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Back-Arc Basin Signatures represented by the Sheeted Dykes from the Muslim Bagh Ophiolite Complex, Balochistan, Pakistan

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Abstract: The sheeted dyke complex is about 1000 meter thick and overlies the mafic cumulate sequence of the Muslim Bagh Ophiolite Complex. This sheeted dyke complex is represented by four phases of metadolerites, the earlier phase shows compositional banding of hornblende and plagioclase. The second phase of metadolerite which cut the earlier phase neither shows foliation nor compositional banding. The third phase which cuts the above two phases has foliation and is relatively more mafic in nature. The final phase is represented by dykes which not only cut the above three phases but also to the plagiogranites. The middle part of sheeted dyke complex is intruded by numerous small bodies of plagiogranites (An $_{8\text{-}30}$). The pillow basalts are not found on top of the sheeted dyke complex. The petrochemical study of metadolerites show that they belong to low-K quartz tholeiite series. In trace elements chemistry they are enriched in LILE and depleted in HFSE relative to N-MORB, and their average Nb/Y, Zr/Nb, K/Rb, Ba/Zr, Ce/Ba, La/Sm, La/Ce and La/Nd ratios are more consistent with back-arc basin basalt relative to N-MORB or island arc basalts (IAB). Their LILE enriched N-MORB normalized patterns and moderately LREE enriched Chondrite normalized REE patterns are also consistent with back-arc basin basalts. It is further suggested that all the Tethyan ophiolite complexes and oceanic island arcs including Muslim Bagh, Waziristan, Semail, Zagros, Chagai-Raskoh and Kohistan-Ladakh were developed in a single but segmented Late Jurassic-Cretaceous Ceno-Tethyan convergence zone.

Keywords: Back-arc-basin; sheeted dykes; Muslim Bagh; Pakistan

INTRODUCTION

The northwestern margin of Indian continent in Pakistan is marked by the Waziristan- Muslim Bagh-Bela Ophiolite Suture Zone. In the regional geotectonic context the ophiolites included in this suture belong to Late Cretaceous Tethyan Ophiolite Belt (Pearce,1980) which also include Semail, Troodos and Vorinous ophiolites in the southwest and west, Waziristan, Malakand, Dargai and other ophiolites associated with Indus-Yarlung-Zangbo (Searle *et al.,* 1987) Suture Zone in the north and northeast of Muslim Bagh. The Muslim Bagh Ophiolite (Fig. 1) is one of the best exposed ophiolite of Pakistan which shows a continuous and complete sequence from ultramafic tectonite to sheeted dykes. The Muslim Bagh Ophiolite is harzburgite type ophiolite and considered to have formed during 82 to 81 Ma and sporadically emplaced on to northwestern margin of Indian Plate during 67-65 Ma (Sawada, *et al.,* 1995).

The present paper mainly deals with the brief geology, petrography and geochemistry of metadolerites from sheeted dyke complex

Previous Work

The Muslim Bagh Ophiolite Complex is studied by many workers. Vredenburg (1901), H. S. C. (1960) and Bilgrami (1964) have considered it as an intrusive complex. Shah (1974) named it as an extrusive complex. Rossman *et al.,* (1971) first designated it as an Ophiolite Complex, later on Khain *et al.,* (1973), Gansser (1979), Sillitoe (1974), Andrieux and Brunei (1977), Ahmad and Abbas (1979) also favoured the nomenclature of Rossman *et al.,* (1971) and described it as an Ophiolite Complex. Munir and Ahmed (1985) have described nature and grade of metamorphic sole of Muslim Bagh Ophiolite Complex and first reported the MORB tholeiites from the Bagh Complex. McCormick (1985 and 1991) first documented the Late Cretaceous intra-plate pillow lava from the Bagh Complex and related it with the Reunion hotspot activity. On the basis of field studies Sillitoe (1974), Otsuki *et al.,* (1989), and on the basis of laboratory studies Ahmed (1975) and Sawada *et al.,* (1992) have considered that this Ophiolite Complex was formed in an oceanic ridge setting in the Neo-Tethys Ocean. Jan *et al.,* (1984) have reported high chromium Al-chromitites from the Muslim Bagh Ophiolite Complex and correlated it with the alpine type peridotites and stratiform complexes.

The age of formation of Muslim Bagh Ophiolite Complex, as proposed by Sawada *et al.,* (1995), is Late Cretaceous (82 to 81 Ma). The paleogeographic reconstructions and paleotectonic data (Dietz and Holden, 1970; Powel, 1979; Besse and Courtillot 1988; Clark, 1974; Beck *et al.,* 1996) on Neo-Tethys (north of the Indian Plate) suggest an island arc rather than a mid oceanic ridge type environment during 100 to 73 Ma. The Bela (Ahmad, 1991 and 1992) and Waziristan (Khan, *et al.,* 2007) ophiolite have already been interpreted to have formed in a supra-subduction zone environment during the Late Cretaceous. The Muslim Bagh Ophiolite Complex was emplaced sporadically onto the continental shelf of Indian Continental Plate during Maastrichtian to Paleocene (Kojima *et al.,* 1993). The age of emplacement on the basis of K-Ar radiometric data is 67 Ma (Sawada *et al.,* 1995) or 71 to 65 Ma (Mahmood *et al.,* 1995).

