The Peshawar Plain Alkaline Igneous Province, NW Pakistan

D.R.C. KEMPE & M. QASIM JAN

Abstract: Complexes of alkaline rocks are distributed in a semicircle around the northern half of Peshawar Plain, NW Pakistan. Stretching west to east for over 200 km, they occur in eastern Afghanistan, Mohmand Agency, Khyber Agency, Warsak, Malakand, Shewa-Shahbazgarhi, Koga-Ambela-Utla, Tarbela and, possibly, Mansehra; also in Dir. The rocks include alkaline granites and microgranites, syenites, albitites, and carbonatites, intruded generally along fault zones into mainly Early Palaeozoic metasediments. It is proposed that they are associated with rifting, caused partly by 'rebound' relief tension or compression release, perhaps during very Late Cretaceous or Early Tertiary times, following contact between the Indian plate and the island arc(s) or southern margin of the Eurasian plate.

INTRODUCTION

Kempe and Jan (1970) and Kempe (1973) suggested that an alkaline igneous province extends across NW Pakistan from Tarbela or even Mansehra in the east, through Peshawar, to the Afghan border, a distance of more than 200 km (Fig. 1). The associated rocks are metasediments generally of Lower Palaeozoic age; distributed about this peneplained fossil 'sea-floor' are Siluro-Devonian massive reef complexes (cf. Jan and Kempe, 1970). The intrusive complexes — comprising alkaline granites and microgranites, syenites, albitites, and carbonatites — generally occur along fault zones in the older metasedimentary rocks and in the Kabul River alluvial plateau forming the Peshawar Plain; they have not been found in the Mesozoic and Tertiary sedimentary sequences occurring to the south of the Plain, which are thrust-faulted against the older metasediments (see map in Tahirkheli and Jan, 1979).

In the last seven years or so, other minor alkaline intrusive bodies have been discovered, as predicted by Kempe (1973). It may be of interest to refer briefly to these and to note additional information which is now available concerning the previously described rocks.

THE ALKALINE COMPLEXES

The complexes lie in a semicircle around the northern half of the Peshawar Plain. They are discussed below in order from west to east and are shown in Fig. 1.

1. Eastern Afghanistan

Within Afghanistan but close to the border with Khyber Agency, Pakistan, there is reportedly a small linear body, orientated (?) N-S, and composed of carbonatites and associated syenitic rocks. This intrusion has not been verified and no further information is available, but its geographical proximity to the Loe Shilman complex (below) is suggestive of a similarity between the two.

2. Mohmand Agency

Another small linear body, again unverified and for which no details are available (as for 1), comprising carbonatites and associated syenitic rocks, has been reported from this area. Samples of 'lapis lazuli', collected by the local people 'near the Afghan border' and brought to one of us (M.Q.J.) for examination, are of sodalite syenite and may possibly derive from this complex.

3. Loe Shilman, Khyber Agency

This complex (Ahmed and Ali, 1977) is intruded along an E-W-trending and north-dipping fault zone between (?) Palaeozoic schists and limestone in the north and (?) Precambrian slates and phyllites to the south. The main intrusion, reaching 170 m in width in the central part, extends E-W for more than 2 km, passing westwards into Afghanistan. Five kilometres east of this body there are additional small outcrops, the intervening alluvium-covered area containing isolated outcrops of metasediments with sills of carbonatite. Jan *et al.* (in preparation) have divided the rocks into carbonatites, silicocarbonatites, and subordinate syenites, lamprophyric rocks, and Fe-rich veins, with gabbro-dolerite sills in the metasediments in the north.

The basic rocks are variously altered or metamorphosed and resemble those of the Warsak area. The carbonatites are represented by at least three phases of intrusion and contain amongst their accessory minerals sphene, rutile, pyrochlore, Fe-Ti oxides, feldspars, quartz, and zircon, some of which are only locally present. The rocks comprise:

a) *Amphibole-apatite carbonatites,* generally layered, with both 'pure' carbonates and mafic segregation bands. They are composed of calcite and/or dolomite (with (?) siderite locally), magnesioarfvedsonite/magnesioriebeckite, apatite, with small amounts of dark mica (Ti-phlogopite more often than biotite) and aegirine/aegirine-augite in some rocks.

Proc. Intern. Commit. Geodynamics, Grp. 6, Mtg. Peshawar, Nov. 23-29, 1979: Spec. Issue, Geol. Bull. Univ. Peshawar, Vol. 13, 1980.

