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PETROLOGY OF A PART OF THE WESTERN LIMB OF THE NANGA PARBAT-HARAMOSH LOOP, NORTHERN PAKISTAN

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ABSTRACT

A part of the western limb of the Nanga Parbat-Haramosh Loop has been studied in terms of petrography and geochemistry of the constituent rocks. In this area a recent fault, the Raikot Fault, separates the tectono-stratigraphic zones of the Kohistan island arc in the west from the Nanga Parbat massif (which forms the basement of the Indian plate) in the east. Major rock types, west of the fault, include a sequence of inter-layered amphibolite-gneiss and gabbro/gabbronorites. Chemical constants of these rocks are indicative of their derivation from an igneous parent, in an inland arc-type environment. East of the fault, the rocks are schists and gneisses of the Nanga Parbat-Haramosh Group. These rocks, on the basis of major-oxide geochemistry, are shown to be formed from a Proterozoic granitic protolith of I-type origin and are geochemically distinct from the S-type Mansehra and equivalent granites in the Indian plate.

INTRODUCTION

The Nanga Parbat-Haramosh syntaxis is one of the most striking geological features in North Pakistan. The Indus Suture Zone (Gansser,1964), which separates the Indian plate from the northern plates (Kohistan-Ladakh island arc in the west and the Tibetan plate in the east), is folded into a crustal-scale antiform in this area (Coward, 1985). A rapid rate of uplift (~7 mm/year: Zeitler, 1985), accompanied by an equally high rate of erosion (Butler and Prior, 1988a), has exposed deep-seated basement rocks of the Indian plate in the core of this fold structure, with the rocks of the Kohistan arc sequence looping around the massif. Although it is the Main Mantle Thrust (Tahirkheli et al., 1979; Bard, 1983), which marked the initial contact between the Indian plate rocks forming the massif and those of the Kohistan arc, recent studies have shown that an active dextral reverse fault zone marks the present boundary between the two tectono-stratigraphic units. This active fault has been termed as the Raikot Fault (Lawrence and Ghauri, 1984; Madin, 1986; Rehman, 1986) and is considered to be equivalent of the Laicher Thrust Zone of Butler and Prior (1988a, b).

In this paper we present petrographic and geochemical data of the rocks from a part of the western limb of the syntaxis, occurring on either side of the Raikot Thrust. The area under discussion (Fig. 1) occupies part of the Survey of Pakistan toposheets 43-I/9,13.

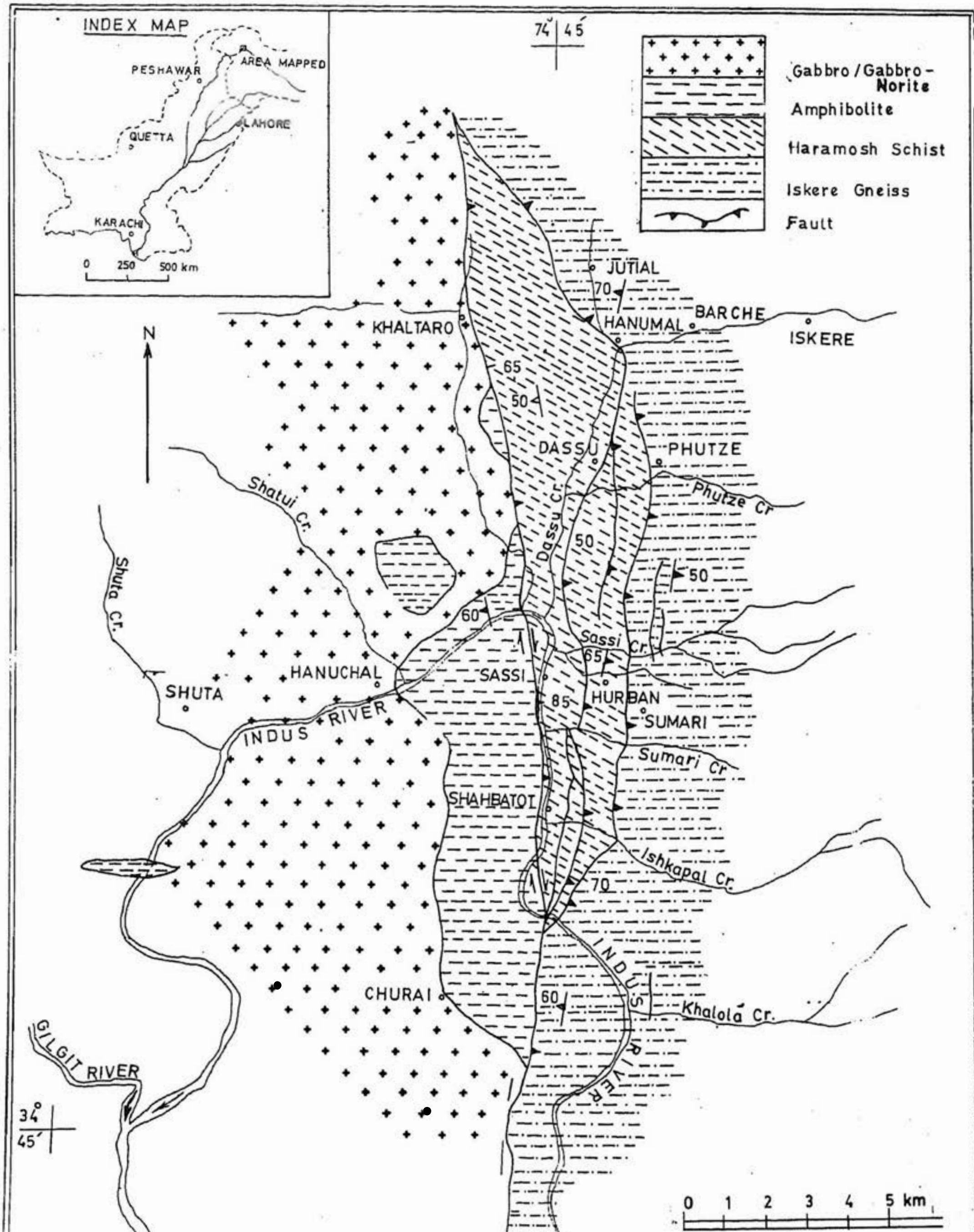

Fig. 1. Geological map of the study area.

