculations, olivines with Fo content of ~ 86 would have been in equilibrium with the B1 basalt.

Spinel

The euhedral octagonal, dark brown to rust red coloured spinels are dispersed in the glassy matrix of plagioclase phytic B1 basalt. These spinels are rich in aluminium (~25 % Al₂O₃) and chromium (34 % Cr₂O₃) and rarely have vermiform glass inclusions. Some residual sulphide minerals in the form of spherules/globules are associated with glass embayments in the olivine phenocrysts. These are observed in B1 basalt only and these globules are rich in iron (~50 % FeO*) and nickel (~15 % NiO), indicating that the melt from which they have formed might be primitive in nature (Natland, 1990b).

Melt Inclusions

Melt inclusions present in olivine are small (10-20 µm) and are circular as compared to inclusions in plagioclase varying from few microns to few tens of microns and are mostly elongated in shape. These melt inclusions are dispersed randomly throughout the plagioclase phenocrysts. Many melt inclusions were analysed from different plagioclases, however, not a single melt inclusion with primitive characteristic was observed in the data set.

Melt inclusions present in the mineral phases are considered as the representatives of the parental / original

Table 3. Representative analyses of plagioclase and olivine from SK basalts

Sample No.	Plagioclase						Olivine						
	B1	B1	B1	B3A	B3A	B4	B1	B2	B3A	B4	B5	B5	
SiO ₂	45.66	49.39	46.58	50.86	50.86	49.79	40.66	40.65	39.76	40.05	41.09	39.36	
TiO ₂	0.10	0.05	0.07	0.02	0.02	0.05	0.01	0.04	0.03	0.05	0.02	0.00	
Al ₂ O ₃	33.98	31.31	32.60	30.58	30.58	30.71	0.01	0.01	0.04	0.21	0.09	0.06	
FeO*	0.37	0.46	0.79	0.62	0.62	0.51	10.89	12.54	12.56	12.53	9.17	10.46	
MnO	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	
MgO	0.05	0.07	0.70	0.23	0.23	0.13	47.98	46.75	46.81	46.84	49.38	48.09	
CaO	18.21	15.93	15.76	14.58	14.58	14.31	0.29	0.33	0.36	0.42	0.24	0.31	
Na ₂ O	1.10	2.78	2.48	3.75	2.75	3.98	0.09	0.03	0.03	0.06	0.33	0.66	
K ₂ O	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.01	0.00	0.00	
An %	90	86	78	81	68	66	Fo %	89	86	87	87	90	89

basaltic melts (Watson, 1976; Donaldson and Brown, 1977) and the composition of these melt inclusions show post-entrapment depletion of selective elements with the host mineral phase (Watson, 1976; Price et al. 1986). Melt inclusions from plagioclase are depleted in Al_2O_3 and CaO and enriched in MgO and FeO* while those within olivine are depleted in MgO and FeO* (Table 4) and enriched in Al_2O_3 and CaO. It is also observed that the composition of melt inclusion varies from core to margin.

Table 4. Representative analyses of melt inclusions

	Inclusions from plagioclase				Inclusions from olivine	
SiO ₂	50.38	51.63	50.54	51.49	50.48	51.13
TiO ₂	1.00	0.56	0.81	1.22	0.82	0.67
Al ₂ O ₃	8.83	13.65	10.42	9.38	16.11	15.85
FeO*	10.02	8.14	9.31	12.08	8.17	8.04
MnO	n.d.	n.d.	n.d.	n.d.	0.00	n.d.
MgO	14.10	10.82	12.73	12.32	6.79	6.46
CaO	11.51	11.10	11.93	12.93	14.47	14.85
Na ₂ O	1.59	3.12	2.34	1.34	1.75	1.88
K ₂ O	0.00	0.03	n.d.	n.d.	0.00	n.d.
Total	97.43	99.05	98.08	100.76	98.59	98.88

n.d. = not determined.