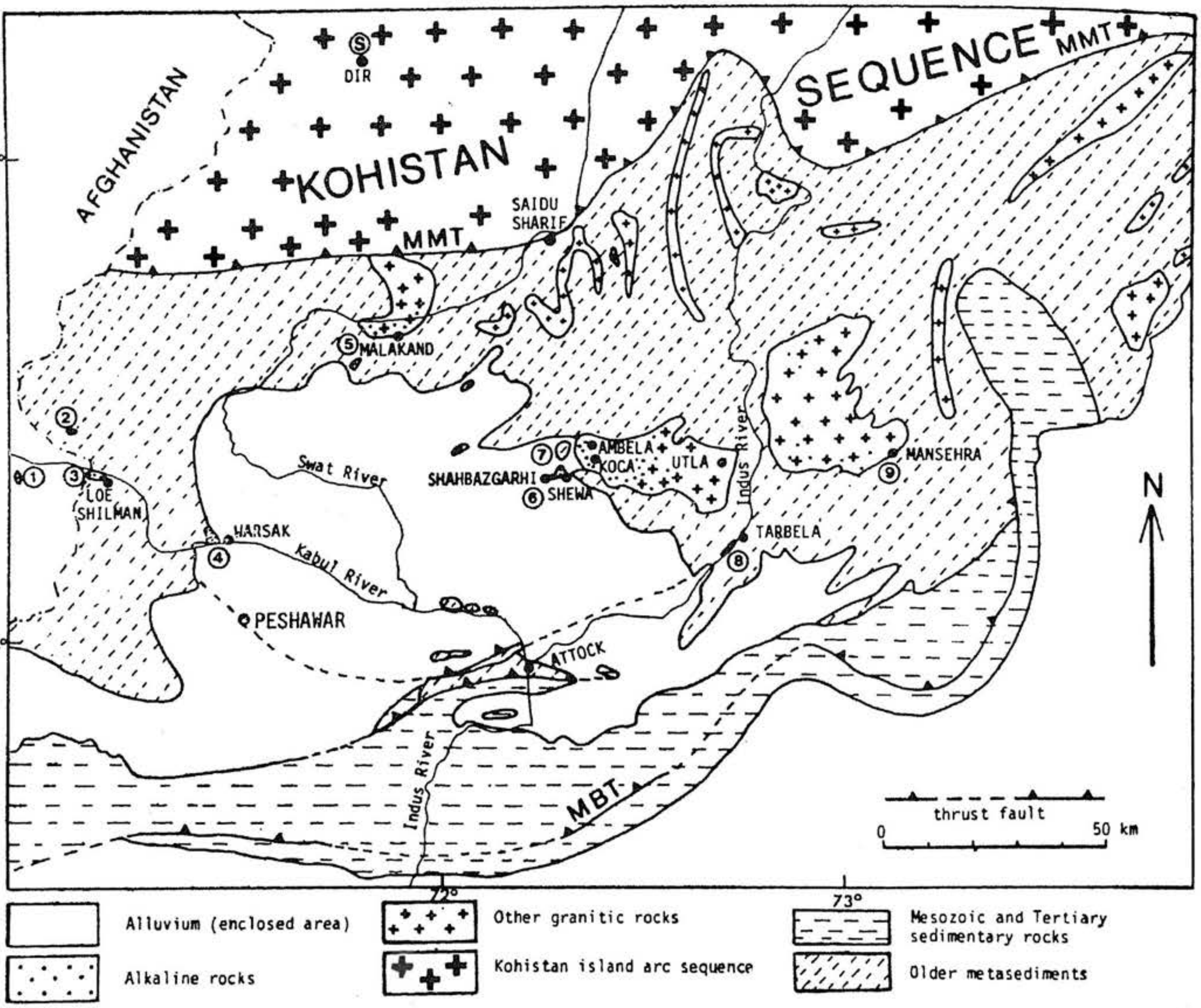

Fig. 1 Geological sketch-map showing the positions of the alkaline complexes and intrusions mentioned in the text; the numbers 1 to 9 relate to those in the text, and 'S' to the Dir metasyenite within the Kohistan Sequence (After the 1:1000,000 geological map in Tahikheli and Jan (1979)).

b) *Dolomitic carbonatite,* with a distinctly higher specific gravity than the other rock types and containing, in addition to carbonate, apatite, alkali amphibole, phlogopite, iron oxide and, rarely, aegirine. The carbonate is relatively rich in strontium and iron. These rocks occur principally in a band along the southern margin of the complex and as small outcrops in the first type.

c) *Phlogopite/biotite carbonatite,* found as patchy intrusions in (a) and generally containing 20% dark mica (locally up to 45%), 45 to 75% carbonate, and small, variable amounts of alkali amphiboles and pyroxenes, and apatite. Alkali feldspars are more common in these than in the other two types.