Two tectonic zones with distinct lithologies occur in the studied area. West of the Raikot Fault, there are mainly metabasic rocks, with both relics and later intrusives of gabbroic composition. These rocks are a part of the Kohistan arc sequence (Tahirkheli et al., 1979; Bard, 1983). To the east of the Raikot Fault, i.e., in the core of the syntaxis, there are rocks of the Proterozoic basement of the Indian shield (schists, gneisses, and migmatites, together described as Nanga Parbat Group by Madin et al., 1989)

The Kohistan Sequence

The Kohistan rocks adjacent to the Nanga Parbat-Haramosh massif are mainly amphibolites, with minor interlayered units of feldspathic schists and gneisses. Additionally, there are gabbroic/gabbronoritic rocks with diverse field relations with the amphibolites (see later).

The Amphibolites: Both homogeneous and banded amphibolites occur in the studied area. The homogeneous amphibolites are massive to moderately foliated, and form tabular sheets (a few meters thick) interlayered with the banded amphibolites. They are medium to coarse grained, with plagioclase (An 50%) and amphibole being the principal minerals, though epidote and quartz may be in significant proportions in some rocks. Biotite, opaque minerals, rutile, sphene and apatite occur in minor/accessory amounts with traces of garnet in some cases. The plagioclase is mostly twined, subhedral and commonly embayed due to alteration of epidote and quartz. Amphibole occurs in subhedral to polygonal grains. Local intergrowths of amphibole and globular quartz have probably formed at the expense of clinopyroxene. At places, a light-coloured variety of amphibole (? tremolite), and opaque dust replaces the dark green amphibole. This replacement is considered to be associated with low-grade, shearing of the rocks following amphibolite facies metamorphism.

The banded amphibolites with alternating hornblende and plagioclase rich bands are generally finer grained than the homogeneous amphibolites. Modal composition of the two varities of amphibolites are broadly similar. In addition to sheets of homogeneous amphibolites, the banded amphibolites also contain interbedded marbles and feldspathic schists/gneisses.

Feldspathic Gneisses/Schists Interlayered with the Amphibolites: The feldspathic schist/gneiss unit interlayed with the amphibolites is an assemblage of strongly foliated rocks, consisting of muscovite schist, biotite gneiss, biotite-garnet gneiss and some highly deformed calc-silicate rocks and marble. The schistose component is rich in muscovite and is less competent as compared to the gneissose unit. The whole sequence is heavily crisscrossed by deformed pegmatite and tourmaline-granite veins.

The gneissic rocks are mineralogically similar to the gneisses of the Nanga Parbat-Haramosh massif on the other side of the fault. However, plagioclase (An 20%) is more abundant in these rocks and occurs in association with alkali feldspar and quartz. It is quite fresh and rarely shows twining and inclusions of biotite and muscovite.

Gabbroic/gabbronoritic rocks: Basic rocks of gabbroic to gabbronoritic composition are common within the amphibolites of the studied area. Field relations suggest two relative age groups for these rocks: 1) older gabbros/gabbronorites, which formed at least partly, the protolith to the amphibolites, and 2) younger gabbros/gabbronorites which intrude the amphibolites.

The gabbros/gabbronorites considered to be the precursors of amphibolites occur as weakly deformed relics within the amphibolites. These rocks form lense-shaped bodies of variable thickness (from a meter to a few tens of meters), enveloped around by the amphibolites. Similar occurrence of pod-like gabbro-gabbronorite bodies dispersed in amphibolites are also descirbed from the Kamila Amphibolite Belt, (Jan, 1979; Treloar et al., 1990). In the Chilas Complex, at places, there is a network of shear zones bearing amphibolites which enclose undeformed gabbronorite masses (Khan, 1988). Khan (1988) and Treloar et al. (1990) have suggested that it is the heterogeneous deformation in the form of anastomosing network of shear zones which produce field relations in which the amphibolites enclose pod-like bodies of relatively fresh gabbronorites.

The younger gabbros in the studied area form distinct intrusions cross-cutting the amphibolites. They are fresh, undeformed and are characterized by typical igneous textures, including euhedral to subhedral prismatic grains of plagioclase, pyroxenes and amphiboles. Although, unmetamorphosed, these gabbros are also hydrated to some extent, so that hydrous minerals such as amphibole and epidote are common constituents of these rocks.

Thin-section studies show textural and mineralogical similarities in the two types of gabbros. Plagioclase and clinopyroxene are the main constituents, with subordinate proportions of orthopyroxene, K-feldspar, amphibole, biotite, and oxide phases (including ilmenite and magnetite). Apatite is a common accessory mineral, found included in plagioclase. Plagioclase occurring in tabular subhedral crystals is relatively fresh and undeformed in the younger gabbros, whereas that of the older gabbros shows common mechanical twining, and local recrystallisation. Clinopyroxene occurs as tabular grains with a weak preferred orientation (shape fabric). It is augitic in composition, with abundant exsolved lamellae and blebs of orthopyroxene. Pink-green orthopyroxene is also found as discrete grains. K-feldspar is either in myrmekitic intergrowth with quartz or occurs as interstitial anhedral grains. Amphibole commonly envelops the clinopyroxene grains, but is also found associated with oxide phases, together with biotite.