Muslim Bagh Ophiolite Complex

The Muslimbagh Ophiolite Complex is harzbergite type ophiolite which represents the upper depleted mantle and oceanic crust of southern Neo-Tethys (Fig. 2). The mantle segment is about 11 Km thick and mainly represented by foliated harzbergite and dunite, followed by a narrow transitional zone in which layering and foliation coexist in harzbergite. This transitional zone is followed by the crustal sequence which is about 6.5 Km thick and is represented in the lower part by a 4000 meter thick intercalations of dunite and wehrlite with minor harzbergite and is folowed by a 200-1500 meter thick cyclic repetition of layyered dunite, wehrlite, pyroxinite and gabbro. This cyclic sequence is followed by mafic cumulate only 600 meter thick and is represented by massive foliated and layered gabbro. The mafic sequence is overlain by sheeted dyke complex, which is about 1000 meter thick and is represented by metadolerites, amphibolites, diorites and quartz diorites with layering and foliation. The middle part of sheeted dyke complex is invaded by numerous small bodies of foliated plagiogranites. The whole ophiolite sequence is transacted by a NW trending dolerite dyke swarm and folded into an overturned syncline. The Dolerite dyke is more thick and persistent in the ultramafic tectonite and cumulate sequence.

The upper mantle sequence is followed by a 6.5km thick crustal sequence. This sequence is recognized in the field by the absence of foliation and the presence of cumulus layering and is represented in the lower part by a 4 km thick intercalation of layered dunite and wehrlite with minor harzburgite and Iherzolite. The thickness of layering ranges from less than one centimeter to several hundred meters.

The ultramafic tectonites are followed by a mixed mafic and ultramafic cumulate sequence, which is represented by numerous isolated lenticular bodies of mafic and ultramafic cumulates. Each lenticular body is mainly composed of single or cyclic repetition of layered dunite, wehrlite, pyroxenite and gabbro representing many isolated magma chambers. The thickness of whole mixed mafic and ultramafic sequence is 200-1500 metres.

The above mafic and ultramafic cyclic sequence is followed by mafic cumulates. This sequence is about 600 m thick and is represented by layered (lower part) and foliated (upper part) gabbro. Two compositional varities are found. Pyroxene gabbro occurs in the lower part which grades into hornblende gabbro in the upper part. The mafic sequence is overlain by the sheeted dyke complex, which is the main topic of this paper. The middle part of sheeted dyke complex is invaded by numerous small bodies of plagiogranites, which occur as small pockets, dykes and xenoliths. Several varieties are identified which include fine, coarse, foliated and mylonitized ones. Whole of the ophiolite sequence is overturned into an syncline and transected by a NW trending diabase dyke swarm. These dykes are 3 to 15 metre thick and extend up to 1 km. At places the dykes are broken and are strongly sheared along with the country rocks forming boudinage bodies.

MATERIAL AND METHODS

Sheeted Dyke Complex

The sheeted dyke complex is 1000 m thick **(Figs. 1and 2)**. Originally these rocks were dolerites (contain 48-53% SiO_2) but metamorphosed into amphibolites. This complex is represented by at least four phases of metadolerites, the earlier phase shows compositional banding of hornblende and plagioclase. The second phase of metadolerite which cut the earlier phase neither shows foliation nor compositional banding. The third phase which cuts the above two phases has foliation and is relatively more mafic in nature. The final phase is represented by dykes which not only cut the above three phases but also to the plagiogranites. This sequence is identified as sheeted dyke complex by earlier workers (Rossman *et al.*, 1971; Ahmed and Abbas, 1979). During the present investigation no clear evidence of asymmetrical chilling is observed which is characteristic of such dykes; rather compositional banding and foliation are well developed at many places.

Petrography

Several textural varities of amphibolite are identified which include coarse and fine grained, layered and non-layered, foliated and non- foliated. Main minerals identified in these rocks include hornblende, ferro-hornblende, ferro-actinolite, ferro-tremolite, plagioclase and minor quartz. Hornblende occurs as small prismatic euhedral to subhedral crystals. Plagioclase found as euhedral to subhedral and tabular crystals shows polysynthetic twining according to albite and combined albite and carlsbad laws. The anorthite contents in plagioclase range from An_{12} to An_{54} and majority is around An_{45}. Hornblende shows minor chloritization and plagioclase is occasionally dusty with argillization and sericitization. Small prismatic grains of apatite are found as inclusions in plagioclase. Small subhedral to anhedral grains of ilmenite, magnetite and hematite are scattered throughout the groundmass.

Geochemistry

Ten rock samples were collected from the sheeted dyke complex. All the samples were analyzed for major and trace elements. Four of the samples were also analyzed for rare earth elements (REE). Bulk chemical analyses of samples from these volcanic rocks are given in **(Table 1)**.