Preliminary trace element chemical determinations are inconclusive; all three types contain Sr at levels compatible with a carbonatitic origin, while type (a) is also rich in niobium.

The syenitic rocks occur in an elongated intrusion in the eastern part of the main outcrop but they are also found in the easternmost body. They consist of alkali feldspars (microperthite being the most abundant), alkali amphiboles and pyroxenes, carbonate, apatite, Fe-oxide, sphene and, in some, a little quartz, rutile, zircon, and biotite or phlogopite, the last locally more common. The rocks contain small pegmatitic patches with up to 25% quartz. The syenites generally have a high proportion of mafic minerals and may grade mineralogically into nearby coarse-grained melanocratic patches; these contain aegirine (up to 47%), carbonate (up to 20%), biotite (13 to 45%), apatite (10 to 20%), sphene (5 to 10%), alkali amphibole (up to 6%), and minor iron oxide. They are poor in feldspars

(< 10%) and in one only of these rocks feldspathoids (cancrinite and an isotropic species) have been noted instead of feldspar.

A few carbonatites and some marginal areas of the syenites are brecciated; in the latter the rocks may be veined by white carbonate possibly representing the final carbonatite phase. Considerable metasomatism has taken place in some banded metasediments found in or near the complex, with the development of alkali feldspars, amphiboles and pyroxenes. Similar carbonatite and fenite rocks have been described, for example, from Sokli, Finland, by Vartiainen and Woolley (1976), which contain a similar lilac-coloured Mg-rich magnesioarfvedsonite.

4. Warsak

A series of sill-like alkaline granites and porphyritic alkaline microgranites, containing aegirine, riebeckite, and astrophyllite, was described by Coulson (1936) and Kempe (1973). Further microgranite bodies were reported from 10 km south of Warsak, north of Jamrud, by Khan *et al.* (1970), while small bodies of foliated microgranite, some porphyritic, were found to the west between Warsak and Loe Shilman(Jan, 1969). Detailed mapping of the Warsak area (Ahmad *et al.*, 1969) has revealed that the granites, associated closely with metagabbros and metadolerites, occur in a northwards plunging synclinal series, possibly faulted on the northeast.

The microgranites were equated by Kempe and Jan (1970) and Kempe (1973) with those of Shewa-Shahbazgarhi and Tarbela, whilst the alkaline granite was considered the broad equivalent of the Koga syenites which, in turn, can be equated with those of Loe Shilman. The Warsak-Shilman complexes together have a close similarity with those of the Koga-Ambela-Utla area, 100 km to the northeast; the main difference lies in the higher proportion of carbonatites at Shilman.

No further work has been carried out on the Warsak granites, but recognition that the acicular hornblende schist of the synclinal series may be a metamorphosed basic tuff (Kempe, 1978), and the occurrence of some other metamorphosed basic agglomerates and (?) pillow lavas in the series, has led to the suggestion that some or all of the metagabbros and metadolerites, and also the porphyritic microgranites, might have an extrusive origin. The close association of alkaline acid with (meta)basic rocks in Warsak, Shewa-Shahbazgarhi, Koga-Ambela-Utla, and Tarbela may not be accidental: Kempe (1978) has shown that the basic and granitic rocks of the Warsak synclinal series possibly represent a differentiated sequence. Few chemical data are available on the basic rocks found in the vicinity of the alkaline complexes and it is not yet known how many of them are of an alkali nature.

5. Malakand

Dykes, sills, and ring-type bodies of carbonatite, measuring between 10 x 30 m and 100 x 200 m in area, have been reported in pelitic-psammitic schists possibly of Precambrian age near Silai Pati, Malakand Agency. The pelitic rocks have been thrust-faulted against calcareous and quartzitic rocks of Cambrian age (Ashraf and Chaudhry, 1977). Extensive outcrops of Malakand granites and granite gneisses are found ten kilometres to the northeast. The carbonatites are porphyritic to subporphyritic and consist of calcite (generally 50 to 90%), arfvedsonite, siderite, ilmenite/magnetite, vermiculite, apatite, chlorite, and K-feldspar, the minerals being unevenly distributed. The Nb, Sr, V, Y, Zr, Sc, La, and Yt contents of three samples confirm their carbonatitic affinity (Ashraf and Chaudhry, 1977).

