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PRELIMINARY GEOLOGY AND PETROGRAPHY OF SWAT KOHISTAN

M. QASIM JAN AND IHSANULLAH MIAN

ABSTRACT

Regional survey, covering 1,400 square miles of area, was carried out in Swat Kohistan to prepare a preliminary geological map and investigate the structure, petrography, and economic geology of the region.

The area is covered by various types of plutonic and a lesser quantity of sedimentary and volcanic rocks. Quartzites, siliceous schists, phyllite, siltstone/shale, and limestone of the Kalam Group (Carboniferous to? Siluro-Devonian) are exposed in the Matiltan - Kalam area. Norites, diorites, and the associated rocks of the Kohistan Basic Complex (Late Cretaceous) cover a large area to the south of Kalam. They form a northeast trending belt that extends to the east in Indus Kohistan and to the west in Dir. To the northwest, the Kalam Group is overlain by a thick sequence of silicic to intermediate lavas, tuffs and agglomerates (the Utror Volcanic Rocks) of probable Creto-Eocene age. These, and the sedimentary rocks, have been cut by various types of plutonic rocks, mainly quartz diorites and granites, in Gabral and Ushu valleys. The plutons are thought to be emplaced during Early to Middle Tertiary period. Quaternary alluvium and glacial deposits occur in small quantity in all parts of the region.

INTRODUCTION

This paper presents a general geologic and petrographic account of the uppermost part of the Swat River valley. The work is a continuation of the project started in 1968 by Geology Department, University of Peshawar, to prepare a reconnaissance map of the area shown unmapped by Bakr and Jackson (1964) on the geological map of Pakistan. The present work covers 1,400 square miles mapped by two field parties during the summers of 1971. The area is bounded by the drainage divides of the Swat and Indus Rivers on the east, and Swat and Panjkora Rivers on the west. The northern limit extends up to a few miles distance from the border of Chitral and the southern limit is marked by 35°15'N Latitude. Kalam, the centrally located village in the area, is connected by a metalled road with Mingora and by unmetalled roads with Gabral and Mahodand in the northwest and northeast, respectively. The roads to the north of Kalam remain closed during winter months because of heavy snow falls. Between Bahrain and Kalam, also, the road may be temporarily closed.

Mapping was carried out on toposheet Nos. 43 A/11, 43 A/12 (both 1″=1 mile), 43 A/8 (1″=0.789 mile), and 43 A (1″=3.946 miles) of the Survey of Pakistan Department. In addition, aerial photographs, covering a limited area on both sides of the river between Ushu and Miandam, were also used. Besides dense vegetation, this area is mainly covered by two types of rocks, therefore the photographs could not be of much use. Long traverses were taken along the main river, major stream courses and foot paths, and over 650 samples were collected for further study. Of these, 200 were cut into thin sections. Two hundred more were quickly studied in crushed grains for better grouping.

Climate and Vegetation : Swat Kohistan is characterized by warm dry summers and cold moist winters (Naqvi and Rahmatullah, 1962). The yearly mean temperature at Kalam is 51°F, with January mean of 34.5°F and July mean of 70.8°F. Precipitation falls mainly in the winter and early spring and averages 30 to 35 inches. Little monsoon rain falls to the north of Bahrain. Accumulated snow at Kalam may reach 8 to 12 feet. In general, the snowfall increases northwards and the rainfall southwards.

Climate and topography has produced a marked altitudinal zonation of plants (Porter, 1970). Open oak forest and scrub vegetation at low altitudes passes upwards at about 6,000 feet into coniferous forest with chirpine, deodar, blue pine, silver fir, beech, and spruce. Walnut trees occur around villages up to 7,500 feet. The altitude of timberline generally lies between 10,500 and 11,000 feet throughout Swat Kohistan.

Geomorphology.

The investigated area is characterised by extreme relief and rugged terrain. There are a number of glacial peaks, some of which reach up to 19,000 feet. The local relief may be more than 10,000 feet in a horizontal distance of only five miles. Towards the south, the relief and mean altitude decrease; the peaks in the neighbourhood of Madyan are only 12,000 feet. The main valley slopes to the north of Madyan, up to Utror and Falakser, are V-shaped. Deep and narrow gorges are formed at some places, indicating the downwards cutting strength of the river. At Madyan the valley gets broader and outwash terraces are seen (Porter, 1971). To the north of Utror and Falakser, and along the upper reaches of many major streams, the valleys are characteristically broader and/or U-shaped. The tributaries may join the major streams, forming hanging valleys with waterfalls that may be over 500 feet in some cases.

The major streams and tributaries of Swat River (Gabral and Ushu Gols) show changes in gradient at many places and they are dammed up, or had been and later drained (see also Matsushita, 1965). Shallow lakes and, locally, low gradients are best seen at Mahodand, Jaba (Mankial), Jaba (Gabral), Kedam stream and elsewhere. In some cases, this change is due to end morains but in others it is due to high quantity of talus or alluvial fans. The latter are a common feature of the area although they are more so in the northernmost part. Some of them in Gabral and Ushu valleys are up to 3/4 mile broad. In addition, some glacial fans are also seen. In one of these, on the eastern bank of the river near Laikot, pillars capped by hard and resistent rock blocks have been produced by erosion. Depositional terraces formed by glaciers, or rarely by river, are also present. The best example of the glacial terraces is seen in the vicinity of Kalam.

