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PETROGRAPHY OF THE LOE SHILMAN CARBONATITE COMPLEX, KHYBER AGENCY

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ABSTRACT

The Shilman complex comprises sill-form bodies emplaced along a fault zone in Palaeozoic to Precambrian metasedimentary rocks. The largest outcrop is 2.5 Km long with a width of 170 m in the central part. The rock-types of the complex include altered (meta)gabbros/dolerite, followed by amphibole–apatite–, biotite/phlogopite–, and dolomitic carbonatites, syenites and lamprophyric rocks, and Fe–rich hydrothermal veins. The syenitic rocks have locally been intruded and brecciated by light-coloured sovitic veins. It is suggested that the basic rocks might be related to the rest of the complex.

The country rocks (slates, phyllites, mica scists, recrystallized limestone and quartzite) have been regionally metamorphosed up to the biotite zone of Barrovian. They display, locally, considerable fenitization with development of alkali pyroboles, phlogopite and alkali feldspars. The complex is a westward extension of the over 200 Km arcuate belt of alkaline complexes found around the northern half of the Peshawar Plain and intruded during Early Tertiary along faults resulting due to the collision of the Indo-Pak plate with Eurasia.

INTRODUCTION

The carbonatite complex comprises sill-like bodies of carbonatites and related rocks emplaced in metasediments near Loe Shilman (71° 9½′ E, 34° 27′ N) in the northwestern part of Khyber Agency. The main complex, exposed along the E-W-running Garang stream, measures 2.5 Km in length, with a maximum breadth of 170 m in the central part. Five kilometers to the east of this body, and co-linear with it, there are additional outcrops of carbonatite and syenite near Kunaster village. The intervening alluvium-covered area contains isolated outcrops of metasediments with small sills of carbonatite. The existence of carbonatite is expected, as also suggested by radon monitoring, under the alluvium. To the W the main complex extends into Afghanistan just in the E of Kabul River, where it has yet not been studied. Further west it submerges under Kabul river bed.

The complex, apparently, is an extension of the Early Tertiary alkaline igneous province of NWFP extending from Warsak to Tarbela and, possibly beyond into Mansehra (Kempe and Jan, 1970; Kempe, 1973). The various alkaline complexes (Tarbela, Utla-Koga-Ambela, Shewa-Shahbazgarhi, Malakand, Warsak, and Shilman) occur in an arcuate fashion around the Peshawar Plain and it is likely that they are associated with "rifting" or graben (Kempe and Jan, 1980; S.K. Kakar, pers. comm.).

The Shilman complex is emplaced along an E-W-trending and N dipping fault zone separating (?)Palaeozoic rocks in the N from (?)Precambrian slates in the S. The country rocks are a westward continuation of those of the Warsak area described in detail by Ahmad *et al.* (1969). The outlines of the main complex show some evidence of faulting, against calcareous rocks in the N and against slates in the S. However, the presence of small carbonatite sills, hydrothermal veins (probably related to the carbonatites), and fenitization in the country rocks suggest that movement along these faults post-dating the intrusive activity must have been very little. Perhaps minor adjustment continued along the major fault after the emplacement of the complex.

The various rocks of the complex and its vicinity can broadly be grouped into the following types.

6. Late stage hydrothermal veins	)	
5. Lamprophyric rocks	)	
4. Syenitic intrusion(s)	)	Carbonatite Complex
3. Carbonatite intrusions	)	
2. Basic sills		
1. Metasedimentary country rocks		

This paper presents a brief petrography of the complex and is based on thin-section study of over 110 samples from outcrops as well as boreholes. In some of the rocks the minerals were studied in some details optically. The only available geological data on the area are the preliminary petrographic accounts by Majid (1976), Shah (1978), Khan and Shah (1979), Kempe and Jan (1980), and the report on phosphate potential of the area by Ahmed and Ali (1977). This paper does not deal with the economic aspects of the complex, however, minerals like pyrochlore, strontianite or Sr–rich calcite, and apatite are worth mentioning. The mineral called pyrochlore in this paper has been identified by Rehman (1980) as betafite. The readers are referred to the paper by Butt (this volume) for additional data on the pyrochlore.