It is not yet known whether or not the carbonatites are temporally associated with the Malakand granitic rocks; neither has the suggestion been made that the granites may themselves form part of the alkaline province. However, the Malakand granite proper, considered 'basically a soda granite' by Chaudhry *et al.* (1976), is chemically not very different from those of Ambela, Shewa-Shahbazgarhi, and Warsak. No sodic amphiboles or pyroxenes have been found in the granite but samples from Benton hydroelectric tunnel commonly contain allanite and sphene (Said Badshah, pers. comm. to M.Q.J., 1979), and the contents of Na_2O, up to 5.6%, and K_2O, up to 4.7%, are similar to those of the other silicic rocks within the alkaline province. The granitic gneisses, forming the principal granitic rock at Malakand, have a little lower Na_2O (average 3.9%) and higher K_2O (average 5.0%) than the granites. F. R. Khattak (pers. comm. to M.Q.J., 1979) reported that the Silai Pati carbonatites occur close to granitic rocks which are similar to those of the Malakand area.

Clearly, for the Malakand granite and those of Ambela-Utla and Mansehra (below) to have contents of Na_2O and K_2O comparable with those of proven alkaline granites does not demonstrate a similar alkaline nature. For this, an excess of alkalis in the norm, yielding *ac,* or the modal presence of alkali pyroxene, amphibole, and/or accessory minerals is necessary. Nevertheless, they are mentioned here because of their close association, in the first two cases at least, with known alkaline rocks.

6. Shewa-Shahbazgarhi

Alkaline porphyritic microgranites ('porphyries'), striking E-W and dipping north, constitute a fault-bounded triangular outcrop between Shahbazgarhi, Shewa, and Machai in Mardan district. The principal outcrop covers an area of about 35 sq km but isolated outcrops 15 km south of Shewa, in the Peshawar Plain, suggest that they may once have covered a much larger area (see map in Martin *et al.,* 1962). Only limited petrographic details of these rocks have so far been presented but it appears that most are of tuffaceous to volcanic or subvolcanic origin, again cut by gabbro-dolerite dykes. Although they are almost identical to those of Warsak (Kempe, 1973), there are considerable textural variations in the Shewa rocks, as at Warsak, with the local presence of aegirine and riebeckite, or of garnet. Chemical analyses of the rocks from Warsak and Shewa (Coulson, 1936; Kempe, 1973) strongly support the suggested consanguinity of the two.

7. Koga-Ambela-Utla

The Babaji peralkaline syenites and granites, Koga nepheline, sodalite, and cancrinite syenites, Naranji Kandao carbonatite and fenite, and the presumably older Chingalai granodiorite gneiss, occupying the west central part of the 'Ambela granitic complex', southern Swat, were the first alkaline rocks to be reported in Pakistan since independence (Siddiqui, 1965, 1967; Siddiqui *et al.,* 1968). No further work on the alkaline rocks has been published but Ahmad and Ahmed (1974) suggest that the large Ambela granite can itself be equated petrogenetically with the Warsak and Shewa-Shahbazgarhi alkaline granites. It has no sodic ferromagnesian minerals but contains similar tourmaline to that of the Warsak hybrid granite (Kempe, 1973) and has Na_2O and K_2O up to 5.0 and 4.8%, respectively.

Recent petrographic studies of the Utla granites (Khan and Hammad, 1978), which form the eastern part of the Ambela complex, suggest their similarity with those of the Ambela area. They also lack alkali amphiboles and pyroxenes but locally contain tourmaline and sphene. Further, (?sheared) porphyritic microgranites are present locally at Utla and some, if not all, of these contain fine-grained (?) aegirine or epidote, sphene, and possibly rutile. The Koga and Babaji syenites and associated rocks thus constitute the largest of the alkaline complexes around the Peshawar Plain, covering more than 500 sq. km. Doleritic dykes are common in the granites, developed in a radial manner at Utla. Outcrops of granites, not yet carefully studied but apparently resembling those of Ambela, also occur locally near Telegram, 25 km north of Mingora, Swat.