The Nanga Parbat-Haramosh Group

The Nanga Parbat-Haramosh Group is divisible into two broad units; Iskere gneisses and Haramosh schists. In terms of field relations, the two units occur as interlayered tabular bodies, with mutually conformable contacts, which are in turn conformable to foliation and lithological layering.

The Iskere gneisses: These have been referred to as Nanga Parbat Biotite Gneiss by Tahirkheli (1979). These form a thick sequence of coarse-grained biotite-rich gneisses which make up the bulk of the Nanga Parbat-Haramosh massif. The long axis of the flattened augens of quartz and feldspar, and parellel alignment of biotite flakes give rise to the regional foliation S_1. From west to east this unit grades into a medium-grained, less competent biotite-gneiss with relatively higher proportions of muscovite. The contact of the two members is sheared but parallel to the regional foliation. Because of minor mineralogical differences, both types of gneisses have been mapped as a single unit. Further to the east, in the core of the syntaxis, the gneisses tend to grade into migmatites.

The Iskere gneisses are medium to coarse grained, well foliated and contain megacrysts of quartz and feldspar. The most common mineral assemblage is quartz + alkali feldspar +

plagioclase + biotite with traces of muscovite. These rocks are generally inequigranular with subrounded to anhedral grains of quartz, feldspar and plagioclase. Muscovite and biotite exhibit alignment with the attitude of foliation. Shearing and kinking of the individual grains is a common feature. Mortar texture signifying cataclasis is also seen in some sections.

Quartz is fine to medium-grained, and in some sections it is fractured and has been stressed along the fabric direction. Most commonly quartz grains show pressure shadows and undulose extinction. Alkali feldspar is commonly orthoclase which occasionally shows myrmekitic intergrowth with quartz.

Haramosh Schist: Schistose rocks from the study area belonging to the Nanga Parbat-Haramosh group are medium to coarse-grained. The most common mineral assemblage found in these rocks is muscovite + plagioclase + quartz + biotite. Garnet and sphene occur in traces. Muscovite is usually found as large, broken and polygonized flakes sometimes showing kinking. Alignment of muscovite and biotite gives rise to S_1 foliation. Quartz is normally present as flattened, fine-grained ribbons showing complete deformation. Plagioclase occurs as equant, anhedral grains or porphyroblasts with occasional twining and little deformation. Plagioclase porphyroblasts are usually wrapped around by S_1 foliation.

GEOCHEMISTRY

Samples of amphibolites and gneissose rocks of both types (including gneisses interlayrered with the amphibolites of the Kohistan arc sequence, hereafter referred to as the Kohistan gneisses, and the gneisses from the Nanga Parbat-Haramosh massif, referred to as Nanga Parbat gneisses), were analysed for major elements by X-ray fluorescence spectrophotometery (using a Shimadzu VF-310 XRF spectrometer in the NCE Geology, University of Peshawar). Total iron was determined as Fe_2O_3, and the weight percent of FeO was calculated using the method of Irvine and Baragar (1971). Results of the analyses (on anhydrous basis) are presented in Tables 1 and 3 for amphibolites and gneissose rocks, respectively. CIPW norms, Niggli values, and solidification, differentiation, felsic and mafic indices have been calculated through computer programmes, and are included in the tables.

Characteristic chemical features of amphibolites (Table 1) are their basic composition and constant concentration of Fe_2O_3. Samples SH-23 and SH-28 are characterized by having proportionally higher content of total iron, and thus plot in the field of tholeiites on AFM diagram (not given here). Rest of the samples are typically calc-alkaline, characterized by a non-enrichment trend comparable to that of the Kamila amphibolites (Jan, 1988) and the Chilas Complex (Khan, 1988; Khan et al., 1989). Chemical parameters of the amphibolites listed in Table 1, when employed graphically in a genetic context, suggest derivation from an igneous parent. The distribution of analyses points on Niggli al-alk vs c diagram and their concentration within the field defined for Karroo dolerites is noteworthy (Fig. 2). This indicates a basic igneous parent material for the derivation of these amphibolites. This view is further supported by the plots of Niggli c vs mg (Fig. 3), and c-mg-(al-alk) (Fig. 4). In both these diagrams the amphibolites plot as middle stage differentiates along the trend line of Karroo dolerites (Leake, 1964).

Similar variation trends signifying an igneous parentage have also been established for the amphibolites occurring west of the studied area in the Shergarh Sar area of Allai Kohistan (Shah, 1986), and the southern amphibolite belt of Kohistan (Jan, 1988).

TABLE 1. MAJOR ELEMENT ANALYSES OF AMPHIBOLITES FROM THE HARAMOSH AREA.