The drainage, in general, is dendritic although trellised pattern may locally be produced. "The Pleistocene glaciers modified pre-existing valleys by straightening their sides, (and) by locally overdeepening them.................... Evidence of an ancient valley floor some 1,500 feet above the present channel of the Swat River .... is found .... Cross-valley profiles above Bahrain exhibit a pronounced change in slope, marking a transition from .... a high, broad valley floor to the steep-walled canyon containing the modern stream. Remnants of the inferred ancient valley floor are preserved as high-level bed rock benches near Kolalai, Laikot, Kalam and Utror .... " (Porter, 1970). The river erosion produces "pod-hole" structures in the norites and diorites. Some such structures have been seen many hundred feet above the present level of the river, especially around Bahrain.

Previous Work.

Although a brief account of the rocks of Upper Swat was given by Pascoe (1950), the main source of information is the paper on reconnaissance geology of Swat by Martin *et al.* (1962). They divided the rocks of the region into six major groups; one of these, *i.e.*, the Upper Swat Hornblendic Group, occupies the southern part of the area under discussion. The group, according to them, is older than the Lower Swat-Buner Schistose Group of the Siluro-Devonian age and is characterised by a predominance of hornblende, containing hornblende gneiss and schist, diorites, and other more basic rocks. Bakr and Jackson (1964) have shown a part of the Utror volcanic rocks, and the plutonic rocks to the south of Kalam, along the river, on the geological map of Pakistan. The former have been put in the Palaeozoic/Mesozoic and the latter, which form a part of the Hornblendic Group, in the Precambrian. King (1964) has discussed the granitic rocks and schists of Lower Swat in detail. Matsushita (1965) briefly described the rocks of the Ushu Valley north of Kalam and gave tentative ages to some of them, along with an account of the glacial deposits. More recently, Porter (1970) has discussed in detail the Pleistocene glaciation in Swat Kohistan. Tahirkheli (1959) studied the lead-zinc mineralization in the Falakser area, and Sultan (1970) has classified some of the volcanic rocks near Kalam into dacites.

Davies (1965) gave a brief description of the Hornblendic Group and considered the rocks to be mainly plutonic. Jan and Tahirkheli (1969) studied these rocks in some detail from lower part of Indus Kohistan and pointed out the abundance of norites in Upper Swat. Jan (1970) described the group from Indus Kohistan and southwestern Gilgit Agency in greater detail. The rocks were divided into amphibolites, norites-diorites, alpine peridotites and granites. Tentative ages were assigned and the norites were considered to be Cretaceous. The Hornblendic Group was also studied in the Shah Dheri-Kabal area (Rehman and Zeb, 1970) and Khwaza Khela (Shah and Sikandar, 1971). The rocks of the Timurgara area, Dir, an extension of the group, was studied by Jan *et al.* (1969). Jan and Kempe (in preparation) have investigated the petrology of diorites, norites, and amphibolites; the latter are to the south of the area. They think that the rocks represent a differentiated series later on metamorphosed to amphibolite facies assemblages in the south.

GENERAL GEOLOGY AND PETROGRAPHY

The rocks of the Swat Kohistan can be broadly grouped into the following subdivisions. Their stratigraphic and, especially, structural relationships are not yet clear in some cases.

TABLE 1

Formation	Age	Major Rock Types
Dewangar Granite Matiltan Granite	? Middle Tertiary	Porphyritic Granite Granite, at places gneissose
The Gabral Plutonites	? Early to Middle Tertiary	Quartz diorites, granites and minor granodiorite
The Deshai Diorites	? Early Tertiary	Quartz diorites, amphibolites, biotite-gneisses, granite and metagabbros
The Utror Volcanics	Creto - Paleocene	Silicic to intermediate lavas ignimbrites, tuffs and agglomerates
Basic Complex	Late Cretaceous	Norites, diorites, bands of pyroxenites/anorthosites, and minor amphibolites and granite
The Kalam Group	Carboniferous to ? Siluro-Devonian	Micaceous quartzites, siliceous schists, phyllite, siltstone, shale and limestone

The Kalam Group.

The Kalam Group, exposed in the vicinity of Kalam and Ushu, includes the only distinct sedimentary rocks of the area. The group (named by Matsushita, 1965) is composed of abundent micaceous quartzites, siliceous schists, and associated phyllites, overlain by siltstone/shale and limestone. One of the best sections is exposed in Karandukai stream, about two miles south-west of Kalam. The quartzites and schists seem to be many thousand feet thick and are folded. The phyllites are even more deformed here; their thickness may be a few hundred feet. The overlying siltstone/shale association is approximately 400 to 500 feet and the limestone about 150 feet thick. To the northeast, the latter two greately diminish in thickness and, in the Ushu area, only the shales and siltstones are seen in inconspicuous beds. The general trend of the rocks is to the northeast but there are variations in strike and dip, at places abrupt, particularly in the phyllites southwest of Kalam.