BULK GEOCHEMISTRY

The SK basalt compositional data was plotted in MgO variation plots (Fig. 2) along with other two chemical data sets of CIR basalts from Price et al. (1986) and Humler and Whitechurch (1988).

Major Elements

In general, the trends observed in the bulk chemical data are: as MgO increases SiO₂ and CaO decreases (Fig. 2a, b, e & f) while FeO* shows increasing trend (Fig. 2d). B1 basalt has higher concentration of Al_2O_3 than the other samples (Table 2) probably due to the higher abundance of plagioclase phenocrysts in this basalt. Other CIR data of Price et al. (1986) and Humler and Whitechurch (1988) show similar abundances like high MgO, low TiO₂.

The bulk chemical composition of SK basalts show that they are enriched in MgO% and are depleted in SiO₂ and Na₂O as compared to the basalts from other two data sets (Figs. 2a and f)- These characteristics are typical of the less differentiated or less evolved basaltic melt. The variation plots of the oxides show a linear trend for SK basalts, except for B1 basalt, which has plagioclase cumulates (Shibata, 1976; Dungan and Rhodes, 1978) and therefore has high Al_2O_3 (16.63%), CaO (12.7%), K₂O (0.093%) and low MgO

(8.18%), FeO* (8.62%) and TiO₂ (0.97%) (Table 2). Basalt B5 is the most primitive amongst the present set of samples as it has highest MgO content (9.52%) (Table 2). However, the total FeO* content in the SK basalts is higher (~9%) as compared to normal MORB (BVSP, 1981). This higher concentration of the FeO* is also indicative of the evolution or fractionation of the SK basalts from the parental basaltic melt.

Effects of the magmatic processes on the chemical composition of these basalts can be observed in terms of Mg # [$100 * (\text{mole MgO}) / (\text{mole MgO} + \text{FeO}^*)$] and CaO/ Al_2O_3 (Stakes et al. 1984) and in the plot of CaO/ Al_2O_3 against TiO₂. Mg # decreases during the fractionation of Fe-Mg mineral phase mainly olivines, but remains constant during the plagioclase fractionation, while CaO/ Al_2O_3 ratio remains unaffected by olivine fractionation. However, lowering of the CaO/ Al_2O_3 ratio is indicative of the clinopyroxene fractionation. Mg # is almost constant (64.8 to 65.9) while CaO/ Al_2O_3 ratio changes from 0.69 in B5 (parental) to 0.76 in B1 (evolved) indicating the effects of plagioclase fractionation (Dungan and Rhodes, 1978). The basalts studied by Price et al. (1986) and Humler and Whitechurch (1988) show the combined effect of plagioclase and olivine fractionation.

SK basalts exhibit a gradual evolutionary path with B1 basalt as the most evolved basalt with low MgO (~ 8.18%) and high Al_2O_3 (16.63%) and CaO (12.71%) (Table 2). B5 basalt, with high MgO (9.52%) and low TiO₂ (1.07%) (Table 2), is considered as a parental basalt with its composition close to near primary basalt. Other basalts, i.e. B2, B4 and B7 represent the in-between evolutionary stages of differentiation from B5 basalt and together they exhibit a continuous liquid line of basalts evolved (Fig. 2).

Trace Elements

SK basalts are enriched in Cr, Ni and Cu (Table 2) as compared to basalts from the other segments (Price et al. 1986; Humler and Whitechurch, 1988) (Figs. 3a, b and c). In all the plots, data from Price et al. (1986) and Humler and Whitechurch (1988) conforms well with the present data (Fig. 3).