Sample No.	SH-4	SH-5	SH-16	SH-23	SH-28	SH-34	SH-36	SH-39
SIO_2	51.52	48.12	53.67	48.63	46.76	52.75	51.28	53.94
TiO_2	0.69	0.91	1.34	1.62	0.90	1.22	0.90	0.88
Al_2O_3	15.85	15.68	16.69	10.67	11.85	15.49	11.70	19.08
Fe_2O_3	2.19	2.41	2.84	3.12	2.40	2.72	2.40	2.38
FeO	4.87	7.30	4.01	11.41	10.70	6.28	5.13	2.80
MnO	0.13	0.16	0.14	0.16	0.15	0.13	0.15	0.10
MgO	4.79	5.80	3.81	7.04	7.93	4.93	9.17	3.68
CaO	10.90	11.06	7.00	10.58	10.89	8.69	9.00	7.07
Na_2O	3.23	3.76	3.44	0.75	2.17	4.24	2.25	4.68
K_2O	0.66	0.97	2.31	0.96	0.79	0.84	2.42	1.83
P_2O_5	0.24	0.17	0.49	0.14	0.08	0.28	0.23	0.30
Total	95.07	96.34	95.74	95.08	94.62	97.57	94.30	96.74
				C.I.P.W. NORMS				
Q	3.26	0.00	6.18	7.08	3.35	0.73	0.14	0.70
Or	4.10	5.95	14.26	5.97	4.67	5.09	15.16	11.18
Ab	28.75	23.94	30.40	6.67	18.36	36.77	20.19	40.93
An	28.19	23.92	24.31	24.10	20.32	21.27	14.61	26.51
Cpx	21.92	26.08	6.90	24.86	23.84	17.14	24.85	6.13
Hy	8.48	0.00	9.81	22.99	8.70	11.93	18.98	8.54
Ol	0.00	9.36	0.00	0.00	0.00	0.00	0.00	0.00
Mt	3.34	3.03	4.30	4.76	0.00	4.04	3.69	3.57
Hm	0.00	0.00	0.00	0.00	13.10	0.00	0.00	0.00
Il	1.38	1.79	2.66	3.24	0.32	2.37	1.81	1.73
Ap	0.55	0.39	1.12	0.32	0.17	0.63	0.53	0.68
Total	99.96	99.97	99.93	99.98	94.63	99.96	99.97	99.96
				NIGGLI VALUES				
al	25.00	23.00	29.00	15.00	16.00	24.00	17.00	33.00
c	31.00	28.00	22.00	27.00	27.00	25.00	24.00	22.00
fm	26.00	13.00	34.00	54.00	52.00	39.00	50.00	20.00
alk	9.00	10.00	14.00	3.00	6.00	12.00	9.00	17.00
si	137.00	119.00	161.00	117.00	106.00	140.00	128.00	158.00
qtz	1.00	121.00	5.00	5.00	−18.00	−8.00	−8.00	−10.00
k	0.12	0.15	0.32	0.48	0.18	0.12	0.43	0.20
mg	0.55	0.52	0.50	0.47	0.52	0.50	0.69	0.58
Diff Index	36.11	34.81	50.83	19.72	26.38	42.58	35.49	52.80
Soli Index	30.43	28.65	23.21	30.24	33.05	25.93	42.91	23.94
Fels Index	26.30	29.95	45.09	13.91	21.37	36.89	34.16	47.93
Maf Index	59.57	62.60	64.25	67.36	62.29	64.60	45.08	58.46

TABLE 2. COMPARISON OF AVERAGE COMPOSITION OF AMPHIBOLITES FROM THE PRESENT STUDY WITH THOSE OF THE KOHISTAN SEQUENCE.

Oxides (Wt. %)	1 (8)	2 (39)	3 (5)
SiO_2	50.83	49.16	52.36
TiO_2	1.06	0.80	0.86
Al_2O_3	14.59	14.45	17.77
Fe_2O_3	2.56	6.58	3.26
FeO	6.56	5.63	5.88
MnO	0.14	0.18	0.20
MgO	5.89	7.70	5.37
CaO	9.40	11.06	9.41
Na_2O	3.07	1.70	3.13
K_2O	1.35	0.10	0.40
P_2O_5	0.24	0.04	0.20

1. This report. 2. Allai Kohistan (Shah, 1986), 3. Kamilla (Jan, 1988).
Numbers in parantheses represent the number of analyses from which average is taken.

Close correspondence between the chemistry of average amphibolite from the studied area and those of Allai Kohistan and Kamila area (see Table 2) further supports their similarlity to each other. As such, the amphibolites occurring to the west of the Raikot thrust in the Nanga Parbat-Haramosh area are considered as the northward extension of the Kohistan amphibolites.

Major element analyses (on anhydrous basis) of 14 samples from gneisses are presented in Table 3. The first three analyses (SH–7, SH–10 and SH–33) represent the Kohistan gneisses interlayered with amphibolites. The remaining belong to Nanga Parbat-Haramosh group.

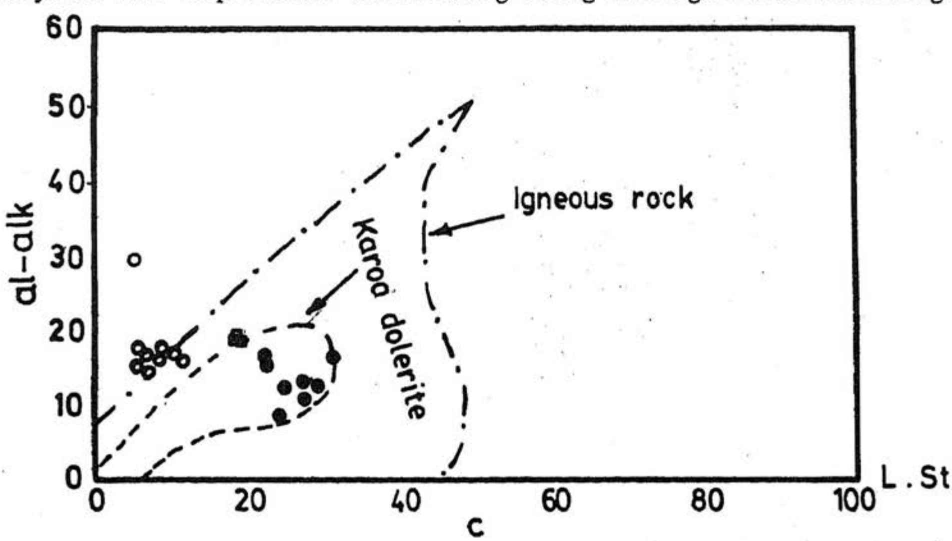

Fig. 2. Plot of Niggli al-alk vs c for the rocks of Haramosh area, after Leake (1964). Solid circles represent amphibolites, squares represent gneisses interlayered with amphibolites, and open circles represent gneisses from the Indian plate.