The quartzites and schists are bluish-grey, or dark, to pink or light green, at places brown. They are fine-grained and mostly thin-bedded or banded. Some are massive to thick-bedded. The bands are generally an inch or so but some may be up to a foot or more thick. Greenish bands are the most abundant although the brownish ones are more conspicuous. Some bands are more micaceous and distinctly schistose. Many directional joints and fractures in the metasediments may produce a rounded and lower topography of some mountain ridges as compared to the rugged terrain of the plutonic ridges, in the southeast of Kalam. They also have excellent microfolds of zig-zag and other patterns, The rocks contain bands and thin beds of rare amphibolite (composed of hornblende, plagioclase, quartz, epidote, ± chlorite) and less abundant calcareous and phyllitic rocks in various places. In addition, thicker phyllite, as said above, overlies them in Karandukai and Matiltan areas. The calcareous rocks and amphibolites, in rare cases, show grooves and furrows due to differential chemical weathering. One of the quartzites to the southwest of Kalam contains limestone pebbles, up to two inches across.

The rocks are composed of abundant quartz and lesser biotite, sericite, and epidote or, rarely, clinozoisite. In some, one or more of the last three may be abundant, especialiy, along certain bands. Many of the rocks also contain variable quantities of ore and, in some, chlorite, green amphibole, sphene, calcite, and plagioclase. Around Matiltan, some have graphite and traces of (?) tourmaline. In some, an intimate association of muscovite, or epidote, with biotite, parallel to cleavages, is noteworthy. The rocks are fine- to very fine-grained and schistose; many are microscopically also banded and, in rare cases, the schistosity is not parallel to the bands. Micro-veins of quartz, and calcite in the calcareous varieties, are common. Close to the contact with diorites, the rocks are hornfelsic in texture and contain a weakly pleochroic, pale clino-amphibole, kaolinized and/or sericitized feldspar in addition to other minerals. The two minerals appear to be produced by contact metamorphism. The green amphibole (? hornblende) is present only when veins of quartz or diorite occur closely. The slates are composed of sericite, chlorite, quartz and ore, with, or without, epidote. They may also show banding and secondary veins. One rock, near Matiltan, contains (?) carbonaceous dust.

The siltstone/shale and limestone, overlying the quartzites and phyllites, are best exposed along the top of the mountain ridges southwest of Kalam.

They appear to have been gradually squeezed towards northeast. The siltstone and shale are red to green and grey interbedded rocks some of which have excellent flaser structure and puckering. The shales are more abundant than the siltstones and are calcareous at places. The red ones may break into typical splinters. Veins of calcite and quartz, some in wedge-shaped cracks, are common at places. Some have isolated coarse rhombs of calcareous material that may have been weathered and refilled by brown, iron-bearing, "clayey" materlal.

The limestones are light grey and have calcite veins. They are fossiliferous and contain algai and coral. The rocks are thin-bedded and, at places, shaly. Joints and fractures are common and the rocks are weathered into cavities and grooves. They are aphinitic, composed of abundant calcite and minor quartz, and traces of carbonaceous material. The fossils are obliterated due to recrystallization and the rocks seem to have undergone a mild metamorphism like the underlying shales and siltstones. In some cases, the whole rock seems to be marmorized. Some phyllites appear to overlie the limestones, however, it is possible that they may be structurally controlled.

Quartz veins, some up to ten feet thick, are common in the quartzites and schists, and, at plaees, make networks. Some of them are folded and distorted, suggesting their older age than, at least, the latest tectonic activity. The quartzites are intruded by small, greenish, often porphyritic dykes between Peshmal and Ushu. They are also intruded by granites. In Matiltan, abundant granite is seen along the stream bed; the 'apophyses' and projections thinning upwards and rarely cutting through the entire cover of thick quartzites. The porphyritic dykes are quartz - microdiorite, composed of very cloudy plagioclase, biotite, pyroxene (both altered), quartz, sphene, and secondary epidote. Their mineralogy, thus strongly resembles that of the main diorites in the south and are thought by us to be connected with them.

Age and Correlation : The Kalam Group, according to Matsushita (1965, p. 84), is not known in the Hindukush-Karakoram region which was surveyed by the geologists of the Kyoto University (see also, Matsushita and Huzita, 1966). Matsuthita thought that the group might be contemporaneous with the Darkot Group (Permo-Carboniferous) of Ivanac *et al.* (1956) in Gilgit Agency, or it may be Early Mesozoic. We found abundant fossils in the limestone exposures in the mountain ridges to the southwest of Kalam. The fossils are poorly preserved and no definite identification is possibls. However, they appear to be aphroid or thamnastreoid, the septa of the individual corallite becomming confluent with one another, and have marked resemblence with Missisipian-Pensylvanian corals (M.A. Khan, personal communication). The thin sections also have columnals of crinoids and a few fragments of (?) fusulinids. The limestone, thus, appears to ba Carboniferous. The underlying thick quartzites and other metasedimentary rocks may be of this age or even older (Siluro-Devonian). The group thus belongs to the many Middle to Late Palaeozoic rocks of the northwestern Pakistan (see Jan and Kempe, 1970).