Country Rocks

The country rocks include slates, phyllites, mica schists, recrystallized limestones, and quartzites. The presence of biotite, muscovite, epidote, chlorite, tremolite, and albitic plagioclase in the metasedimentary country rocks suggests metamorphism in the greenschist facies. In general, the grade of metamorphism appears to increase northwards and garnet has been found 1 Km to the north; however, there is no evidence to suggest that regional metamorphism surpassed the greenschist facies. In the Warsak area, 30 Km to the E, also, conditions of metamorphism (Kempe, 1978) were more or less similar (T = 465°C). In the vicinity of the complex, higher grade may have prevailed due to contact metamorphism. The mineral assemblages in various metasediments are just the usual Barrovian type and are not discussed any further.

Interesting is the occurrence of banded metasedimentary rocks in the environs of the complex. These rocks, in addition to the usual metamorphic minerals such as quartz, white and dark micas, carbonate, opaque minerals, sphene, apatite, and zircon, may contain alkali pyroxene, alkali amphibole, and alkali feldspars. In a few rocks, two varieties of amphibole, a strongly pleochroic alkali type and a very light green type are also seen. The presence of the alkali minerals in these rocks, and also of alkali amphiboles in the slates, suggests alkali metasomatism (fenitization). Thin veins containing various combinations and proportions of phlogopite/biotite, feldspars, quartz, amphibole, and aegirine also suggest connection with the complex. Modal composition of two banded rocks is given below:

KAS–16

Bio-Mus band with Qz and Ab

Bio-Ab-Qz band with a little Mus and traces of Ore/Rt (½ mm)

Bio-Ab-Qz band with traces of Ore/Rt (½ mm)

Bio-Ab-Qz-Ab band with traces of Ore/Rt (½ mm)

Ab-Bio-Qz-Ore-Sph-Mus band, coarser grained than above (5 mm)

Ab-Qz-Alk Amph-Aeg– CO_3– Sph-Ore- ? Zir band (3 mm)

Ab-alk Amph-Bio-Sph-Qz-Ore-Mus band, very fine-grained and with amph porphyroblasts (1 mm)

Ab-Qz-Alk Amph– CO_3–Aeg-Sph band

KASC 43–7/78

Alk Amph Qz-Plg-Micr-Bio band

Bio-Plg-Qz-K-fels-CO_3–Ore band (3 mm)

Alk Amph-Qz-Plg-Bio-Ore band (1 mm)
Bio-Qz-Plg-Orth-Ore band (2 mm)
Alk Amph-Bio-Qz-Plg-Ore band (1 cm)
Bio-Qz-Plg-Micr-CO_3–Zir band (½ mm)
Alk Amph-Bio-CO_3–Qz-Plg band (2½ mm)
CO_3– alk Amph-Bio-Ap-fels-Qz-Ore band
(minerals above are arranged in decreasing order of abundance).
(For mineral symbols, see explanation under Table 1. Thickness of the bands is indicated in parentheses).

Basic Rocks

Gabbroic and doleritic rocks, arbitrarily divided on grain-size basis, occur in sills generally up to a few meters thick. They do not occur in the area covered by the main complex but are found in the east and north in the country rocks. Some dolerites have distinct parallel fabric and may thus be older than the carbonatites. Although no geochemical data is yet available there is a possibility of a direct or indirect relationship between these rocks and the carbonatites, as evidenced by the presence of basic rocks in a number of alkaline complexes of NWFP. In Warsak, (Ahmad *et al.,* 1969; Kempe, 1978), Shewa-Shahbazgarhi (Martin *et al.,* 1962), Ambela (Ahmad and Ahmed, 1974) and Utla (Khan and Hammad, 1978) basic rocks associate (alkaline) acidic rocks. In Koga (Buner), dolerites are found in Chingalai granodiorite which forms a part of the alkaline complex (Siddiqui *et al.,* 1968). At Tarbela, gabbroic rocks, alkali granites and microgranites, albitites, and carbonate-albite rocks constitute yet another interesting complex (Kempe and Jan, 1970, Jan *et al.,* 1981). It is thought here that this consistent close association of basic rocks with various types of alkaline rocks means more than just an accidental occurrence.