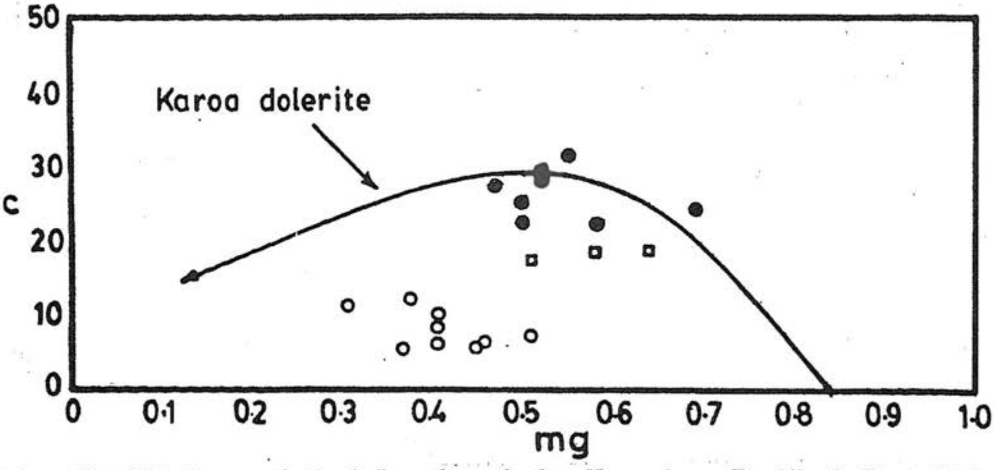

Fig. 3. Plot of Niggli c vs mg for the similar rock samples from Haramosh area. Trend line for Karroo dolerites after Leake (1964). Symbols same as in Fig. 1.

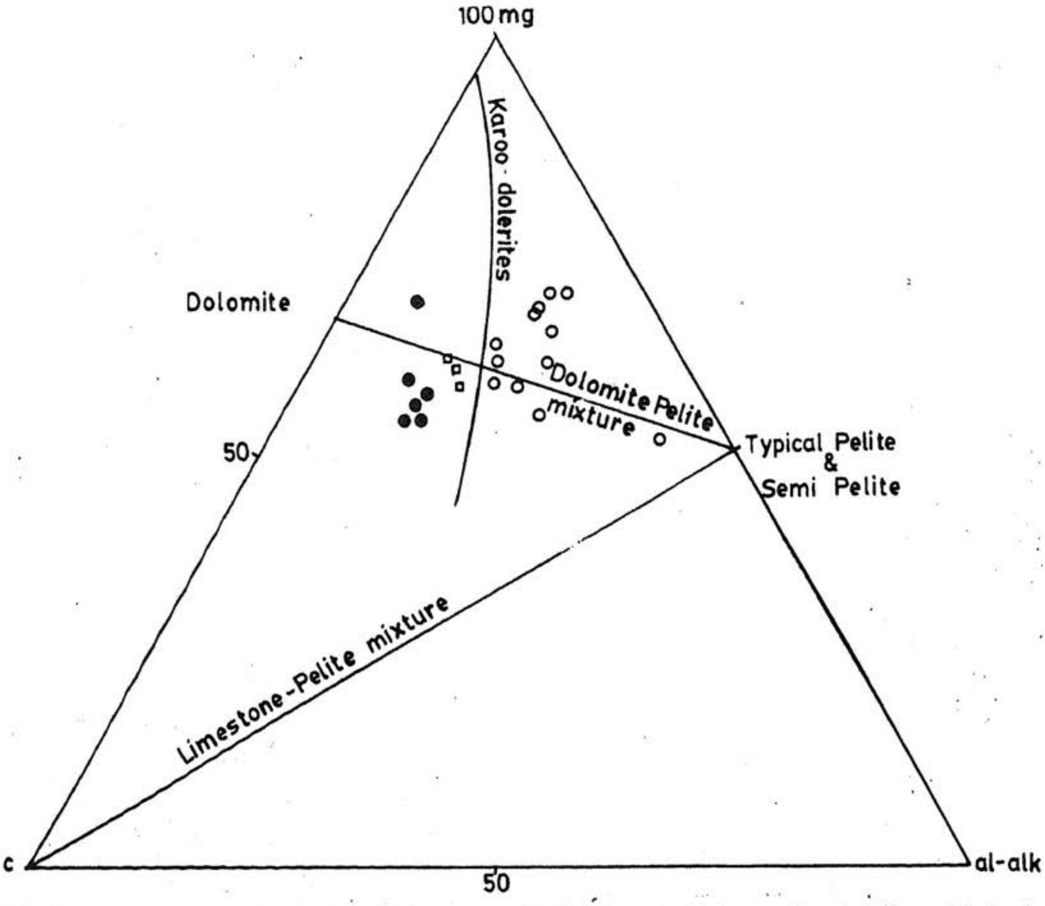

Fig. 4. Plot of mg-(al-alk)-c for the gneisses and amphibolites from the study area. Trend of Karroo doletites is after Leake (1964). Symbols same as in Fig. 1.