Trace elements Cr, Ni and Cu show positive relation with MgO (Figs. 3a, b and c) while Zr, Y and V have scattered distribution with MgO % (Figs. 3d, e and f). B1 basalt is enriched in Cr (529 ppm), may be due to the high modal content of Cr-rich spinels. These spinels might have fractionated at much later stage than the olivine probably resulting in the enrichment of Cr in basalt B1. The presence of low forsteritic olivines indicates the evolved/differentiated nature of the basaltic melt. Low nickel content

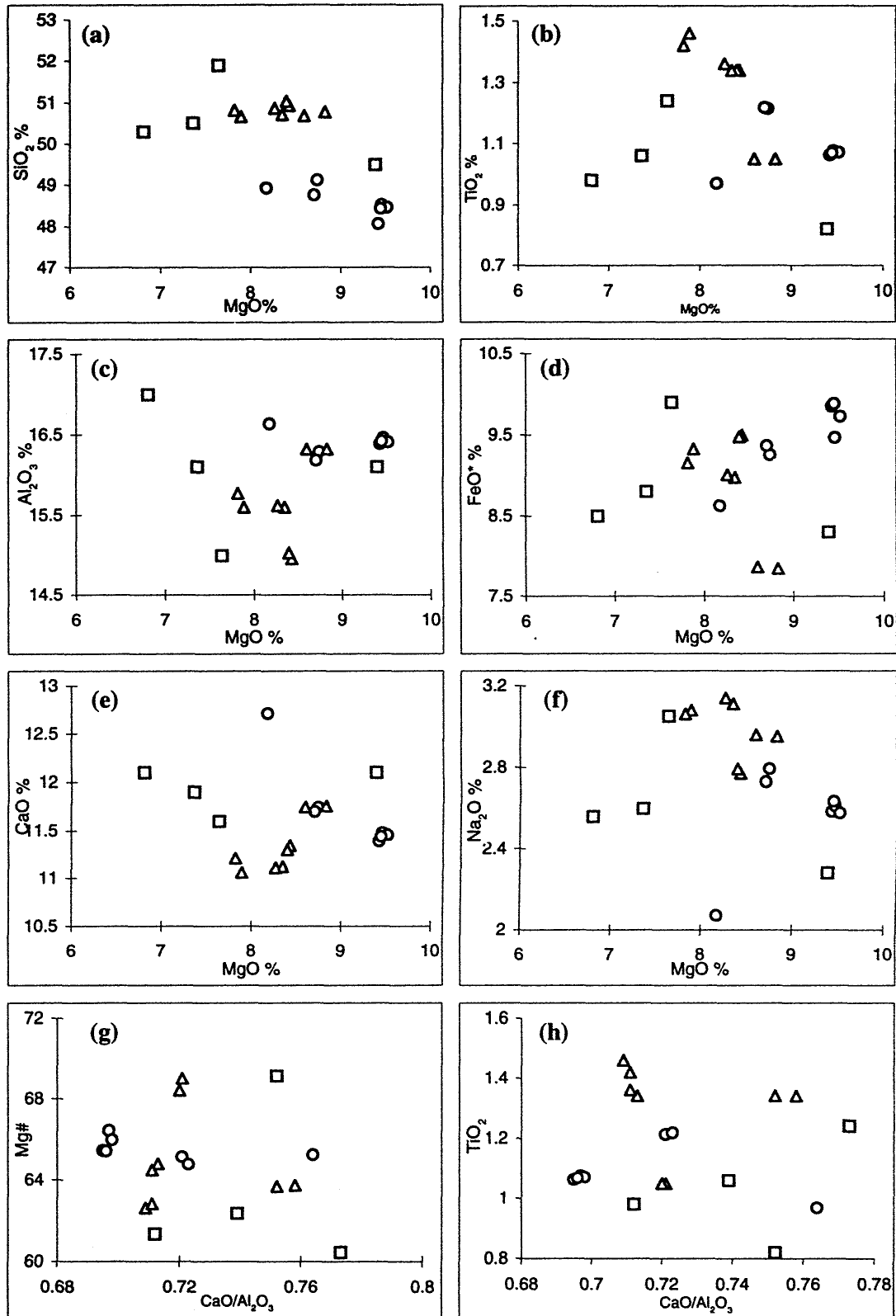


Fig.2. Variation plots of the major element against MgO%. O = present data set, □ = Humler and Whitechurch (1988) and Δ = Price et al. (1986).