The Shilman basic rocks are composed of amphibole, plagioclase, biotite and varying amounts of ore, quartz, epidote, apatite, sphene, etc. (Table 1). The rocks are variably altered and metamorphosed and resemble the gabbro-dolerites of the Warsak area (Ahmad et al., 1969; Kempe, 1973) and also those of Tarbela (Jan et al., 1981) except for a higher degree of metasomatism in the latter area.

The amphibole, 30 to 60%, is generally of two types: an earlier (primary) brown or brownish green hornblende and a later, more abundant, pale to blue green type. The latter is clearly secondary, with relics of the former, as well as of pyroxene in some cases. The alteration may be due to late magmatic/autometasomatic process or/and regional metamorphism. Much of the biotite and some other minerals are also replacive and have secondary textural features. The alteration process has substantially reduced the quantity of plagioclase.

TABLE 1. MODAL COMPOSITION OF THE BASIC ROCKS

Sample No.	Amph	Plg	Bio	Ore	Qz	Epi	Ap	Sph	CO_3	Others
KAS G–1 gabbroic	50	35	5	Tr	—	—	2	—	Tr	Cpx (7) Micropegm (1)
KAS G–2 gabbroic	30	41	8	5	9	Tr	3	Tr	2	Kf (2) in Micropegm
KAS G–3 doleritic	45	30	10	1	6	1	2	5	—	
KAS–6 gabbroic/ doleritic	35	17	15	5	3	15	2	7	1	Bio includes Chl
KAS–8 doleritic	60	17	8	10	Tr	—	Tr	5	—	
KAS–8A gabbroic	45.0	8.9	9.3	12.5	7.6	6.8	1.8	—	1.1	Chl (6.8)

In this and subsequent tables, modes expressed decimally are point counted whilst those in whole members are visual estimates.

Symbols indicate: Ab = albite, Aeg = aegirine/aegirine augite, Amph = amphibole, Ap = apatite, Bio = biotite, Chl = chlorite, CO_3 = carbonate(s), Epi = epidote, Kf = K–feldspar, Micr = microcline, Mona = Monazite, Mus = muscovite, Or = orthoclase, Ore = opaque Fe–minerals(s), Per = perthite/antiperthite, Phl = phlogopite, Plg = plagioclase, Pyr = pyrochlore, Qz = quartz, Rt = rutile, Ser = sericite, Sph = sphene, Zir = zircon.

Carbonatites

The carbonatites, making much of the complex, are generally medium-grained and hypidiomorphic. Porphyritic texture is common in the biotite/phlogopite type but rare elsewhere. They are generally weathered on surfaces and commonly contain carbonate and quartz veins; but carbonatite breccia, suggesting explosive activity of CO_2, is only locally present. A common feature of the rocks is compositional variation due to layering, banding and segregation. The layers, in general conformity with the country rocks, trend E-W with steep northwards dips.

Although distinct parallel fabric, suggesting deformation, is seen in some marginal carbonatites, the texture and mineralogy of the rocks do not indicate large-scale metamorphic recrystallization. Metamorphism in the area was up to the biotite grade (below the top (garnet) zone of the greenschist facies); such conditions are not capable of producing parageneses found in the Shilman complex. Similarly, there is no evidence that the entire complex has been emplaced by faulting from a deep-seated metamorphic zone. Therefore, it is suggested that the layering was produced by the *in situ* differentiation of carbonatite magma, but it may locally have been modified by deformation. This, coupled with the high dip-angles of layering, lead to think that the complex has been tilted due to regional folding by more than 50° since its solidification.

The carbonatites are mainly composed of calcite or dolomite but other carbonates (Sr-calcite or strontianite, siderite) have also been found. Other minerals include apatite (almost ubiquitous), alkali pyroboles, biotite/phlogopite, sphene, opaque Fe-minerals, alkali feldspars, quartz, pyroclore, (?)monazite, and zircon. The pyrochlore tends to be associated with mafic minerals, which makes the mafic segregations favourable for its search. It usually forms cubic grains, yellowish, brown to almost opaque in thin section. In certain cases brown pyrochlore envelopes on opaque core; this may be due to zoning or alteration. (For additional details, see Butt, 1981). The rocks are frequently traversed by calcite and quartz veins. Also seen are veinlets of apatite, opaque ore, and of biotite/phlogopite which may have apatite, ore and amphibole.