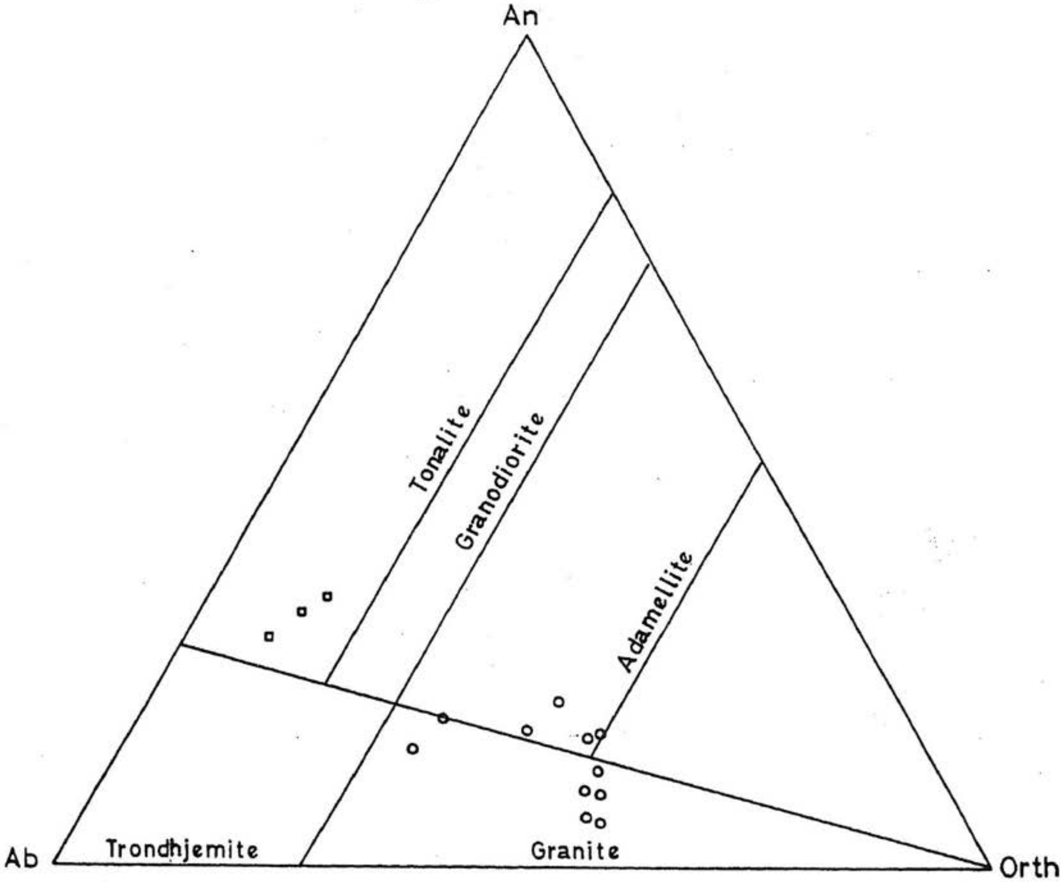

Fig. 5. Ternary plot of normative Anorthite-Albite-Orthoclase for the gneissose rocks from the study area. Boundaries after O'Conor (1965). Symbols same as in Fig. 1.

The two groups of gneisses differ considerabely in composition from each other in terms of the average Ab/Or and Ab+An/Or ratios.The Nanga Parbat gneisses have Ab/Or and Ab+An/Or ratios 7 times higher than the respective average values of the Kohistan gneisses (Table 4).

On the Normative Ab–Or–An diagram (Fig. 5), the Nanga Parbat gneisses classify as granite and adamellite whilst the Kohistan gneisses classify as tonalite. The chemical contrast between the two types of gneissic rocks is further exhibited in Figure 6 where selected oxides (weight %) have been plotted against the differentiation index (D.I). The chemical data of the amphibolite have also been included in Figure 6. It is interesting to note that the data points representing the Kohistan gneisses constitute a slightly scattered continuum of variation with the associated amphibolites at the high D.I. end. The distribution pattern of the data in Figure 6 signifies a genetic relationship between the amphibolite and associated gneissic rocks. Gneissic rocks from the Nanga Parbat-Haramosh group, on the other hand, constitute a distinct trend and remain isolated from the variation trend of the Kohistan amphibolite-gneisses in Figure 6.

TABLE 3. MAJOR ELEMENT ANALYSES OF SCHISTS AND GNEISSES FROM THE WESTERN MARGIN OF HARAMOSH AREA.