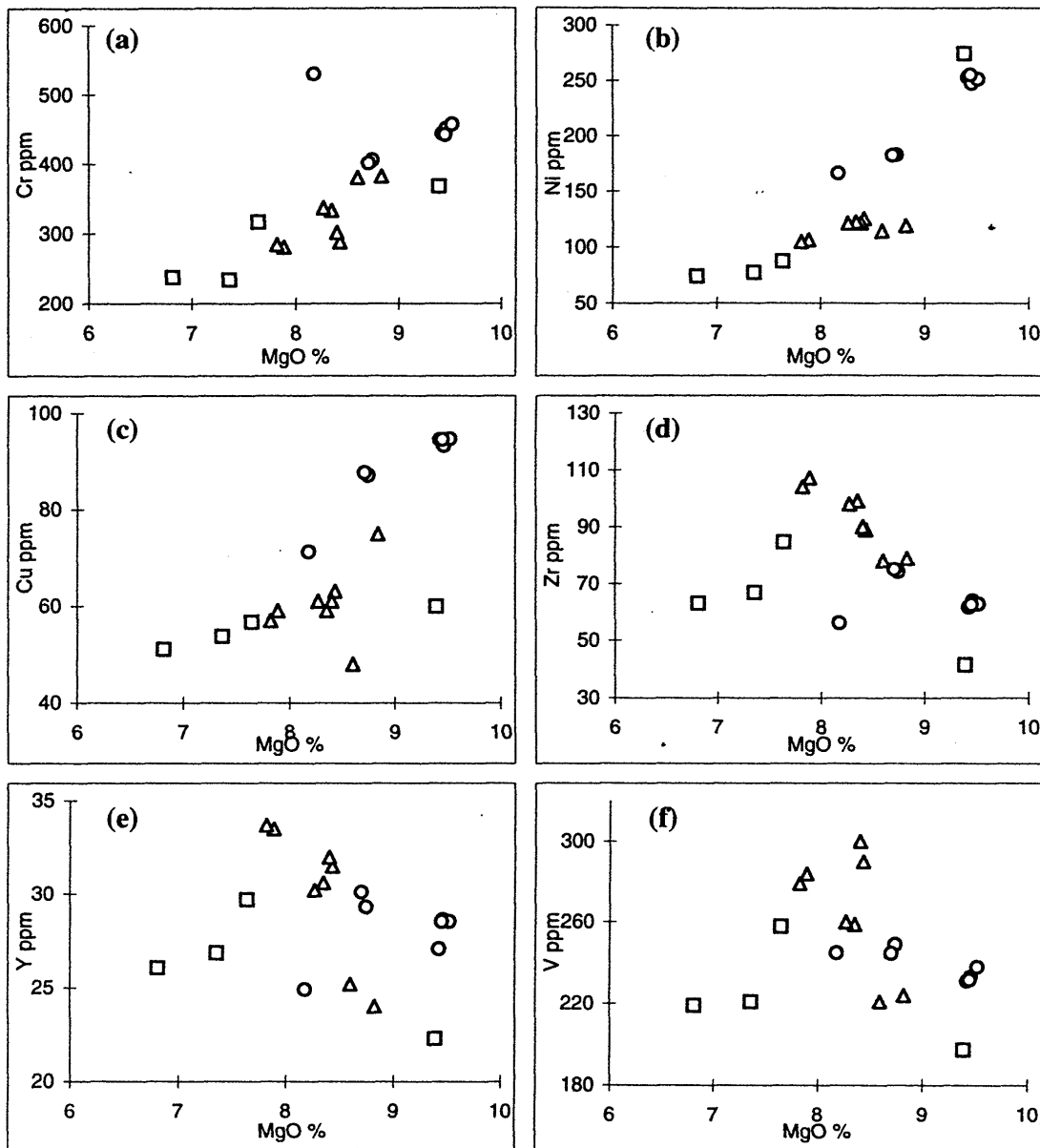


Fig.3. Variation plots of all the trace element against MgO %. Symbols same as Fig. 2.

in B1 may be due to early separation of olivine (Sato, 1977). Chromium and nickel show negative relation with FeO^*/MgO ratio (Fig. 4a and b) which is similar to that reported by Subba Rao et al. (1979) for MIOR basalts.