Although in some carbonatites it has been suggested that strontianite and witherite have exsolved from calcite/dolomite (Heinrich, 1967), the textural features of the Sr–carbonate and calcite, when found together in Shilman, suggest direct crystallization of the two from the magma. The amphibole of the carbonatites is pleochroic in shades of blue and green and optical data indicate that it ranges from magnesio-riebeckite to magnesio-arfvedsonite. In some the amphibole is zoned, whilst in a few rocks a colourless or very pale green (?) magnesio-hornblende may also occur, sometimes in the cores of alkali amphibole. The alkali pyroxene is generally aegirine-augite with $Fe^{3+} < 0.4$ per formula unit on the basis of six oxygen; however, in some rocks it may be aegirine. The dark mica may be phlogopite or biotite; in a number of rocks it has a deep orangey colour and may thus be Ti-phlogopite (Deer *et al.*, 1963). The latter, usually, has a reverse pleochroic scheme ($\alpha > \gamma$) compared to common biotite ($\gamma > \alpha$) and, thus, looks like astrophyllite under the microscope. Apatite may be fractured, filled with carbonate, and in some cases is concentrated in patches.

On field and petrographic grounds, the carbonatites can be divided into at least three types. Amphibole-apatite variety, the most extensive and containing more pyrochlore, forms the earliest phase. This was followed by biotite-phlogopite carbonatite found in the form of patches in it. The third variety (dolomitic carbonatite) is rich in Sr, devoid of pyrochlore, and occurs principally in a band along the southern margin of the complex, but also as veins and dykes in the other carbonatites as well as in the country rocks in the south. There, apparently, has been another late phase sovitic carbonatite activity found in the form of light-coloured veins and dykes, and responsible for the local brecciation seen in the syenitic rocks (Fig. 1).

Amphibole-apatite carbonatites: These rocks show a greater degree of layering than the other carbonatites; thus a variety of rocks ranging from apatite carbonatites (Ap > 7% > Amph) to amphibole carbonatites (Amph > 7% > Ap), apatite-amphibole carbonatites (Amph and Ap > 7% each), pure carbonatites, i.e., sovites (carbonate ≧ 90%), and mafic to ultramafic silicate bands have been produced. Almost all the carbonatites are essentially composed of carbonate(s), amphibole and apatite, with a variety of other minerals (see Table 2).

TABLE 2. MODES OF LAYERED AMPHIBOLE-APATITE CARBONATITE

Sample No.	CO_3	Amph	Ap	Ore	Bi	Phl	Others
Ap-Carbonatite							
KAS–2	88.8	1.0	8.5	—	—	—	Aeg (1), Kf (0.4), Plg (0.3), Zir (Tr)
KAS–21A	75.0	—	9.3	8.6	7.0	—	Traces of Epi & Zir
KAS–25	87	1	10	1	—	—	Unidentified turbid mineral (1)
KAS–22	77.2	3.3	11.8	7.6	Tr	—	Traces of Rt & Zir
KAS–37	87.4	Tr	10	1.5	—	Tr	Traces of Zir, Pyr and (?)Mona
KASC 23–6/77	83	4	8	4	—	Tr	Sph (Tr), Mona (Tr)
KASC 23–11/77	89.6	1.0	8.9	0.3	0.2	—	Trace of Zir
KASC 23–17/77	80	5	10	4	—	—	Traces of Sph and Pyr/Mona
KASC 29–7/77	80.1	2.6	7.0	1.4	—	6.7	Aeg (1.0), Sph, (Tr)
KASC 49–10/77	82	7	9	1	—	1	Traces of Sph
KASC 54–1/78	77.1	5.8	10.6	4.0	—	2.5	Traces of Sph & Pyr
KASC 54–6/78	59.6	4.8	27.8	Tr	—	7.6	Traces of Epi, Sph, and Zir
KASC 66/79	86.3	2.7	8.0	1.0	—	1.8	