Sample No.	SH-7	SH-10	SH-13	SH-14	SH-17	SH-20	SH-21	SH-22	SH-24	SH-25	SH-26	SH-27	SH-33	SH-37
SiO_2	62.77	67.99	68.51	70.86	67.57	65.19	64.52	70.79	66.89	66.91	67.64	69.95	63.83	71.56
TiO_2	0.41	0.73	1.02	0.85	1.32	1.22	1.43	0.80	1.14	1.04	0.90	0.77	0.93	1.06
Al_2O_3	18.52	17.32	15.02	15.72	14.97	15.00	14.95	15.98	15.74	15.23	15.29	14.97	19.39	16.52
Fe_2O_3*	3.70	2.50	4.50	2.20	4.50	5.50	6.00	2.40	3.80	4.70	5.00	4..40	3.30	4.70
MnO	0.11	0.07	0.06	0.04	0.06	0.08	0.07	0.04	0.06	0.06	0.08	0.07	0.06	0.08
MgO	2.64	2.30	1.57	1.24	1.56	1.77	2.04	0.96	1.68	1.61	1.76	1.02	1.73	1.41
CaO	4.96	4.48	1.99	1.36	2.10	2.72	1.81	0.90	1.25	1.22	2.08	2.20	4.68	1.03
Na_2O	4.64	4.77	3.57	2.60	2.29	2.52	2.26	2.80	2.69	2.57	2.71	2.45	5.76	1.66
K_2O	1.62	1.34	2.79	5.41	4.91	4.36	4.80	5.70	4.97	4.93	3.90	4.98	1.17	3.44
P_2O_5	0.15	0.12	0.28	0.18	0.21	0.26	0.28	0.15	0.45	0.08	0.16	0.19	0.29	0.05
Total	99.52	101.62	99.31	100.46	99.49	98.62	98.15	100.52	98.58	98.35	99.52	101.00	101.14	101.51
C.I.P.W. NORMS														
Q	15.52	22.07	31.47	30.64	29.38	26.48	27.38	29.60	29.19	28.78	30.47	30.64	13.91	43.91
Or	9.62	7.79	16.60	31.82	29.16	26.12	28.90	33.51	29.79	29.62	23.16	29.14	6.84	20.03
Ab	39.45	39.72	30.42	21.90	19.48	21.62	19.48	23.57	22.40	22.11	23.04	20.50	48.19	13.34
An	23.74	21.10	8.10	5.55	9.09	11.96	7.29	3.47	3.31	5.62	9.32	9.58	21.08	4.71
C	0.48	0.16	3.20	3.53	2.59	1.84	3.48	3.91	4.94	3.70	3.23	1.98	0.82	8.19
Hy	6.61	5.64	3.94	3.07	3.91	4.47	5.18	2.38	4.24	4.08	4.40	2.52	4.26	3.46
Hm	3.72	2.46	4.53	2.19	4.52	5.58	6.11	2.39	3.85	4.78	5.02	4.36	3.26	4.63
Il	0.24	0.15	0.13	0.09	0.13	0.17	0.15	0.09	0.13	0.13	0.17	0.15	0.13	0.17
Ap	0.33	0.26	0.62	0.39	0.46	0.58	0.62	0.33	1.00	0.18	0.35	0.41	0.63	0.11
Ru	0.29	0.64	0.96	0.80	1.26	1.15	1.38	0.75	1.09	0.99	0.81	0.68	0.85	0.96
Total	99.98	99.98	99.96	99.97	99.97	99.96	99.96	99.98	99.94	99.99	99.98	99.97	99.96	99.99

NIGGLI VALUES

al	38.00	39.00	40.00	46.00	40.00	37.00	37.00	47.00	43.00	41.00	39.00	41.00	41.00	48.00
c	19.00	19.00	10.00	7.00	10.00	12.00	8.00	5.00	6.00	6.00	10.00	11.00	18.00	5.00
fm	24.00	21.00	26.00	18.00	26.00	29.00	32.00	16.00	25.00	27.00	28.00	23.00	18.00	28.00
alk	19.00	21.00	24.00	30.00	24.00	22.00	22.00	32.00	26.00	26.00	22.00	26.00	23.00	19.00
si	219.00	263.00	311.00	349.00	304.00	274.00	274.00	353.00	308.00	306.00	297.00	323.00	229.00	352.00
qz	43.00	79.00	115.00	129.00	108.00	86.00	86.00	125.00	104.00	102.00	109.00	119.00	37.00	176.00
k	0.19	0.15	0.34	0.57	0.59	0.53	0.59	0.57	0.56	0.55	0.49	0.56	0.11	0.57
mg	0.58	0.64	0.41	0.51	0.41	0.38	0.41	0.45	0.46	0.41	0.41	0.31	0.51	0.37
Diff. Index	64.58	69.58	78.48	84.35	78.01	74.22	75.75	86.67	81.37	80.51	76.66	80.29	68.92	77.97
Soli. Index	20.95	21.08	12.63	10.82	11.76	12.50	13.50	8.09	12.86	11.65	13.16	7.93	14.46	12.57
Fels. Index	55.79	57.69	76.16	85.48	77.41	71.66	79.59	90.42	85.84	86.00	76.06	77.15	59.68	83.19
Mafi. Index	58.35	52.08	74.13	63.95	74.25	75.65	74.62	71.42	69.34	74.48	73.96	81.18	65.60	76.92

*Total iron expressed as Fe_2O_3.

TABLE 4. AVERAGE Ab/Or AND Ab+An /Or RATIOS OF THE GNEISSIC ROCKS FROM THE HARAMOSH AREA.

Sample No.	Ab/Or ratio	Ab+An/Or ratio
SH–7	4.10	6.56
SH–10	5.09	7.80
SH–33	7.04	10.12
Average	5.41	8.16
SH–13	1.83	2.32
SH–14	0.68	0.86
SH–17	0.66	0.97
SH–20	0.82	1.28
SH–21	0.67	0.92
SH–22	0.70	0.80
SH–24	0.75	0.86
SH–25	0.74	0.93
SH–26	0.99	1.39
SH–27	0.70	1.03
SH–37	0.69	0.92
Average	0.84	1.11

SH 7–33 : Gneisses interlayered with amphibolites.

SH 13–37 : Indian plate gneisses.

TABLE 5. COMPARISON OF AVERAGE COMPOSITION OF GNEISSES FROM THE HARAMOSH AREA WITH THOSE FROM ALLAI KOHISTAN AND MANSEHRA GRANITE.

Oxides (Wt %)	1 (14)	2 (10)	3 (6)	4 (15)
SiO_2	67.49	67.33	70.77	71.79
TiO_2	0.98	0.12	0.88	0.39
Al_2O_3	16.04	18.01	15.02	14.49
Fe_2O_3*	4.09	3.31	4.24	2.91
MnO	0.07	0.08	0.10	0.05
MgO	1.66	1.07	0.80	0.73
CaO	2.34	0.98	1.28	1.01
Na_2O	3.09	4.00	2.86	2.87
K_2O	3.88	4.47	3.92	4.55
P_2O_5	0.20	—	0.21	0.10
Total	99.84	99.37	100.08	98.89

1, 2. Nanga Parbat feldspathic gneisses (1. This report; 2. from Shams and Ahmed, 1979). 3. Granitic gneisses from the Shergarh Sar area, Allai Kohistan (Shah, 1986). 4. Mansehra Granite (Le Fort et al., 1980).