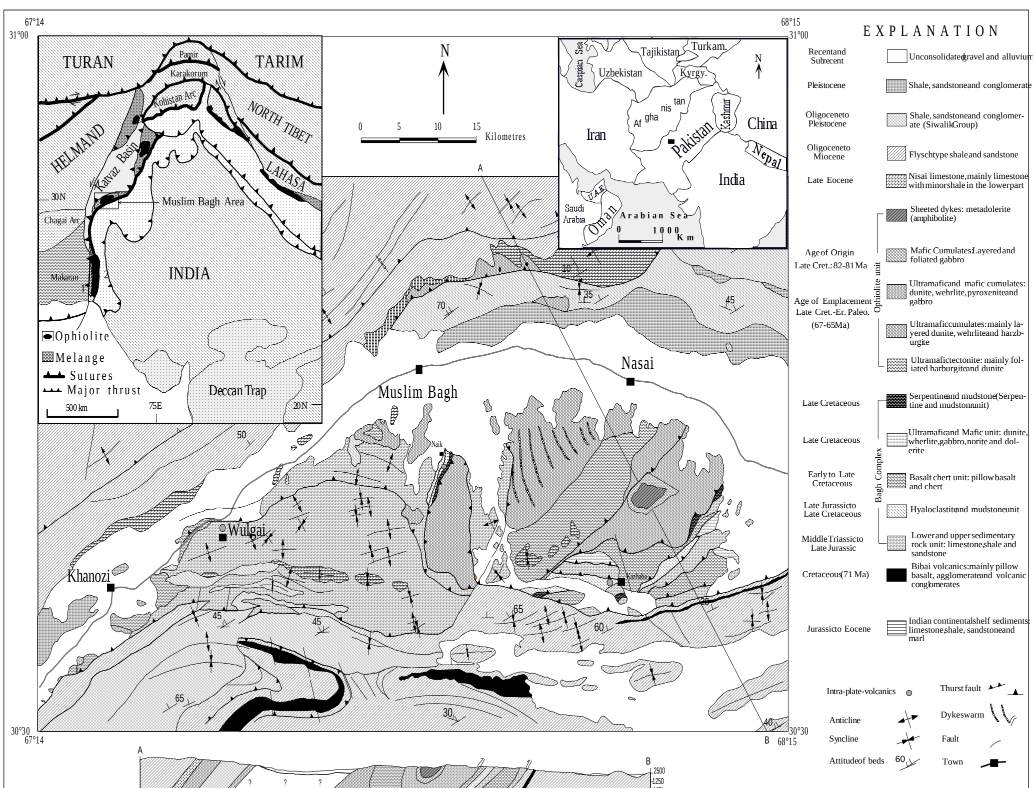

Fig. 1

Fig. 1 Geological map of the Muslim Bagh Area, Balochistan, Pakistan (modified and reproduced after Siddiqui Mengal, 1996).

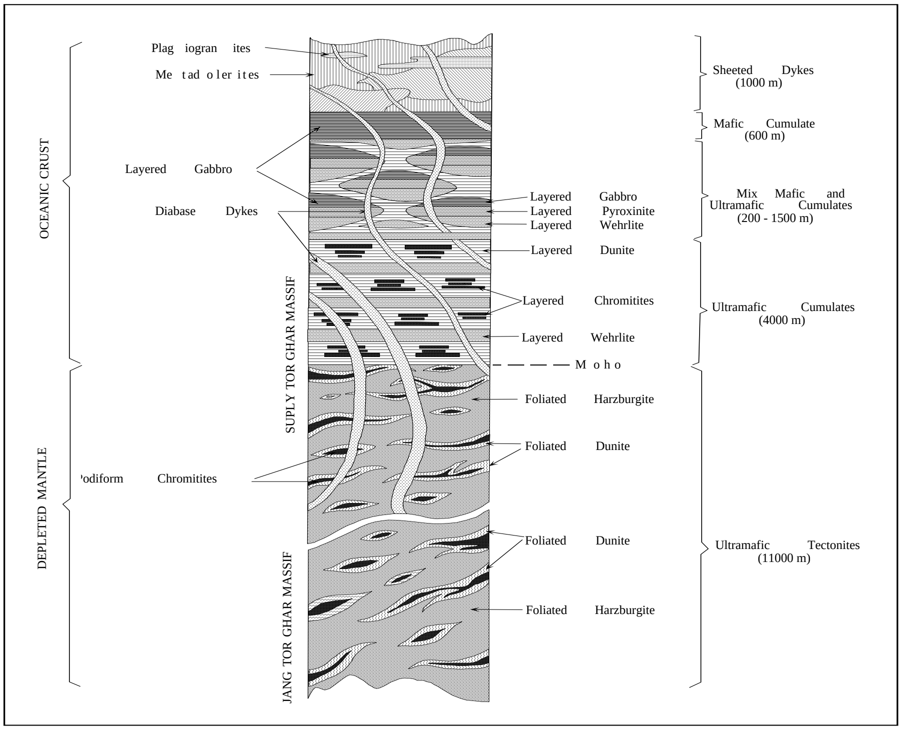

Fig. 2 Generalized columnar section of Muslim Bagh Ophiolite Complex, Balochistan, Pakistan (modified and reproduced after Siddiqui et al., 1996).

Table 1. Bulk Chemistry of metadolerites from the sheeted dykes of Muslim Bagh Ophiolite Complex.