Ap-Amph carbonatite							
KASC 25–11/78	71	8	17	2	—	2	Traces of Pyr
S–4	62	10	25	Tr	—	2	Traces of Pyr
KAS–24	66	10	15	2	7	—	Traces of Zir
KAS–31	46.6	23.1	14.2	16.0	—	—	Traces of Sph, Pyr, (?)Mona
Amph carbonatite							
S–11	70	16	3	2	—	2	Aeg (7), Pyr (Tr)
KASC 56–2/78	87	10	Tr	2	—	1	Traces of Pyr
"Pure" carbonatite							
S–1	99	—	—	Tr	—	—	Epi (1), Pyr (Tr)
S–2	99.8	—	0.1	0.1	—	—	Traces of Zir
KAS–3	96.3	1.1	2.1	0.5	—	—	
S–8	97	Tr	2	Tr	Tr	—	
KAS–21	99.8	Tr	—	Tr	—	—	
KAS–27	99.2	Tr	Tr	0.7	—	—	Epi (Tr); ~ 10% CO_3 is sideritic
KAS–35	93.7	—	1.0	5.3	—	—	Traces of Pyr & Zir
KASC 23–10/77	90	2	5	2	—	Tr	Sph (1), Mona (Tr)
KASC 23–8/77	99	Tr	—	1	—	—	
KASC 29–15/77	90.7	2.3	2.9	2.7	1.2	—	Traces of Plg, Epi and Pyr
KASC 56–6/78	96	Tr	Tr	3	—	—	Trace of Mona and Zir
KAS–24	93	—	6	1	—	—	More than half the CO_3 is sideritic.
KASC 25–6/78	91	3	—	4	—	2	Tr of Plg, Epi, Pyr

Dark mica, usually Ti-bearing phlogopite, is usually less than 3% but in some up to 8%. The carbonate is usually more than 70% except in the apatite-amphibole type. It is commonly represented by only one kind, however, a biaxial variety (of ? calcite) is noticeable in a number of rocks. In a few rocks, a clear and a red-stained (? siderite) variety are closely associated, the latter sometimes "zoned" by the clear variety. Iron ore minerals are consistent accessories of the rocks.

The pure carbonatites (sovites) are whitish to grey rocks, locally sacchoroidal, and occur as patches and segregations within the rest. Although Majid