The Kohistan Basic Complex.

The complex includes diorites, norites, amphibolites and the associated rocks, previously called the Upper Swat Hornblendic Group by Martin *et al.* (1962). We propose the new name because it is mor meaningful than the old, ambiguous one. Besides, such rocks are abundant in Kohistan of Dir and Hazara, and in southwestern part of Gilgit Agency. The rocks probably extend as far to the east as Nanga Parbat, and to the west in Afghanistan (Jan, 1970). In the investigated area, the complex is dominated by norites and diorites, with minor amphibolites, granites, and layers of pyroxenites and anorthosites. Davies (1964), who considered the rocks plutonic, has also reported granodiorites and syenites.

Geologists of Peshawar University, who worked in various parts of Upper Swat, Indus Valley, and Timurgara (Dir), have proposed the following general subdivision of the complex : amphibolites, norites/diorites, peridotites, and granitic rocks. Jan and Kempe (in preparation) have recently shown that the granites and some peridoties are later in age and are not related genetically to the basic series. They have also suggested that the three major rock types (amphibolites, norites, and diorites) represnt a metamorphosed differentiated igneous series. A characteristic field feature of the norites is the flesh-pink plagioclase and dark, greenish-pink hypersthene. Where the feldspar is not pink, the rocks look greyish to dark gabbroic. They turn light grey on weathering but, in the upper reaches of Mankial valley, they are dark brown due to arid weathering.

Most of the rocks are medium-grained and gneissose. A few are fine-grained and some are characteristically coarse, such as those of the Miandam area. With rare exceptions, foliation is well-developed and, in a few, lens-shaped feldspar may impart the look of augen-gneisses. In rare cases, large crystals of pyroxene may be studded like buttons in planes often parallel to foliation. Some norites exhibit textural and/or compositional layering (Jan and Kempe, in preparation) parallel to foliation. Most of the layers are about an inch thick and diminish laterally in short distances. Associated with these, according to Jan and Kempe, are thin layers and streaks of anorthosite and pyrexenite. The latter may be up to ten feet thick and often form zones that reach 60 feet thickness at their maximum and many hundred yards in length, although they are much rare as compared to anorthosite layers.

The rocks are characterized by many sets of well-developed joints, generally spaced closely. In a few, they are widely spaced and the rocks break into huge blocks with smooth surfaces. Over 1,050 poles of joint readings were plotted on Schmidt's stereonet to determine the direction of forces. The rocks also have fractures, microfractures, and shear zones, that may brecciate the rock for many feet, with greenish colour due to secondary chlorite, amphibole and epidote. In some, the middle part is crushed fine. Slickensides, at places abundant, are often coated by epidote and/or quartz with, or without, chlorite. In one case, 3½ miles west of Madyan, shearing has produced a flaser structure in a hornblende pegmatite with development of ovoid feldspar and smaller hornblende in a finely crushed groundmass of the two (Jan and Kempe, in preparation).

The norites are essentially composed of labradorite, hypersthene, and clinopyroxene, the three making over 95% of the rocks in most cases. About two per cent of ore minerals (magnetite/ilmenite, rarely pyrite), and even smaller proportion of hornblende, biotite, quartz, and apatite are their other constituents. The mafic minerals usually range from 35 to 40%. The diorites, on the other hand, normally have a higher quantity of biotite, hornblende, quartz (in some up to 12%), and accessory sphene. Most of the diorites are proxene-bearing; their plagioclase is in the andesine range. The anorthosite and pyroxenite layers (with mafic minerals less than 25 and more than 75%, respectively), besides plagioclase or pyroxene (s), may have any of the above-mentioned minerals as accessory constituents.

The plagioclase, in some strained, is locally cloudy due to secondary clayey, sericitic or saussuritic alterations. In some, one set of twin lamellae is more altered than the alternate one. In rare cases, blebs of another (?) feldspar, with lower relief, are common in the plagioclase; these might be exsolved K-feldspar. The pyroxenes show exsolution lamillae which are usually traced by brown iron oxide. Some are changed to brown serpentine, talc, and/or uralite. Such phenomenon is more common along fractures and margins; in some, abundant secondary ore granules are associated. The hypersthene, which is usually more abundant than the clinopyroxene, is always strongly pleochroic.

The latter is always pale green, weakly pleochroic, and lies at the border of augite and salite fields (Mg_{38} Fe_{17} Ca_{45}), according to Jan and Kempe (in preparation). The hornblende and biotite, in some of the diorites, grow into poikilitic patches. More interesting are the myrmekitic and quartz-biotite intergrowths. In some of such intergrowths, biotite develops into radiating blades. Some of the diorites are leucocratic and a few are melanocratic.