Samples	RMD-1	RMD-2	RMD-3	RMD-4	RMD-5	RMD-6	RMD-7	RMD-8	RMD-9	RMD-10
SiO_2	49.75	51.71	50.45	49.37	46.8	53.08	52.43	47.21	49.51	52.51
TiO^2	0.52	1.12	0.55	0.46	0.9	0.87	1.09	0.42	0.46	1.15
Al_2O_3	13.22	15.68	16.33	16.7	15.41	16.2	15.8	20.02	19.2	15.35
Fe_2O_3	10.61	11.67	9.6	9.34	13.24	10.75	11.35	7.92	7.95	12.99
MnO	0.17	0.19	0.13	0.15	0.21	0.17	0.19	0.13	0.11	0.19
MgO	11.56	4.56	7.85	8.14	7.93	5.3	4.69	6.96	6.09	4.95
CaO	12.19	8.19	11.6	12.5	13.27	9.16	8.67	13.91	12.24	8.26
Na_2O	1.45	3.57	2.35	1.87	1.85	2.76	3.27	1.27	2.25	2.95
K_2O	0.19	0.57	0.3	0.6	0.12	0.39	0.65	0.17	0.12	0.41
P_2O_5	0.1	0.17	0.07	0.09	0.09	0.12	0.2	0.06	0.04	0.13
V	267	389	228	211	362	371	402	196	217	427
Cr	592	11	2.4	244	48	47	34	270	152	54
Ni	138	11	51	75	28	21	13	52	34	15
Ti	3115	6709	3295	2755	5391	5211	6529	2516	2755	6889
Y	14	24	15	13	24	24	23	11	13	21
Zr	40	62	47	42	33	59	68	33	33	72
Nb	3.3	6.6	3.4	2.7	3.7	2.7	6	2	4	4
Rb	4.5	6.1	5.9	11	4.7	6.9	11	4	3	8
Sr	225	246	167	244	246	257	280	333	260	215
Ba	123	143	120	180	117	183	214	99	37	72
La	7	0	5	8	0	0	0	0	0	0
Ce	14	0	12	14	0	0	0	0	0	0
Nd	5	0	5	5	0	0	0	0	0	0
Sm	2.6	0	1.9	2.3	0	0	0	0	0	0
En	0.5	0	0.5	0.5	0	0	0	0	0	0
Gd	0	0	0	0	0	0	0	0	0	0
Er	0	0	0	0	0	0	0	0	0	0
Yb	1.4	0	1.7	1.3	0	0	0	0	0	0
Zr/Nb	12.12	9.39	13.82	15.56	8.92	21.85	11.33	16.50	8.25	18.00
Ti/V	11.67	17.25	14.45	13.06	14.89	14.05	16.24	12.84	12.70	16.13
Ti/Zr	77.88	108.21	70.11	65.60	163.36	88.32	96.01	76.24	83.48	95.68
Rb/Sr	0.0200	0.0248	0.0353	0.0451	0.0191	0.0268	0.0393	0.0120	0.0115	0.0372
Ba/Zr	3.08	2.31	2.55	4.29	3.55	3.10	3.15	3.00	1.12	1.00
La/Ce	0.50	0.00	0.42	0.57	0.00	0.00	0.00	0.00	0.00	0.00
La/Sm	2.69	0.00	2.63	3.48	0.00	0.00	0.00	0.00	0.00	0.00
La/Nd	1.40	0.00	1.00	1.60	0.00	0.00	0.00	0.00	0.00	0.00

Major elements are in wt. % and trace elements are in ppm.

Analytical Techniques

The major and trace elements were analyzed in the Geoscience Laboratory, Geological Survey of Pakistan, Islamabad, by X-ray fluorescence spectrometry (RIGAKU XRF-3370E). The sample powder (< 200 mesh), weighing 0.7 gram was thoroughly mixed with 3.5 grams of lithium tetra borate (flux). The analyses were carried out on 1: 5 rock powder and flux fused disks commonly known as glass beads. The samples thus obtained were analyzed by XRF using corresponding GSJ (Geological Survey of Japan) standard samples with every batch of ten samples. The results of analyses were then compared with the recommended values of USGS (United State Geological Survey) standard reference samples. A check of precision of the instrument was made using JA-3 standard sample (Govindaraju, 1989). The analysis of rare earth elements (REE) and Hf, Th, U and Ta were carried out in the Chemics Laboratory, Canada by NAA.

All the rock samples are plotted in SiO_2 versus alkali (wt. %) diagram **(Fig. 3)** of Le Bas *et al.*, (1986).

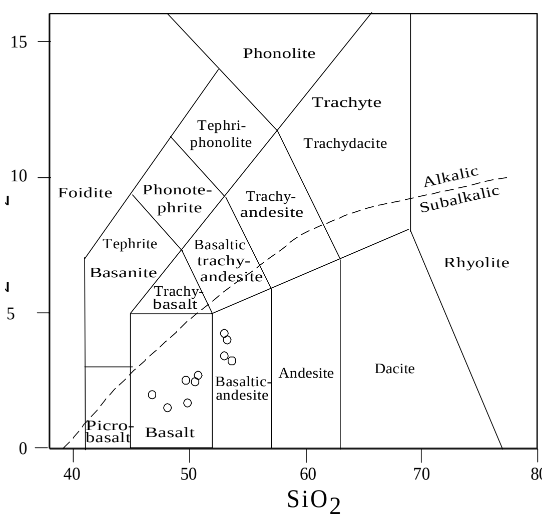

Fig. 3 Alkali versus SiO_2 plot (after Le Bas, et al., 1986) for the metadolerites from the sheeted dykes from the Muslim Bagh Ophiolite Complex.

In this diagram six samples plot in basalt field and four in basaltic-andesite field. All the samples from Sheeted dyke complex rocks are again plotted in Ti/Zr versus Nb/Y diagram **(Fig. 4)** (Winchester and Floyd, 1977). In this diagram five samples plot in sub-alkaline basalt and five in combined field of basalt/andesite. ous variation diagrams for major elements (Fig. 5). In these diagrams all samples from the sheeted dyke complex show sharp to scattered negative correlation for MgO and CaO probably due to the partitioning of these elements in pyroxene and plagioclase during fractionation. Na_2O and K_2O