Numbers in parentheses represent the number of analyses from which average is calculated.

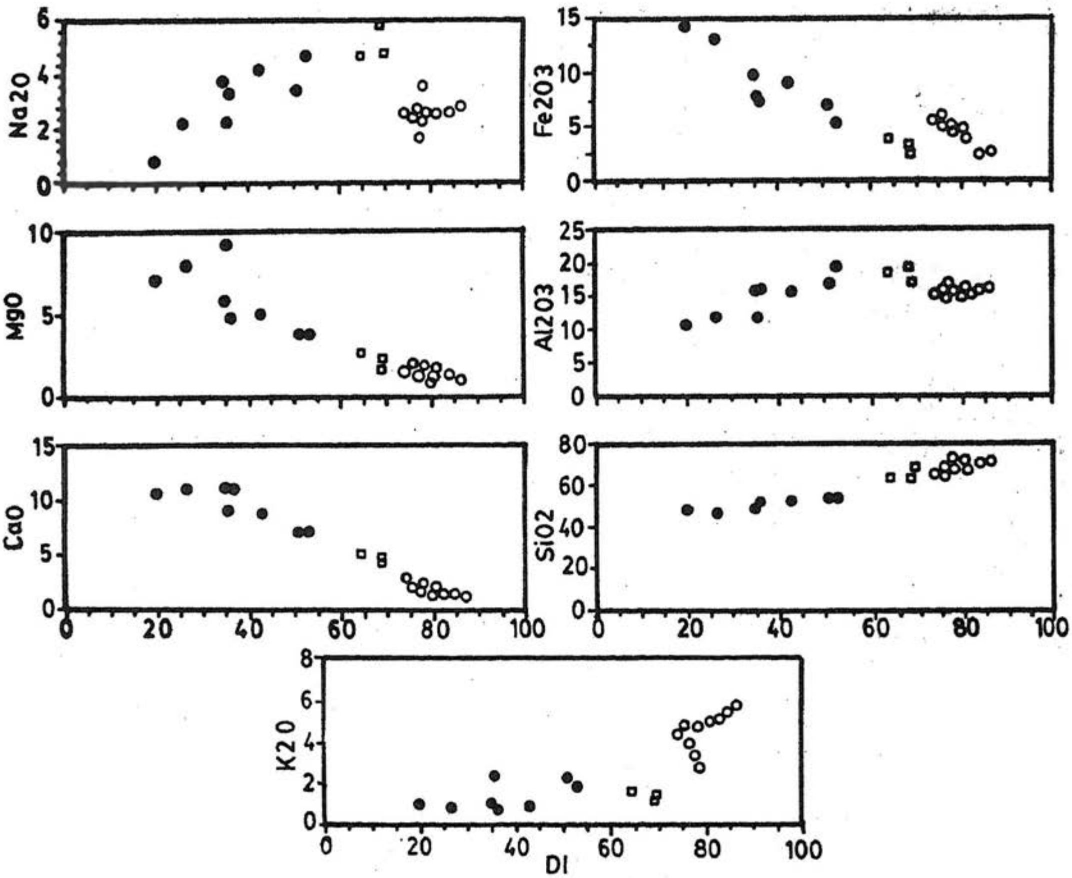

Fig. 6. Plots of Na_2O, Fe_2O_3, MgO, Al_2O_3, CaO, SiO_2, and K_2O vs Differentiation Index of Thornton and Tuttle (1960) for the rocks of Haramosh area. Symbols repeated.

Feldspathic gneisses similar to those of the Nanga Parbat-Haramosh massif are commonly found in the internal zone (Coward et al., 1988) of the Indian plate, where the basement rocks are involved in thrusting. The Nanga Parbat-Haramosh gneisses are compared with apparently equivalent rocks in the Allai Kohistan southwest of the studied area (Shah and Majid, 1985; Shah, 1986; Ashraf et al., 1980). Ashraf et al., (1980), on the basis of field observartions, described the granite gneisses of the Indo-Pakistan subcontinent sequence in Allai Kohistan as part of the Mansehra granite (516 Ma old granites intruding the basement slate of the Indian plate in the upper Hazara region; Le Fort et al., 1980). Shah (1986) further signified the equivalence of the granite gneisses of Allai Kohistan with Mansehra granite through a chemical comparison (analyses reproduced in Table 5). A comparison of the Nanga Parbat gneisses with those of the Allai Kohistan and Mansehra shows notable differences in the concentration of Al_2O_3, Na_2O, CaO, MgO and SiO_2. These chemical differences are a reflection of differences in time and mode of origin (R. Zartman, personal communication).

The molecular $Al_2O_3/Na_2O + CaO + K_2O$ ratio of 1.1 for the Nanga Parbat-Haramosh gneisses calssify these rocks as I-type granite according to the criteria proposed by Chappel and White (1974). This granitic magmatism is attributed to a Proterozoic orogenic episode (Valdiya, 1983) about 1.8 billion years ago (U/Pb dating on Zircon, Zeitler et al., 1989). On the other hand, the Mansehra granite and gneisses from Allai Kohistan have a molecular $Al_2O_3/Na_2O + CaO + K_2O$ ratio of 1.3, suggesting an S-type origin. This diversity of origin, coupled with substantial differences in ages, may account for the observed chemical differences between the Nanga Parbat gneisses and the gneisses from Allai Kohistan and Mansehra.

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