The basalts (B3 and B3A) have higher content (~75 ppm) of Zr while the primitive basalt (B5) has low Zr content (63 ppm). Zr exhibits positive relation with TiO_2 % and also with Y (Fig. 4c and d), indicative of a typical N-MORB characteristic with $\text{Zr}/\text{Y} \sim 2.2$. The Zr vs. Y plot (Fig. 4d) shows a positive relation and the Zr/Y ratio gradually increases from samples under study having the least 2.20, through 2.4 for samples of Humler and Whitechurch (1988)

to that of Price et al. (1986) at ~3.2. This graphical trend was compared with the observed and model fractionation trends developed by Pearce and Norry (1979; Fig. 6a), and it was found that the all CIR data follows the trend of olivine and plagioclase fractionation. Zr vs. Zr/Y trend (Fig.4e) as well the Zr vs. Zr/Ti plot (Fig. 4f) indicates that the CIR basalts might have differentiated from a melt derived from typical N-MORB type source (Pearce and Norry, 1979).

Ti/Zr for the present set of basalts, is higher (100 ± 3) than those reported by Frey et al. (1980) for Carlsberg Ridge basalts (84) and by Klein et al. (1991) for basalts from Australia-Antarctic Discordance (AAD) (87). SK basalts

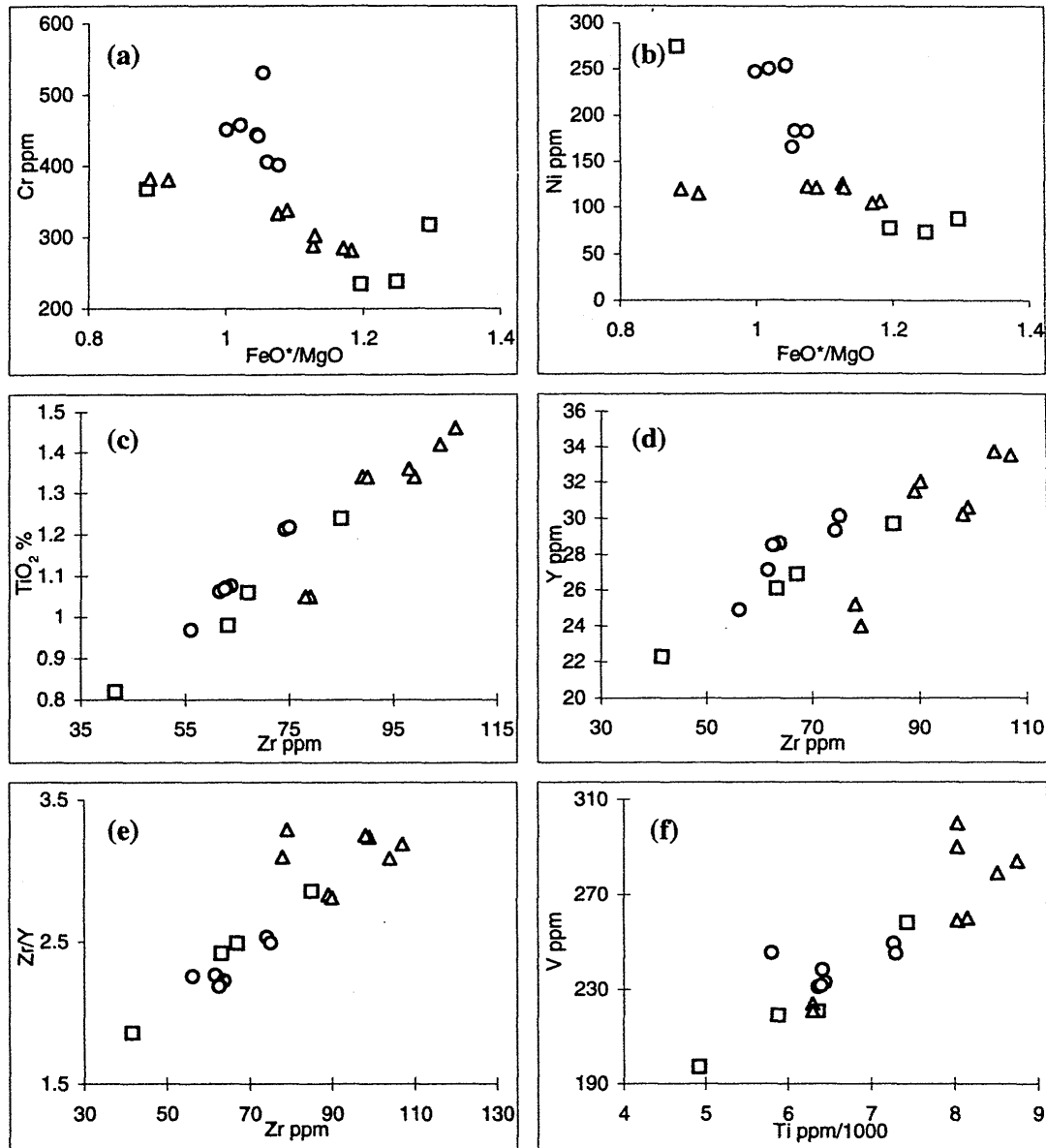


Fig.4. Variation plots. Symbols same as Fig.2.

have maximum Ti/Zr ratio, which is similar to that of the N-MORB type of melt (Price et al. 1986). Even the CIR basalts studied by Price et al. (1986) and Humler and Whitechurch (1988) have low Ti/Zr ratio (80 ± 5 ppm and 90 ± 5 ppm respectively). High Ti/Zr values of SK basalts indicate a more primitive melt as source for the SK basalts (Klein et al. 1991).