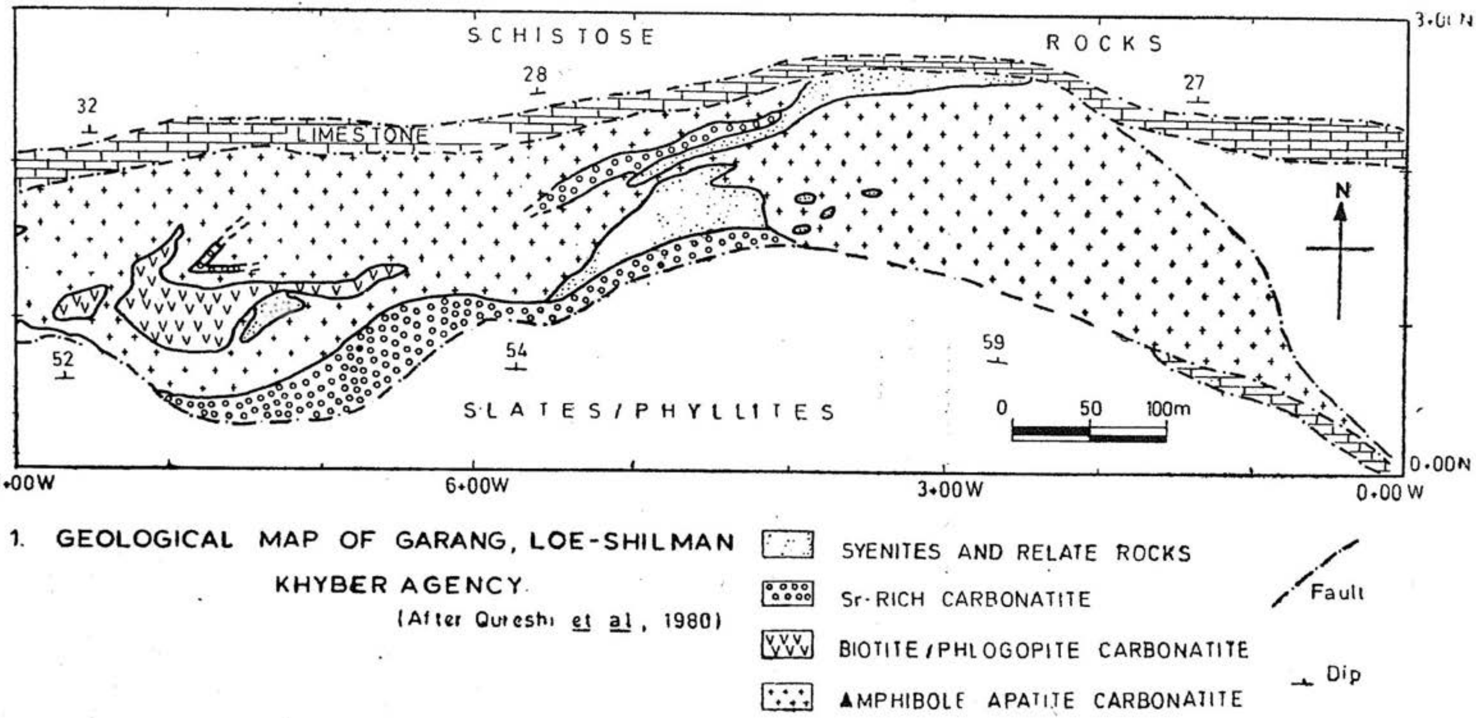

FIG 1. GEOLOGICAL MAP OF GARANG, LOE-SHILMAN KHYBER AGENCY

(After Qureshi *et al*, 1980)

(1976) and Shah (1978) have described them as a separate phase of carbonatites, we have not been able to see clear intrusive relations between them and the rest. However, the sovitic rocks intruding the syentics are an exception. A cursory look on the Table 2 suggests that the subdivisions of the apatite-amphibole carbonatites are arbitrary; the various subtypes clearly show mineralogical gradations.

Table 3 presents the modal composition of ultramafic silicate segregations and layers which are generally thin (a few centimeters). In these, carbonate is up to 25% whilst dark mica, alkali amphibole or alkali pyroxene may reach 45% to 50%. It is worth noting that whilst in the carbonatite "layers" sodic pyroxene is lacking (except in three rocks), in most ultramafic bands it is an important constituent. On the other hand, the quantity of opaque iron oxide is generally lower in these bands than in the carbonatites.

TABLE 3. MODES OF MAFIC-RICH SEGREGATION BANDS/LAYERS

No.	Amph	Aeg	Phl/Bio	Ap	CO_3	Ore	Sph	Others
KASC 23–15/77	45	—	20	9	25	1	—	Traces of Pyr
KASC 25–9/78B	42	—	37	5	15	1	—	Traces of Pyr
KASC 25–13/78B	15	40	30	6	5	< 1	Tr	Plg (2), Pyr (Tr)
KASC 49–2/78	Tr	7	48	20	10	< 1	10	Fels (5), Pyr (Tr)
KASC 49–9/78	—	51	30	4	15	—	Tr	
S–5 A	5	50	25	4	14	< 1	Tr	Plg (1–2)

Biotite/Phlogopite carbonatites: These rocks occur in patches of varying but small sizes in the amphibole-apatite carbonatites with which they have distinct intrusive contacts. They are generally medium-grained and dark brownish in colour, and show obvious effects of solution activity. Dark mica (usually biotite but in a few, e.g. C 23-27/77, phlogopite) in these rocks may be phenocrystic and is usually 20% to 45% but in some it is as low as 10%, whilst the carbonate ranges from 45% to 75% (Table 4). Apatite and amphibole are generally less than in the above-described type but feldspars are found more frequently. The feldspar may be represented by perthite, microcline, and/or albite. Amphibole is pale green to green pleochroic whilst apatite may sometimes be concentrated in patches or along fractures.