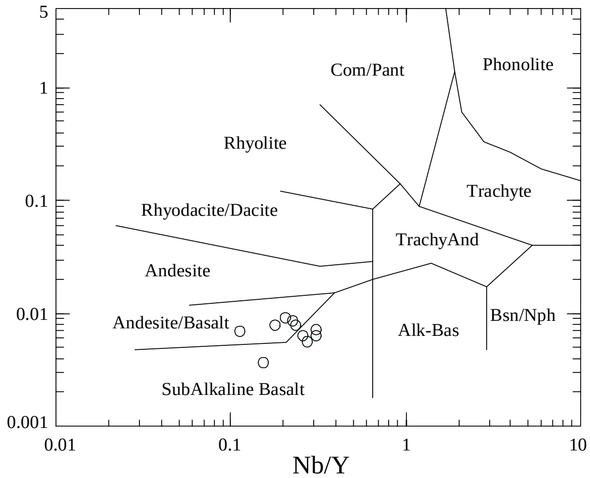

Fig. 4 Zr/Ti versus Nb/Y plot (Winchester and Floyd, 1977) for the metadolerites from the sheeted dykes from the Muslim Bagh Ophiolite Complex.

generally exhibit scattered positive correlation due to the accumulation of these elements in the residual phase. In SiO_2 versus trace element variation diagrams **(Fig. 5)** sheeted dyke rocks show scattered positive

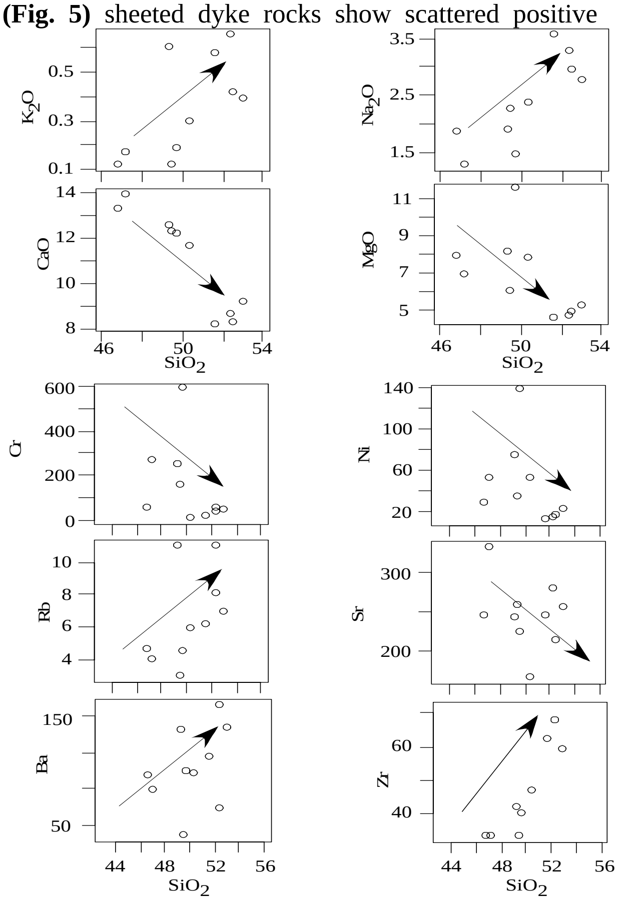

Fig. 5 SiO_2 versus major and trace element variation diagrams showing fractionation trends in the metadolerites from the sheeted dykes from the Muslim Bagh Ophiolite Complex.

trends for Ba, Rb and Zr due to the accumulation of these elements in the residual phase. Sr shows scattered negative trends due to the partitioning of this element in the plagioclase, while Ni and Co shows scattered negative trend due to the partitioning of these elements in olivine and pyroxene during fractionation.

All the samples are also plotted in FAM diagram (Irvine and Baragar, 1971), which shows that they are tholeiitic in nature **(Fig. 6)**. The SiO_2 versus FeOt/MgO plot (Miyashiro, 1974) further confirms their tholeiites parentage **(Fig. 7)**. In Ti-Zr-Y (Pearce and Cann, 1973) and Nb-Zr-Y (Meschede, 1986) tectonomagmatic discrimination diagrams majority of the samples are plotted in the overlapping field of island arc tholeiite and mid oceanic ridge tholeiite **(Figs. 8 and 9)**. The samples from South Scocia Sea, Lao and Mariana back-arc basins are also plot in the same field. The primitive mantle-normalized spider

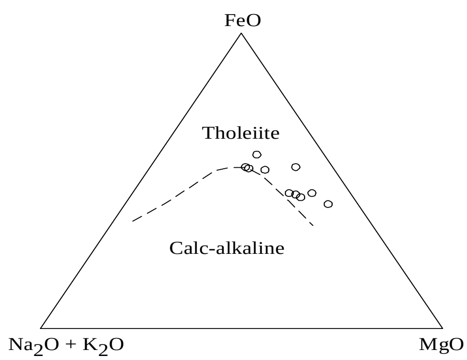

Fig. 6 The FAM diagram (after Irvine and Baragar, 1971) for the metadolerites from the sheeted dykes from the Muslim Bagh Ophiolite Complex.

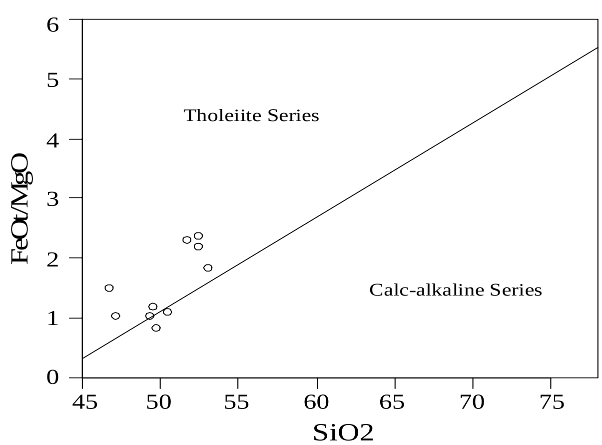

Fig. 7 The FeOt/MgO plot (after Miyashiro, 1974) for the metadolerites from the sheeted dykes from the Muslim Bagh Ophiolite Complex.