It is observed that SK basalts have almost uniform concentrations of vanadium (~ 240 ppm) (Table 2) indicating that possibly all the basalts erupted in a uniform oxidising environment. Basalts from other two data sets i.e. from Price et al. (1986) and Humler and Whitechurch (1988) have not

much different concentrations of vanadium (av. 264 ppm and 223 ppm respectively), but are within the range for MORBs as projected by Shervais (1982) and indicate that the CIR basalts erupted under comparatively low oxidising conditions. The Ti/V ratio (~ 25) conforms well with the reported MORB values, and as suggested by Shervais (1982) indicates olivine and plagioclase differentiation trend.

PETROGENETIC EVOLUTION OF SK BASALTS

SK basalts compositionally are typical N-MORBs and show a gradual chemical compositional trend from a

Table 5. Results of least square modelling of SK basalts (all data normalised to 100 percent). Differentiating parental basalt B5 to other basalts

	B5 Observed	After fractionating to B4	After fractionating to B7	After fractionating to B2	After fractionating to B3A	After fractionating to B1
SiO ₂ Calc	48.736	48.663	48.831	48.925	48.550	48.078
TiO ₂ Calc	1.077	1.052	1.094	1.081	0.962	1.187
Al ₂ O ₃ Calc	16.496	16.576	16.445	16.440	16.721	16.884
FeO*Calc	9.776	9.901	9.693	9.604	10.166	10.584
MnO Calc	0.152	0.151	0.151	0.148	0.159	0.169
MgO Calc	9.575	9.562	9.594	9.622	9.528	9.306
CaO Calc	11.516	11.426	11.586	11.528	11.265	10.514
Na ₂ O Calc	2.591	2.594	2.529	2.574	2.569	3.210
K ₂ O Calc	0.081	0.076	0.077	0.077	0.080	0.069
Fractionated phases (in wt pet)						
		F689 1.14	Fo88 6.59	Fo89 65.13	Fo88 13.22	Fo88 9.53
		An86 44.12	An86 39.77	Fo88 5.05	An86 47.73	An86 44.24
		An78 4.73	An78 53.64	An78 29.81	An78 39.04	An78 46.23
r ²		0.361	0.0282	0.0714	0.3155	2.7078