TABLE 4. MODAL COMPOSITION OF BIOTITE/PHLOGOPITE CARBONATITE

Sample No.	CO_3	Bio/Phl	Ap	Ore	Kf	Plg	Amph	Others
S–9	70	20	5	1	3	Tr	—	Traces of Zir & Epi
KAS–41	75	20	3	Tr	—	1	—	Sph (1), Zir (Tr)
KASC 23–27/77	46	45	Tr	Tr	5	Tr	3	Trace of Sph
KASC 43–3/78	55	40	2	Tr	1	2	—	Trace of Sph
KASC 68–1/79	49	30	5	1	—	—	15	Trace of Sph
KASG–6	75.0	10.0	2.0	7.3	4.5			Traces of Epi and Zir. At least 15% CO_3 is siderite
KAS–32	70	10	5	2	—	5	—	Aeg (8), Sph (Tr)

Dolomitic Carbonatites: These rocks were briefly described by Shah (1977) as strontium-bearing carbonatites. They occur principally in a band of varying thickness along the southern margin of the main carbonatite complex, but outcrops of these rocks are also found in the other two carbonatites. The rocks are compact, generally reddish brown (due to Fe-leaching), having a higher density than the other two types, and at least locally banded. There is nothing exceptional about their mineral composition (Table 5) but their high density suggests the presence of Sr-bearing carbonate (strontianite and witherite ?) as is also suggested by the 2V determinations and refractive indices. Other minerals in these rocks include dolomite, apatite, phlogopite, alkali pyroboles and Fe-ore.

TABLE 5. MODAL COMPOSITION OF DOLOMITIC SR–RICH CARBONATITE

No.	CO_3	Ap	Phl	Na– Amph	Aeg	Ore
S–5	88	2	2	3	—	5
S–6	81	5	1	2	1	10
S–7	90	15	2	—	—	2
KAS 40	70	15	2	10	—	2 Tr of Mona

Syenitic Rocks

Small syenitic intrusions, locally attaining a thickness of 60m, occur as elongated intrusions in the eastern part of the main complex as well as near Kunaster village. They are generally medium-grained but a few are either coarse or fine-grained and porphyritic. In a number of places they have a high proportion of mafic minerals and look dioritic. Locally they may have a higher amount of mafic minerals and such rocks bridge the gap between syenites and lamprophyric rocks described below. The rocks also contain small patches of pegmatitic aspect with up to 25% quartz (KAS33 and C33-2/788), as well as alkaline micrograniltic "veins".

The rocks are composed of alkali feldspars (perthite, antiperthite, microcline, sodic plagioclase) and varying amounts of alkali pyroboles, carbonate, and small amounts of a number of other constituents including rutile, sphene and zircon (Table 6). In some cases, the alkali amphibole appears to replace alkali pyroxene. The latter may be zoned with bright, bluish to green pleochroic cores; in one case aegirine contains purplish Ti-augite cores (KAS–48).

TABLE 6. MODES OF SYENITES, AND COARSE LAMPROPHYRIC & GRANITIC PATCHES

No.	Fels	Aeg	Na–Amph	Bio/Phl	Qz	Ap	Ore	CO_3	Others
X	92	1	3	Tr	? Tr	3	—	—	Tr of Sph and Rt
B	60	13	20	—	—	5	1	—	Sph (1)
KAS 17	48	40	5	—	? < 1	3	Tr	2	Sph (1), Tr of Pyr
KAS 43	70	15	4	2	1	4	—	2	Sph (1), Tr of Ser
KAS 18	58	24	7	Tr	1	3	Tr	6	Sph (1), Tr of Epi, Rt
KAS 20	68	17	8	Tr	? Tr	2	Tr	4	Sph (1), Tr of Zir and Rt
KAS 33	43	28	20	—	? Tr	2	Tr	5	Sph (2)
KASC 33–2/78B	44	20	25	—	—	1	Tr	10	
KAS 15	73	2.5	1.3	—	22	Tr	Tr	—	Tr of Epi and Zir, Sph (1)
KASC 23–2/77	70	1	6	—	20	2	—	Tr	Sph (1), Zir (Tr)
A–XX	—	47	Tr	13	—	12	2	20	Sph (6), Foids (2) Pyr (Tr)
KASC 49–2/78	5	7	Tr	48	—	20	< 1	10	Sph (10)

Feldspar includes both Na and K varieties, mesoperthite being the most abundant.