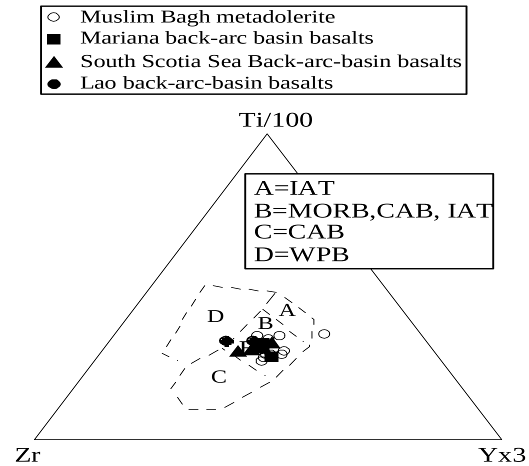

Fig. 8 The Ti-Zr-Y tectonomagmatic discrimination diagrams (after Pearce and Cann, 1973) for the metadolerites from the sheeted dykes from the Muslim Bagh Ophiolite Complex.

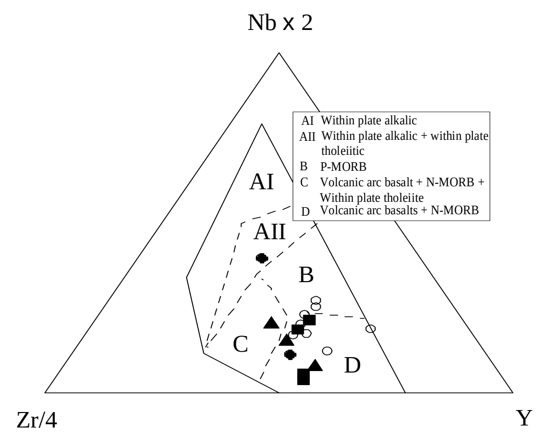

Fig. 9 The Nb-Zr-Y tectonomagmatic discrimination diagram (after Meschede, 1986) for the metadolerites from the sheeted dykes from the Muslim Bagh Ophiolite Complex.

diagram (Sun and McDonough, 1989) of various samples from metadolerites from sheeted dyke complex exhibit enrichment of LIL elements and depletion in HFS elements relative to N-MORB **(Fig. 10)**. The patterns do not show marked negative Nb anomalies but exhibit positive spikes on Sr and Ba. The absence of marked negative Nb anomalies negate typical island arc signatures for the sheeted dyke samples .The average values of Island Arc Tholeiite (IAT), Back-Arc-Basin basalt (BABB) (Wilson, 1989) and Normal Mid-Oceanic Ridge Basalt (N-MORB) (Sun and McDonaugh, 1989) are also plotted in the same diagram, which show close resemblance of metadolerite rocks to the BABB relative IAT and N-MORB. The primitive mantle-normalized spider patterns of the average values of metadolerites from sheeted dyke complex, Island Arc Tholeiite (IAT), Back-Arc-Basin Basalt (BABB) (Wilson, 1989) and Normal Mid-Oceanic Ridge Basalt (N-MORB) (Sun and McDonaugh, 1989) show close resemblance of metadolerite rocks to the BABB relative IAT and N-MORB **(Fig. 11)**.

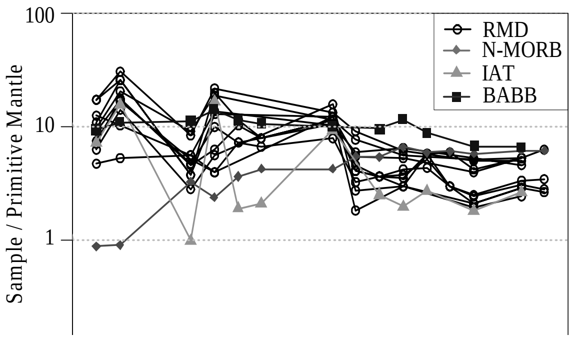

Fig. 10 Primitive mantle normalized spider diagram for the metadolerites from the sheeted dykes from the Muslim Bagh Ophiolite Complex. Average N-MORB and normalization values are after Sun and McDonough (1989). The average values of island arc tholeiite (IAT), back-arc-basin basalt (BABB) (Wilson (1989) and normal mid-oceanic ridge basalt (N-MORB) (Sun and McDonaugh, 1989) are also plotted in the same diagram

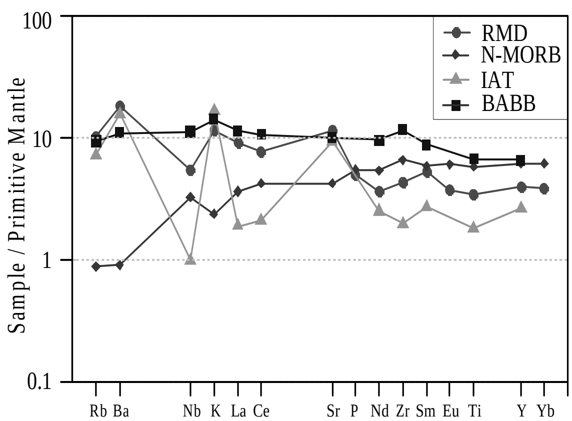

Fig. 11 The primitive mantle-normalized spider patterns for the average values of metadolerites from sheeted dyke complex, island arc tholeiite (IAT), back-arc-basin basalt (BABB) (Wilson (1989) and normal mid-oceanic ridge basalt (N-MORB) (Sun and McDonaugh,1989)

The Chondrite-normalized REE patterns (Nakamura, 1974) of metadolerites show enrichment in LREE relative to HREE with positive spike on Sm **(Fig. 12)**. The average values of island arc tholeiite (IAT), back-arc-basin basalt (BABB) (Wilson (1989) and normal mid-oceanic ridge basalt (N-MORB) (Sun and McDonaugh, 1989) are plotted in chondrite-normalized REE diagram (Nakamura, 1974) **(Fig. 13),** which show close resemblance of metadolerite rocks to the BABB relative IAT and N-MORB.