Minor amphibolitic rocks are intimately associated with the norites. Such assocications also occur in Indus Valley (Jan, 1970). In some cases, a gradual passage between the two is seen along the trend of foliation. Such rocks occur throughout the area although they are more common to the south of Madyan, ultimately passing into the zone of amphibolites in the south of Fatehpur (Jan and Kempe). Some of these rocks have a high proportion of hornblende and contain hornblende streaks, bands, and irregular patches. They appear to be metanorites but some might be due to incomplete assimilation, The rocks are composed of plagioclase, in some strongly saussuritized, and hornblende (with? actinolite in some). Rutile, sphene, epidote, ore, and quartz are minor constituents. The hornblende is bluish-green, in some seived, and appears to be growing at the expense of pyroxene, quartz being a by product (sea also Jan, 1970, p. 38).

In addition to these, the complex also has metasedimentary amphibolites which are often banded. They are in the form of small, isolated beds in norites and diorites but some are many hundred yards thick, such as those of Asrit. More rarely, pelitic "gneisses" composed of quartz, biotite, sericitized feldspar, hornblende and another clinoamphibole are also seen in Mankial Valley. In the upper reaches of Bishigram stream, rare calcareous schists of brown colour and composed mainly of carbonate with subordinate quartz, biotite, epidote, ore, and muscovite are also found. The banded amphibolites are more common outside the area. Some of them have short epidote bands and porphyroblasts of plagioclase and hornblende. Many, thin bands of quartzites are associated with them in Cham and Kedam streams, suggesting a metasedimentary origin for the rocks. Banded amphibolites of Timurgara (Jan *et al.*, 1969), Shah Dheri (Rehman and Zeb, 1970), and Indus Kohistan (Jan, 1970) have already been considered metasedimentary. Close to the amphibolites, the norites have an unusually high quantity of hornblende, especially in streaks and patches. Other than these, the norites have rare xenoliths. The diorites near the northwestern part, however, have common inclusions of brown quartzite with green margins, in addition to patches of hornblende-feldapar that ore streched parallel to foliation. In some cases, the norites seem to be incorporated by texturally different rocks of similar composition.

Local, small intrusions of granites occur in the upper part of the complex. They are composed of sodic plagioclase, quartz, hornblende and/or biotite, ore, apatite, and secondary epidote and chlorite. Some have isolated cubes and veins of marginally oxidized pyrite. In addition, some varieties of diorites may be free of pyroxene, light coloured, and, at places, very coarse-grained in handspecimens. Such rocks are more common to the north of Laikot, and in Kedam stream.

Pegmatites and Veins : An interesting feature of the complex is the presence of hornblende pegmatites, at places unusually coarse. Some of these definitely look to be true pegmatites with quartz, micas and sulphides occupying the spaces between larger crystals of hornblende and plagiclase. Others are mica-free, rarely containing garnet, the individual minerals have widely varying sizes in different grains, and the feldspathic part being rather hard and often greenish or pinkish. At least, some of these might be secondary (rodingites), as suggested by Bilgrami (personal communication). The coarse texture of the rocks is always displayed better by hornblende which may reach 18 inches in length (see also, Jan and Kempe). Some of such large crystals have coarse inclusions of quartz and feldspar. The hornblende often grows perpendicular to the walls and may be concentrated in the middle or on the margins (Fig. 1). In a few thin veins it runs in the form of a dark central 'cord.' In some veins (2-4 inches thick), the hornblende crystals may be five inches long and only half an inch broad. Some rocks appear to be chilled on margins with much smaller hornblende than in the middle.

Small, simple pegmatites also occur in the area. They are composed of quartz, feldspar and mica (muscovite and/or vermiculite). Some also contain minor lepidolite, chalcopyrite and other sulphides. In a few, copper leaching has coloured the feldspar, and some quartz, greenish. Swelling, thinning, and folding is seen in some of the bodies.

Abundant veins, some only a fraction of a millimetre thick, filling the fractures and joints, are also seen throughout the complex. They are mostly greenish and contain secondary amphibole, epidote, chlorite and, occasionally, feldspar. In rare cases, numerous of such veins are closely - spaced and the rocks look to ba amphibolitized. These veins share many characters with some of the pegmatitic rocks, *e. g.*, the feldspar or amphibole may be concentrated in marginal or central parts, the amphibole may grow perpendicular to the walls, and the norites on margins of these may have a higher quantity of amphibole. Since the veins are definitely of secondary origin, a similar origin may be suggested for, at least, some of thc pegmatites. A few of these veins are complex and the light minerals may be concentrated on one side, the dark on the other, In one case, and epidote-rich part is bordered by a feldspar-rich material (both ½ inch thick), which, in turn, is bordered by hornblende-rich part that grades into norite with irregular extensions. The veins may be more, or less, resistant to weathering than the norites. In addition to these, primary veins of quartz-feldspar also occur in the area.