8. Tarbela

In addition to the alkaline granites and porphyritic micrograntes, some of them containing aegirine and riebeckite (Kempe and Jan, 1970; Kempe, 1973), which have now been removed or covered by construction work connected with Tarbela dam, there are extensive outcrops of an albite-carbonate rock, albitite, and carbonate breccia, closely associated with intrusions of dark gabbroic and doleritic rocks. The igneous rocks extend for 3.5 km, with a width up to 200 m, intruded along a major fault separating the Precambrian Salkhala series from (?)Cambrian Tanol quartzites. Tahirkheli (pers. comm. to M.Q.J., 1980) thinks that the Tarbela fault is post-Early Eocene (<45–50 m.y.); it extends from Tarbela, through Topi and under alluvium, to the Precambrian-Lower Palaeozoic rocks of the Attock-Cherat Range at Lakrai.

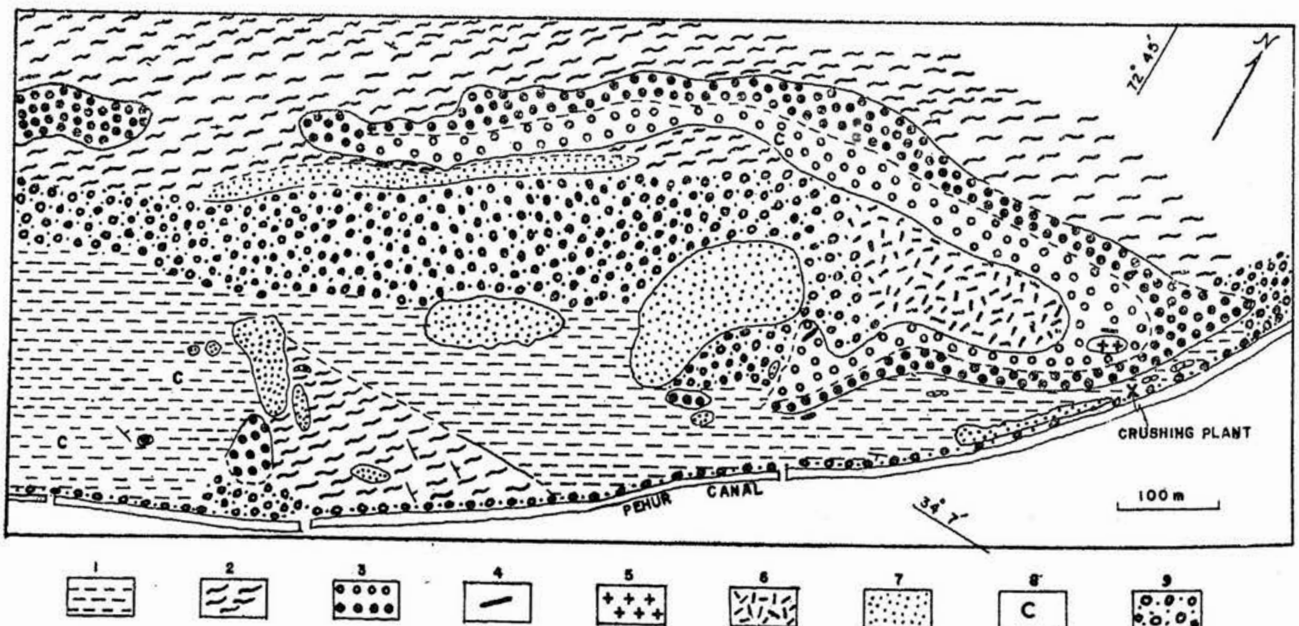

Fig. 2 Geological map of a portion of the Tarbela alkaline complex 1) Graphitic schists and calcareous rocks of Salkhalas, 2) Tanol quartzite, 3) Gabbroic intrusion, melanocratic on the margins and leucogabbroic/dioritic on the inner side, 4) Dolerite intrusions, 5) Hornblende albitite/oligoclasite, 6) Other albitites, 7) Albite-carbonate breccia, 8) ? Carbonatite intrusion, 9) Overburden/alluvium.