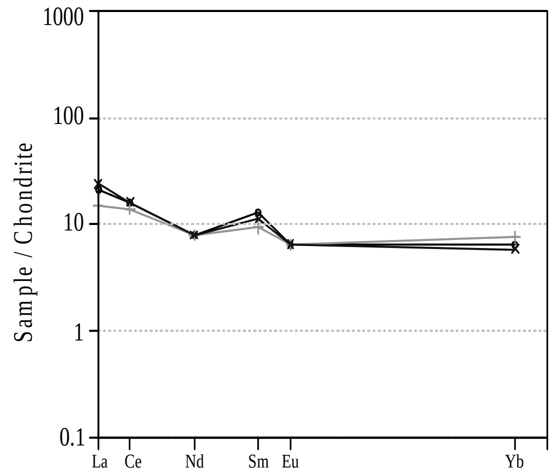

Fig. 12 The Chondrite normalized REE diagram for the metadolerites from the sheeted dykes from the Muslim Bagh Ophiolite Complex. The normalization values are after Nakamura (1974).

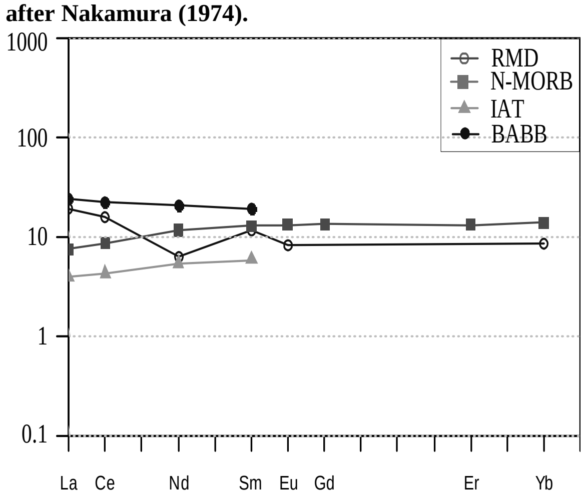

Fig. 13 The Chondrite normalized REE diagram for the average values of metadolerites from sheeted dyke complex, island arc tholeiite (IAT), back-arc-basin basalt (BABB) (Wilson (1989) and normal mid-oceanic ridge basalt (N-MORB). The normalization values are after Nakamura (1974).

The trace element ratios of incompatible elements also play important role to discriminate tectonic environments. The Zr/Nb ratios in the samples from metadolerite range from 11.67 to 16.24 and averages 14.64, which are much lower than those found in average N-MORB (32) and IAT (31) respectively and are much closer to the average BABB (Table 2). The averages Rb/Sr ratios in metadolerite is 0.026, which is generally higher than those found in average N-MORB (0.013) and IAT (0.020) respectively and are closer to the average BABB (0.028). The Ba/Zr ratios in most of the samples range from 0.95 to 3.55 and average for metadolerite and northern pillow lavas are 2.84 and 1.55 respectively which are quite different than those found in average N-MORB (0.085) and IAT (5.0) respectively **(Table 2)** and are relatively closer to the average BABB (0.59). The Ti/V ratios in most of the samples range from 11 to 25 which are generally much closer to these ratios reported for IAT (10-20) relative to the documented ratios for N-MORB (20-50) (Shervais, 1982).

Table 2. A comparison of average trace elements and REE chemistry of metadolerites from sheeted dykes with normal mid-oceanic ridge basalt (N-MORB), island arc tholeiites (IAT) and back-arc basin basalts (BABB).

Sample	RMD	N-MORB	IAT	BABB
Ti	4493	7607	2336	8745
Y	18	28	12	30
Zr	49	74	22	130
Nb	3.84	2.33	0.7	8
Rb	6.51	0.56	4.6	6
Sr	247	90	200	212
Ba	129	6.3	110	77
La	6.25	2.5	1.3	7.83
Ce	13.5	7.5	3.7	19
Nd	5	7.3	3.4	13.1
Sm	2.35	2.63	1.2	3.94
En	0.63	1.02	0	0
Gd	0	3.68	0	0
Er	0	2.97	0	0
Yb	1.9	3.05		
Zr/Nb	12.76	31.76	31.43	16.25
Ti/Zr	91.69	102.80	106.18	67.27
Rb/Sr	0.0264	0.0062	0.0230	0.0283
Ba/Zr	2.63	0.09	5.00	0.59
La/Ce	0.46	0.33	0.35	0.41
La/Sm	2.70	1.03	1.09	1.45
La/Nd	1.25	0.34	0.38	0.60

All the elements are in ppm.

The average REE ratios including La/Ce, La/Sm and La/Nd in metadolerite are 0.46, 2.02 and 1.56 respectively. These average ratios in N-MORB are 0.33, 1.07 and 0.38, in IAT 0.35, 1.08 and 0.70 and in BABB are 0.41, 1.99 and 0.60 respectively. This show relatively more resemblence of La/Ce, La/Sm and La/Nd ratios of average BABB with metadolerites and northern pillow basalts rather than these ratios in average N-MORB and IAT. All the aforementioned studies suggest that the metadolerites were formed in a suprasubduction zone or back-arc-basin environment.