Age and Correlation : The complex, covering many thousand square miles, extends from Afghanistan to southern Gilgit Anency. It has been considered, with certain reservations, to be older than the Siluro-Devonian rocks of the Lower Swat - Buner Schistose Group by Martin *et al.* (1962) and Davies (1964). Bakr and Jackson (1964) have shown these rocks to be Precambrian in age. It were the quartz diorites of the complex, apparently, that Matsushita (1965, p. 84) called granite, and correlated with the granites of Shungi Gol (Middle to Early Mesozoic) of Gilgit Agency. Jan (1970, p. 30) noted that the norites extend, at least, up to ten miles to the east of Chilas and can be correlated with those of the Nanga Parbat massif. The latter are genetically related to the Creto-Eocene volcanic rocks of Kashmir and may, thus, be contemporaneous with, or slightly younger, than the volcanics (Misch, 1949, p. 216). On these grounds, Jan (1970) considered the norites to have been emplaced during the earliest phases of the Himalayan orogeny and Middle to Late Cretaceous in age. A pegmatite hornblende near Bahrain has been dated to be 67 *m. y.* by K/Ar method (Jan and Kempe, in preparation). Since the pegmatites are considered by them to be the final products of the igneous and metamorphic episode which produced the basic series of Upper Swat, a Late Cretaceous age can be assigned to the complex.

The Utror Volcanics.

Grey, green, red and, rarely, white volcanic rocks cover a large area to the northwest of Kalam. To the east they extend in Ushu Valley and to the west in Dir. The Utror village is surrounded on all sides by volcanic exposures. Mottling of various colours, particularly the red and green, is conspicuous in many places. In these, larger volcanoclasts lie in a matrix of a different colour. In the red and green ones, the matrix is nearly always of green colour. This may suggest a higher frequency of the reddish material in the early stages of the volcanic activity. The green mass appears to be more readily altered than the red; the colour of the former is mainly due to secondary chlorite and epidote, and that of the latter due to oxidized iron ore granules.

In general, volcanoclastic rocks are more abundant than flows. They may be fine-grained, homogeneous tuffs or, as is often the case, composed of larger fragments set in a tuffaceous or lava matrix (Fig. 2). Some are a confused mixture of pyroclastics and lava; the former may be over 50% in the form of fragments coarser than ash. The fragments may be angular or rounded, and up to a foot

Fig. 1. Pegmatite near Bahren with giant hornblende crystals some of which contain coarse felsic inclusions.

Fig. 2. Volcanic breccia near Bankhwar along road side.

across. Some pyroclastic rocks have banding which may be due to variations in colour, texture, or mineralogy. A few of the green rocks have white phenocrysts or pyroclastic material greately varying in size and proportion in different layers, in some they are stretched parallel to (?) flow bands. Rarely, an interbedding of pyroclastic material and lava is also seen. It appears that throughout the eruptive cycle, the explosive activity was a rule rather than an exception. However, between Gabral and Utror, an area prabably occupied by later eruptions, lavas dominate over the pyroclastic rocks.

The flows are always crystalline, however, a local showed us a few small pieces of obsidian supposedly collected in the Paloga area. Nearly all of the rocks have phenocrysts or xenocrysts of feldspar and, rarely, a sulphide, etc. They are a millimetre or two across and sparsely distributed. Some of the grey rocks in Batandar stream have rounded, coarse, crystal aggregates that reach an inch in length. In some, such as those to the southeast of Utror, the phenocrysts make more than a third of the rocks. Some of the pink and grey flows are distinctly banded and a few of them also have platy joints. Excellent columnar jointing is seen in a place 500 yards to the north of Utror bridge. A few of the rocks are extremely sheared. In rare cases, yellowish brown (?) baked zones, many inches thick, are noticeable between the flows.

Some of the rocks have wedge-shaped cooling cracks in which carbonate has deposited. More characteristic is the frequent occurrence of veins and, less common, patches of yellowish-green epidote and chlorite. Along with these, quartz, calcite, and feldspar are also present in some. Most of the veins are clearly filling the fractures and joints. Xenoliths of quartzites with sharp margins are common; rare shales are also seen. Some of the quartzites are in huge blocks and do not seem to have been picked up by flows or blown up by volcanic activity. They may have been contemporaneusly deposited in local depressions formed by volcanic activity or tectonism. However, the absence of volcanic material in them, and their resemblence to the quartzites around Kalam, which are older than the volcanic rocks, suggest that they may have been brought to their present position by complex folding and faulting.

Microscopically, the rocks are divided into rhyolites, dacites, andesites, and their tuffs; a few are ignimbrites. Such a subdivision, however, could not be extended to the field; the three rock types (based on 30 thin sections that we have studied) show random distribution. The rocks may vary in short distances and detailed work is needed to find out the sequence of rock types connected with the volcanic cycle. It must, however, be added that intense alteration in some cases, and the very fine-grained groundmass may have been a hindrence in the exact identification of some of the rocks. The general presence of chlorite, epidote, and the altered nature of feldspar suggest that the rocks have undergone a mild degree of regional metamorphism.

Rhyolites : These rocks contain sodic plagioclase, quartz, in some, ore and, rarely, potash feldspar phenocrysts in a microcrystalline to cryptocrystalline groundmass of these minerals, along with chlorite, epidote (abnndant in some), and very occasional biotite. Some also contain sphene that appears to be secondary after ilmenite. Rare microveins of calcite or quartz are seen. Some are tuffaceous with rather high quantity of sericite. In the ignimbritic types, the lithic fragments and crystals always lie in a reddish groundmass that is mainly made of welded glass shards (Fig. 3). In some, the glassy base seems to be devitrified. Many of the lithic fragments themselves seem to be ignimbritic.