One incomplete concentric outcrop (Fig. 2) near the crushing plant on the west bank of the Indus has an outer gabbroic intrusion showing *in situ* differentiation from dark marginal gabbro, particularly rich in ferromagnesian minerals and locally grading into ultramafic rock at the margin, with progressive plagioclase enrichment to central leucogabbro or diorite. The leucogabbroic part contains an amphibole albitite and a dolerite intrusion. Both the gabbro and amphibole albitite are intruded by coarser-grained leucocratic albitite and by a sphene albitite dyke. The relationship of the latter to the other albitites is not yet clear. The central part of the concentric mass is occupied by other albitites: there are at least two and possibly three phases. These include (a) a coarse-grained sub-porphyritic type with greenish acicular feldspar, locally pegmatitic, and containing veins of coarse-grained siderite + calcite; (b) a medium-grained equigranular carbonate albitite; and ? (c) a medium-grained equigranular quartz albitite. To the west of these albitites and elsewhere, the dominant alkaline rock is albite-carbonate breccia. Carbonate veins are common throughout and these may be carbonatites; one grey mass, measuring 3 x 6 m, consists of porphyritic 'carbonatite' containing large euhedral carbonate crystals as well as oxidised veins, pockets, and disseminations of pyrite, generally weathered and giving a rusty brown colour to the rock. At another locality an albite-carbonate breccia cuts calcareous rocks, both in turn being cut by an irregular, brecciated, white 'carbonatite' mass, 2 x 4 m in area. Similar white veins also occur in the bacic rocks. Some of the albitites are fine- or very fine-grained and occur as independent outcrops, with little or no amphibole and no gradational relationship with gabbros.

The sequence of intrusions thus appears to be, from oldest to youngest:

(1) Gabbroic rocks, cut by dolerite;

(2) Amphibole albitite-oligoclasite;
both cut by albitite, coarser-grained than the amphibole albitite, and by the sphene albitite dye; the mutual relationship of these two albitites is not clear.

(3) Other albitites, possibly in the order: coarse-grained albitite; carbonate albitite; and/or quartz albitite.

(4) Albite-carbonate breccia.

(5) Carbonatite and carbonate veins.

The Tarbela rocks present the authors with the most puzzling complex in the alkaline province. Preliminary trace element data show that the albite-carbonate rock is rich in Zr (830-1300 ppm); Nb (100-120); Sn (100); Zn (700); and *REE* (Ce, 520; Y, 40-60); whilst Sr is low (60-100), as is Ba (100-190). Ti (in rutile) is high throughout the suite. These data do not support a carbonatitic origin for the rocks, but strongly suggest association with, say, alkaline granites. Unfortunately their relationship with the now removed Tarbela alkaline granites and porphyritic microgranites cannot be traced; the latter may, however, be the equivalents of the quartz albitite. In a personal communication (1973) to M.Q.J., S. F. A. Siddiqui stated that ijolites occur west of Tarbela. Many of the igneous and sedimentary rocks show a considerable degree of alteration with frequent development, among other minerals, of scapolite. In the metasomatised limestones this mineral is common and sometimes forms prismatic or lensoid aggregates, up to 4 x 0.4 x 0.4 cm, in a matrix of carbonate, feldspar, and quartz.

Some of the albitites resemble adinoles — albitized sediments — and it is suggested that the alkaline activity at Tarbela includes a considerable metasomatic element, possibly under explosive Pco_2 conditions. Possibly calc-alkaline lavas, such as andesite or dacite, are present, which have been extensively metasomatized by CO_2 and sodium. Some of the textures may have been produced by shearing. The petrogenesis of the Tarbela rocks is therefore far from clearly understood. The possibility of liquid immiscibility should not be totally ruled out: a trachytic magma could originally have split into mafic and CO_2 rich albitic fractions, followed by further differentiation and metasomatism.

9. Mansehra

The albitites in the Mansehra and Batgram granites and associated metamorphic rocks have been described by Ashraf and Chaudhry (1976). They are of three types, two of which — pegmatitic and medium-grained — are associated with the granites, whilst the third — fine-grained — type is related to the metamorphic rocks. Ashraf and Chaudhry (1976) consider that the albitites have a strong genetic relationship with the granitic complex of the area. If this is so, it would mean that petrogenetically the albitites could have no connection with the alkaline province, since an isochron age of 516 m.y. for the Mansehra granite (Le Fort *et al.*, this volume) would place it as much older than the alkaline rocks. However, the accessory mineralogy of the albitites, which includes rutile, sphene, apatite, zircon, and tourmaline, is not incompatible with some connection with an alkaline magma; further, the presence of alkaline albitites at Tarbela, 40 km to the southwest, suggests that more detailed investigations (including age determination) should be made before ruling the Mansehra albitites definitely out of the alkaline province.

THE DIR METASYENITE

Although strictly outside the alkaline province, mention should perhaps be made of the Dir metasyenite (Fig. 1), which lies some 3 km north of Dir town, near Panakot village, just within the Dir Group of Utror Volcanics and related rocks (see geological map in Tahirkheli and Jan (1979)).

This newly discovered and undescribed gneissose body consists of bands of melanite garnet, alkali feldspar, epidote, and aegirine-augite, with lesser altered nepheline, sphene, and scapolite. Although a metasedimentary or metasomatic origin is possible, the rock is provisionally regarded as a metamorphosed syenitic (?) intrusion.