RESULTS AND DISCUSSION

The plots of sheeted dyke's samples from the Muslim Bagh Ophiolite Complex in various Fig.s and studies of trace and rare earth elements in foregoing pages lead to interpret that they were formed in a back-arc basin or supra-subduction environment, which developed in Tethyan Convergence Zone during the Late Cretaceous.

The development of the Tethyan convergence zone during the Cretaceous and associated oceanic island arcs between Gondwana and Eurasia has already been suggested (Powell, 1979; Tahirkheli *et al.*, 1979; Pearce *et al.*, 1981; DeJong, 1982; McCall and Kidd, 1982; Petterson and Windley, 1985; Jan et al., 1989; Siddiqui *et al.*, 1996; Khan *et al.*, 1993; Treloar *et al.*, 1996; Gnos *et al.*, 2000). It was proposed that one of the Tethyan oceanic island arc, the Kohistan arc, was initially developed near the Equator and later on accreted with Eurasia (Khan *et al.*, 1997; Zaman *et al.*, 1999; Jan and Rafiq, 2007). Siddiqui *et al.*, (1986) has suggested that the Chagai and Kohistan arcs are disrupted parts of a single arc. Siddiqui (1996) has proposed that the Raskoh and Kohistan arcs were developed in the same convergence in the Neo-Tethys.

The wedge shaped ocean that once existed between the Gondwana in the south and the Eurasia in north is generally known as the Tethys (Dewey and Bird, 1970; Sengor, 1979). The Tethys is further divided into three ocean systems, named Paleo-Tethys, Meso-Tethys and Ceno-Tethys (Brookfield, 1993; Metacalfe, 1995; Wakita and Metcalfe, 2005; Metcalfe, 2006). These three ocean systems are equivalent to Tethys-1, Tethys-2 and Tethys-3 of Boulin (1981), whereas Meso-Tethys and Ceno-Tethys correspond to Neo-Tethys of Sengor (1979). It is suggested that all the Tethyan supra-subduction zone ophiolites including Semail, Muslim Bagh, Waziristan, Bela and oceanic island arcs and including, Zagros, Chagai-Raskoh, and Kohistan-Ladakh were developed in a single but segmented Late Jurassic-Cretaceous Ceno-Tethyan convergence zone **(Figs. 14 and 15)**, between the Gondwana and one of the earlier separated collage of continental blocks (Iran, Afghan, Karakorum and Lhasa) during the Cretaceous and latter on accreted with the southern margin of Eurasia. Later on these ophilite and arcs were emplaced on to the adjacent continents or sandwiched in between them.

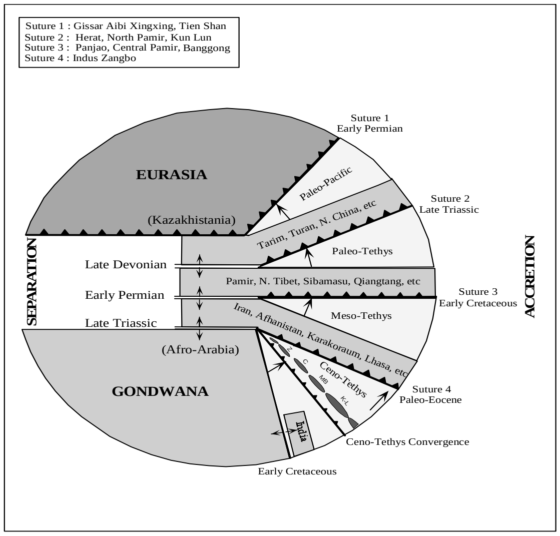

Fig. 14 Schematic diagram showing the tectonic history of South Asia (modified after, Naka *et al.*, 1996). The Z, C, MB and K-L represent Zagros, Chagai-Raskoh, Muslim Bagh and Kohistan-Ladakh arcs respectively. The separation and accretion ages of the continents are after Brookfield (1993) and Metacalfe (1995).

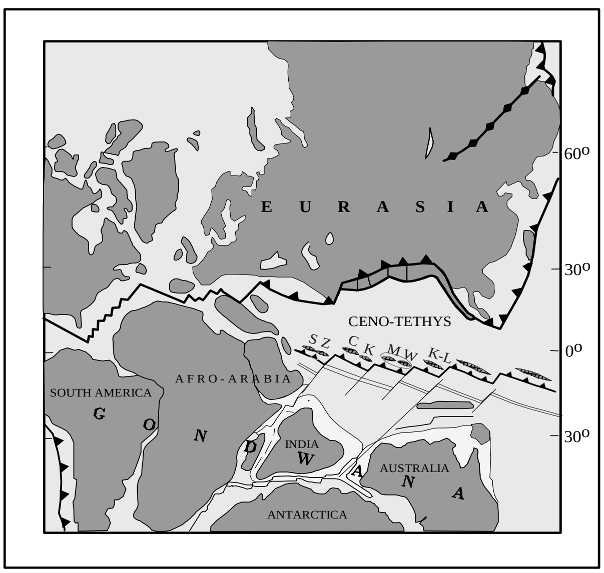

Fig. 15 Paleogeographic reconstruction of Ceno-Tethys and surrounding continents during 150-130 Ma (modified after Kazmin, 1991). The S, Z, C, K, M, W and K-L represent Semail, Zagros, Chagai-Raskoh, Kandhar, Muslim Bagh, Waziristan and Kohistan-Ladakh arcs respectively.

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