Some of the rhyolite flows are spherulitic. In one case, about a mile north of Utror, abundant spherules, smaller than a pea grain, are seen in a grey rock. The spherules are made of radiating minerals, with ore dust, around a nucleus of a single crystal or crystal aggregate (Fig. 4). Some aggregates contain abuudant, well-formed grains of epidote in the middle parts. The radiating "fibres" are usually longer around single crystals than around the aggregates. In rare cases, the central parts of the aggregates are arranged in rose-petal fashion (Fig. 5). The aggregates do not seem to be xenocrysts or xenoliths.

Dacites : These rocks, first described by Sultan (1970) from a locality three miles northwest of Kalam, have a subparallel arrangemsnt of the groundmass minerals in most cases. Some are strongly trachytoid and a few are banded. Some of them are tuffaceous or agglomeratic. The phenocrysts, generally, are plagioclase, often altered to saussurite or epidote and showing only faint twinning. They are oligoclase to andesine in composition and are accompanied by a lesser amount of quartz, ore and, in some, chloritized hornblende. The groundmass is also composed of these minerals, epidote and, in some, sericite. The rocks may have abundant chlorite and epidote, somewhere in clusters, or hematite dust. In a few, leucoxene or sphene has formed at the expense of ilmenite. In rare cases, the groundmass may also have a clear or hematite - rich glass. In the banded and mottled varieties, variations in the grain size, type and quantity of mafic minerals are common. In the former, the groundmass is microcrystalline along certain bands and cryptocrystalline along others. The microcrystalline bands, according to Sultan (1970), might represent later crystallization of the normal cryptocrystalline material.

Andesites : Compared to the other rocks, the andesites are less abundant. Their texture resembles with those of the others; many are pilotaxitic, some are strongly porphyritic. Their phenocrysts are mainly of plagioclase (calcic oligoclase to andesine), with some ore, hornblende and, rarely, minor quartz.

Fig. 3. Thin section of ignimbrite, 3 miles northwest of Kalam along road side (× 30).

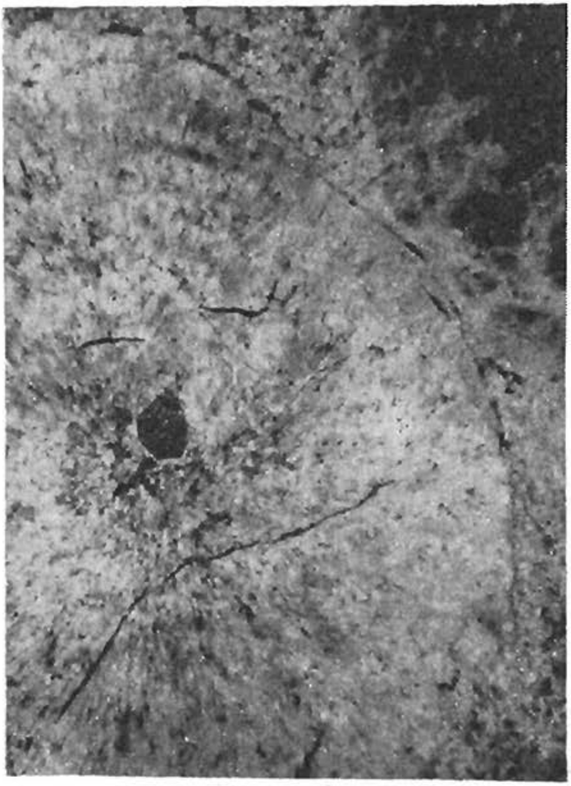


Fig. 4. Spherulitic rhyolite, 1 mile north of Utror (× 30).

Fig. 5. Rose-petal growth of felsic minerals is above (× 43).

The groundmass also appears to be made of these. Alteration is common; the plagioclase may have been completely destroyed to epidote, sericite, chlorite and clay; the hornblende may be chloritized and the ore hematitized. Chlorite and epidote may also occur in groundmass which is loaded with reddish ore dust in some. Large patches of secondary sphene are occasionally seen. The larger crystals of feldspar and quartz, like in dacites, may rarely be corroded on margins due to reaction with the magma.

The andesites generally have higher quantity of hornblende than the other rock types. In some of the cases, where they are banded and stongly trachytoid, hornblende may be abundant along some bands and nearly absent from others. The latter bands are usually coarser than the former. In one case, near Gabral, an andesite has labradorite phenocrysts and the quantity of the mafic minerals, mainly hornblende, is more than 40%. However, the average plagioclase of the rock may be around An_{50}.