The alkali pyroboles in a number of cases appear to have grown later than feldspar so that the latter are embayed and cut by the former. Various types of veins containing one or more of the constituent minerals of the syenites are found in the rocks, including fine-grained quartzo-feldspathic veins. In at least one rock, aegirine veins are slightly off-set and cut by syenite matrix; this leads to think that aegirine veins developed before the complete solidification of the matrix. Biotite is more frequent than phlogopite in these rocks.

Lamprophyric Rocks

These rocks occur in small isolated outcrops in carbonatites in the vicinity of syenites (e.g., at 12 + 30 W, 1 * 50 N). They are generally coarse-grained but some have radially grown coarse-grained mafic minerals in a finer-grained light-coloured groundmass-a feature also seen in some syenitic rocks. They contain aegirine (up to 47%), carbonate (up to 20%), biotite (13 to 48%), apatite (10 to 20%), and sphene (6 to 10%) as their most important minerals (see Table 6, Nos. KAS–C49-2/78 and xx), however, we have not studied enough sections of these rocks to consider that these modes are truly representative. The lamprophyric rocks are poor in feldspars ($< 10\%$) and it is in only one of these rocks that feldspathoids (cancrinite and an isotropic species) occur instead of feldspar.

Hydrothermal Veins

In addition to quartz veins the country rocks in the vicinity of the complex, especially near Ghaki Sar (zero point), contain reddish brown Fe-rich veins. They are up to a few meters in length and less than half a meter thick, are generally concordant but in some cases cross-cut the host rocks; some of them show pinching and swelling. They are mainly composed of iron ore mineral(s) (50 to 85%); carbonate, quartz, biotite, feldspar, sericite and brown pyrochlore are amongst the other minerals and at least some of the veins are thorium-bearing. Their mineralogy and proximity to the complex suggest that they are related to the carbonatite complex and, probably, are hydrothermal in origin.

DISCUSSION

The possibility of an alkaline igneous province extending for 200 Km from Warsak to Tarbela or even beyond was suggested by Kempe and Jan (1970), Kempe (1973) and lately by Ashraf and Chawdhry (1977). Kempe (1973) suggested that the alkaline rocks were possibly intruded in two stages, perhaps towards the end (Early Tertiary) of the Himalayan orogenic and metamorphic episodes. The alkaline rocks were regarded by Kempe to have been derived from a quartz trachyte magma which, in turn, was derived from Himalayan tholeiitic magma (Jan and Kempe, 1973). This basic magma may have directly produced the basic rocks found in association with the alkaline rocks. Work on the petrogenesis of the Shilman complex is yet to be done to postulate a sound scheme for its origin, however, it appears to be an extension of the alkaline province. It is possible that the rocks represent some CO_2 and REE–rich differentiates of the trachyte magma, but the possibility of liquid immiscibility followed by further differentiation should not be ruled out.

Alkaline rocks are commonly associated with rifiting: the heat so generated has been suggested as partially melting residual magmatic material and so generating alkaline liquids. Alternatively, extreme fractionation of basic magma could yield a similar magma (Sorensen, 1974). Kempe and Jan (1980) proposed that the Peshawar plain is a rift valley or graben, extending E-W for over 200 Km. Such rifting may have been generated by rebound relief tension or strain release, following the Indo-Pakistan-Asian plates collision and subsequent events. The chronology of events given by Kempe (1973), i.e., Upper Swat basic rocks (metamorphism)–67 m.y., Koga syenites–50 m.y., Warsak alkaline granite–41 m.y., is consistent with this suggestion. Thus the situation around Peshawar Plain would resemble east Greenland where rifting is also thought to have followed tectonism, in which case the tensional opening of the Atlantic also yielded plutonic alkaline rocks. S.K. Kakar (personal comm), following structural and other arguments, and Butt *et al.* (1980) also suggest a rift valley origin for the Peshawar Plain.

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