near-primitive basaltic melt (B5) to an evolved basalt (B3A), which correspond mineralogically as well. A computer programme of Stormer and Nicholls (1978) for mass balance calculations for different petrogenetic processes such as assimilation, differentiation etc. was used to understand the possible petrogenetic sequence/ trend for the evolution of the SK basalts. The mathematical results of these petrogenetic processes are considered as acceptable if the sums of squares of residuals (r^2) of the calculation is < 2 . Accordingly, all the results presented in this section

Table 6. Results of least square modelling. Differentiating B4 basalt to B1 basalt

	B4 Observed	After differentiating to B1
SiO ₂	48.861	48.089
TiO ₂	1.082	1.242
Al ₂ O ₃	16.576	16.844
FeO*	9.534	10.289
MnO	0.151	0.172
MgO	9.528	9.245
CaO	11.555	10.969
Na ₂ O	2.628	3.068
K ₂ O	0.086	0.081
Fractionated phases (in wt pot)		
		Fo 88 9.53
		An 86 44.24
		An 78 46.23
r ²		14825

have the sigma value of below 2, and is given at the end of the calculation (Tables 5 and 6). As described in the mineralogy and geochemistry section, it can be observed that the set of SK basalts has a parental basalt with a primitive chemical composition as well as evolved basalts with comparable composition. An exercise was carried out to check how these basalts are related to each other. To carry out the mathematical petrogenetic calculations, B5 was used as a parental basalt and from this basalt all the remaining basalt compositions i.e. B2, B3, B4, B7 etc. could be derived by fractionating the various mineral phases which are present within these basalts with low σr^2 values. Most common mineral phases that are used for the fractionation calculation are Fo= 89,88 and An= 86, 78, which is in conformation with the actual mineral phases present in the SK basalts. The details of these calculations are given in Tables 5 and 6. It can be seen from the Table 5, all the basalts like B2, B3A, B4 and B7 could be differentiated from the B5 basalt except for B1 as the σr^2 value is greater than 2 (Table 5). However, basalt B1 could be differentiated from B4 basalt with low σr^2 (1.88). This shows that basalt B4 was an in-between stage for the evolution of the B1 type of phyric basalt

CONCLUSION

Main mineral present in the SK basalts are plagioclase and olivine with varying anorthite and forsterite content respectively. Clino-pyroxenes are absent High anorthitic plagioclases (~ 89-90) and high forsteritic olivines

($F_0=89,90$) indicate primitive nature of the magmatic melt from which these minerals have crystallised. The presence of these minerals in a basaltic melt, with which these minerals are not in equilibrium, are xenocrystic. This suggests that the differentiated melt, while erupting on the seafloor, might have scoured the walls of the magma chamber along which these high forsteritic olivines might have formed. The presence of the low anorthitic plagioclases, in the same basalt indicates evolved type of basaltic melt as the source for these plagioclases. Such characteristics might have developed due to the gradual differentiation of a single near-primitive basaltic melt (B5), since the high anorthitic plagioclases and forsteritic olivines have crystallised from the near-primitive melt. Some of these minerals are transported along with the evolving melt and thereby do not remain in equilibrium. They try to remain in equilibrium with evolved basaltic melt and thus create resorption features in the mineral phases in the evolved basalts (B1). At the same time, low anorthitic plagioclases and forsteritic olivines crystallise from this evolving melt (B3, B3A).

Mathematical calculations confirm the main petrogenetic

process responsible for the evolution of the SK basalt is the fractionation of olivine and plagioclase while at the same time, the basaltic melt was fractionating low F_0 olivines and low An plagioclases.

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