TECTONIC HISTORY

Kempe (1973) presented a hypothetical differentiation scheme for the alkaline rocks, relating them to the upper Swat basic and intermediate rocks (Jan and Kempe, 1973) and to a Himalayan tholeiitic magma. Recent interpretation of the upper Swat rocks as part of the Kohistan Sequence (Tahirkheli and Jan, 1979), an island arc mass caught up in the Himalayan collision between the Indian and Eurasian plates, and obducted on to the Indian plate (Tahirkheli *et al.*, 1979), does not invalidate the earlier suggestion but calls for its reassessment.

Alkaline rocks are commonly associated with rifting: the high heat flow so liberated has been suggested as capable of partially melting residual magmatic material and so producing an alkaline liquid. Alternatively, extreme fractionation at low pressures could yield a similar magma (Sorensen, 1974). It is proposed here that the Peshawar Plain is an irregular rift valley, extending east-west for over 200 km, and greatly modified by Pleistocene glacial and fluvial action, of which the Kabul and Swat Rivers alone remain. In addition to the major thrusting, faulting occurs in association with many of the alkaline intrusions; for example a fault lies northeast of Warsak (Ahmad *et al.*, 1969) and the Shilman, Malakand and Tarbela rocks are intruded along faults. Thus a line of rifting might run from Loe Shilman to Malakand and then continue eastwards. However, faults suggestive of doming or flexuring, or dyke swarms, such as might be associated with rifting, are not known to the authors. Safdar Khan Kakar (pers. comm. to M.Q.J., 1976) regarded the Peshawar alkaline magmatism as the result of lithospheric doming caused by mantle plumes within a rift system. Such rifting might, perhaps, have been assisted by 'rebound' relief tension, or compression release, following the initial plate collision. The chronology given by Kempe (1973) — an Upper Swat hornblende pegmatite at 67 m.y., the Koga syenite at 50 m.y., and the Warsak alkaline granite at 41 m.y. — is consistent with this suggestion, and also with Powell (1979), who notes that whilst the Indian plate moved rapidly to the north at an average rate exceeding 15 cm/year between 80 and 53 m.y., a marked slowing to between 4 and 6 cm/year occurred at about 53 m.y., coinciding with its apparent 20° counter-clockwise rotation, and following initial contact at about 55 m.y. ago between the Indian plate and either the island arcs bordering the southern edge of the Eurasian plate or its continental margin.

Rifting is also evident, in the Narbada River valley, in the case of the domed Amba Dongar carbonatite and related syenites, ijolites, and phonolites, in Gujarat (Sukheswala and Udas, 1964), and may also occur in association with other Indian alkaline intrusions and/or with those to the west in Afghanistan, such as Khanessin (30° 27′ N, 63° 34′ E).

A rift valley origin, then, is proposed for the Peshawar Plain alkaline province, with the generation of, perhaps, a quartz trachytic magma. The suggestion is repeated that further investigation of the region, especially in the neighbourhood of basic and granitic igneous rocks, and preferably accompanied by boreholes, would probably reveal further alkaline igneous intrusive complexes.

Acknowledgements: Dr. A. R. Woolley is thanked for critically reading the manuscript. Thanks are also due to Brigadier Iqbal Khan and Dr. M. Majid for providing material and data relating to the Loe Shilman complex; to D. J. Bland, A. Livingstone, and Dr. T. Deans, of the Institute of Geological Sciences, London, for the Tarbela trace element data; and to Miss E. E. Fejer, J. G Francis, and Miss A. L. Scott for X-ray powder film determinations on the Loe Shilman minerals.

REFERENCES

Ahmad, M., Ali, K. S. S., Khan, B., Shah, M.A., & Ullah, I. 1969. The geology of the Warsak area, Peshawar, West Pakistan. Geol. Bull. Univ. Peshawar 4, 44-78.

Ahmad, S. & Ahmed, Z. 1974. Petrochemistry of the Ambela granites, southern Swat district, Pakistan. Pak. Jour. Sci. Res. 26, 63-69.

Ahmed, R. & Ali, S. T. 1977. Occurrence of phosphate in Loe Shilman Carbonatite. Geol. Surv. Pak. Inf. Rel. 101, 1-19.

Ashraf, M. & Chaudhry, M. N. 1976. The geochemistry and petrogenesis of albitites from Mansehra and Batgram area, Hazara division, Pakistan. Geol. Bull. Punjab Univ. 13, 65-85.

——— & ——— 1977. A discovery of carbonatite from Malakand. Geol. Bull. Punjab Univ. 14, 89-90.

Chaudhry, M. N., Ashraf, M., Hussain, S. S., & Iqbal, M. 1976. Geology and petrology of Malakand and a part of Dir (Toposheet 38 N/4). Geol. Bull. Punjab Univ. 12, 17-39.

Coulson, A. L. 1936. A soda-granite suite in the North-West Frontier Province. Proc. Nat. Inst. Sci. Ind. 2, 103-111.

Jan, M. Q. 1969. Preliminary geology of the Shilman area, Khyber Agency, with notes on a copper-bearing gabbro. Geol. Bull. Univ. Peshawar 4, 92-93.

——— & Kempe, D. R. C. 1970. Recent researches in the geology of northwest West Pakistan. Geol. Bull. Univ. Peshawar 5, 62-89.

——— & ——— 1973. The petrology of the basic and intermediate igneous rocks of upper Swat, Pakistan. Geol. Mag. 110, 285-300.

———, Khan, T. M., & Shah, S. In preparation. The petrography of the Shilman carbonatite complex, Khyber Agency.

Kempe, D. R. C. 1973. The petrology of the Warsak alkaline granites, Pakistan, and their relationship to other alkaline rocks of the region. Geol. Mag. 110, 385-404.

——— 1978. Acicular hornblende schists and associated metabasic rocks from North-West Pakistan. Mineral. Mag. 42, 405-406 & M33-36.

——— & Jan, M. Q. 1970. An alkaline igneous province in the North-West Frontier Province, West Pakistan. Geol. Mag. 107, 395-398.

Khan, M. I. & Hammad, M. 1978. Petrology of Utla granite, Gadoon area. Unpublished M.Sc. thesis, Univ. Peshawar.

Khan, A. B., Shah, Z. H., & Naeem, S. M. 1970. Geology of the Ghundai Sar and vicinity, Jamrud, Khyber Agency. Geol. Bull. Univ. Peshawar 5, 115-130.

Le Fort, P., Debon, F. & Sonet, J. 1980. The "Lesser Himalayan" cordierite granite belt typology and age of the pluton of Mansehra (Pakistan). This vol., 51-61.

Martin, N. R., Siddiqui, S. F. A., & King, B. H. 1962. A geological reconnaissance of the region between the Lower Swat and Indus Rivers of Pakistan. Geol. Bull. Punjab Univ. 2, 1-14.

Powell, C. McA. 1979. A speculative tectonic history of Pakistan and surroundings: some constraints from the Indian Ocean. In A. Farah & K. A. DeJong. Eds. *Geodynamics of Pakistan.* Geol. Surv. Pakistan, Quetta, 5-24.

Siddiqui, S. F. A. 1965. Alkaline rocks of Swat, Chamla. Geol. Bull. Punjab Univ. 5, 52.

——— 1967. Notes on the discovery of carbonatite rocks in the Chamla area, Swat state, West Pakistan. Geol. Bull. Punjab Univ. 6, 85-88.

——— Chaudhry, M. N., & Shakoor, A. 1968. Geology and petrology of feldspathoidal syenites and the associated rocks of the Koga area, Chamla Valley, Swat, West Pakistan. Geol. Bull. Punjab Univ. 7, 1-30.

Sorensen, H. (Ed.) 1974. *The alkaline rocks.* Wiley, London, xii +622 pp.

Sukheswala, R. N. & Udas, G. R. 1964. The carbonatite of Ambadongar, India — some structural considerations. Rep. XXII Int. Geol. Congr., Pt. 7, 1-13.

Tahirkheli, R. A. K. & Jan, M. Q. (Eds) 1979. *The geology of Kohistan, Karakoram Himalaya, Northern Pakistan.* Geol. Bull. Univ. Peshawar 11 (spec. issue), ii + 187

———, Mattauer, M., Proust, F., & Tapponnier, P. 1979. The India-Eurasia suture zone in northern Pakistan: some new data for interpretation at plate scale. In A. Farah & K. A DeJong, Eds. *Geodynamics of Pakistan.* Geol. Surv. Pakistan, Quetta, 125-130.

Vartiainen, H. & Woolley, A. R. 1976. The petrography, mineralogy and chemistry of the fenites of the Sokli carbonatite intrusion, Finland. Bull. Geol. Surv. Finland 280, 1-87.