The volcanic rocks have been intruded by granites in many places. Some of the volcanic rocks along the northern slopes of Paloga stream have minor association of pink and green mixed schists (or metavolcanics) bordering granite. They are made of plagioclase, quartz, chlorite, ore, epidote, calcite, sericite and, usually, show some degree of banding and patchy concentration of various constituents. About $1\frac{1}{2}$ miles north of Pologa, they have been intruded by a small granitic dyke. Near the contact zone, a number of small, green, porphyritic dykes of dacitic composition intrude both the granite and volcanic rocks (see also, Matsushita, 1965, p. 40 and 42). Such dykes also occur in the volcanic rocks in the north. Their mineralogy is similar to the dacites already described althoagh they are subporphyritic and contain abundant calcite along fractures and cavities. Near Gabral, the volcanic rocks have been intruded by dark dioritic rocks followed by granitic rocks. It is not clear as how far to the northeast of Gabral do the volcanic rocks extend. However, volcanic pebbles have been collected in the Gabral River about twelve miles to the north of Gabıal village.

Age and Correlation : The Utror volcanic rocks form a thick horizon overlying the Kalam Group. Bakr and Jackson (1964) gave them a broad Palaeozoic/Mesozoic age. Sultan (1970) has correlated them with those of the Lidar Valley (Davies, 1956), and other volcanic rocks of the Panjal Series which are considered to be mostly of Upper Carboniferous to Permian age (Wadia, 1966, p. 221). A few of the rocks of Utror are fairly similar to those of the Shewa Formation which is correlative of the Panjal Traps of the Upper Lidar Valley (see Martin *et al.*, 1962). It would, thus, seem that the Utror Volcanics are also Permo-Carboniferous; or equivalent of the lava members of the (?) Triassic Greenstone Complex of Ivanac *et al.* (1956) in Gilgit Agency. However, we have noted some breccies to the southwest of Kalam which contain pebbles of the Kalam Group sediments, especially limestone, and quartz diorites. Recent studies in the adjacent Dir (Kakar *et al.*, 1971) have shown that similar volcanic rocks and (?) reworked tuffs have interbedded sediments of undoubted Paleocene age. The Swat rocks tend to extend southwest into Dir, whereas those of the western Dir extend northest towards Swat, the two might be representing the same volcanic belt. We have also seen the outcrops in Dir and some of them have great resemblence to those of Utror. In Dir, there are a number of dykes in diorites, and a large (?) plug, which might have been the feeders; the dykes resemble some of the volcanics. If the diorites are equivalent to those of Swat (which one thinks to be), a post-Cretaceous age is highly probable for the volcanics on this basis also. The extreme relief and high elevations to the southwest of Kalam have not allowed us to clearly see the contact relations of the volcanic rocks and diorites, however, there is a great likelihood that the Swat volcanic rocks are of Late Cretaceous to Paleocene age and correlative of the Dir rocks.

The Deshai Diorites.

The Ushu River valley between Dewangar confluence and a mile south of Jabba (Falakser Stream) is occupied by medium- to coarse-grained quartz diorites, amphibolites and the associated rocks. A few are fine-grained; nearly all are gneissose (foliated) and some are banded. Jointing is a common feature; in many placee, the coarse types break into huge blocks of many yards dimensions and the medium-grained types into blocks a few feet across. Thus, the two may be separated in the field even from a distance. Some of the rocks, however, are not well-jointed. Near Deshai, about 1½ miles to the south of Dewanger confluence, the rocks develop excellent orbicular texture (Fig. 6). The orbs are rounded or ellipsoidal and may reach more than a foot in length. The central parts of the orbs, in most, are dioritic, surrounded by many shells of finer texture. The material surrounding the orbs looks similar to that in the centre. A detailed account of the petrography of these will be presented later by one of us (M. Qasim Jan).

Inclusions of amphibolite, less abundant quartzite, are usually seen. Some diorites have xenoliths of medium-grained diorite, not much different in appearance from the enclosing mass, except for their darker look. In addition, larger masses of amphibolites are also associated and it appears that they may be the country rocks. They are usually a few feet thick, at places banded, and run parallel to the northeasterly foliation of the diorites. However, for about half a mile in the vicinity of Mahodand, and about 600 yards north of Falakser stream, they dominate the diorites. The ones near Mahodand are mostly banded. Lit-par-lit injection ef dioritic and granitic material, and microfolding are common.

Fig. 6. Orbicular diorite, Deshai.

Fig. 7. Migmatite, one mile southwest of Dewangar confluence.

The rocks to the southwest of Dewangar (west of river) are a bit different from those to the east of the river. They are mainly amphibolites, quartz, mica schists and gneisses, various types of granites, and dark dioritic rocks some of which look smokey, whereas those to the east are mainly diorites. Amphibolites are the most common and usually have veins and lenses of granitic material. The rocks look migmatitic with common ptygmatic and microfolding. (Fig. 7) The granites may be foliated or not, a few are porphyritic. Some of the amphibolites are weathered spongy and a few are rather heavy. These rocks are spread for about two miles along the river and look to be metasedimentary in origin. The igneous material is less than half of the total.

Intrusions of granites are common in the diorites and amphibolites. They are specially abundent near Jabba (Falakser stream) and Dewangar, and are probably connected with the large granite plutons in these areas. In the first area, some of the granites are fairly large and repeatedly intrude the diorites, roughly along the northeast - southwest foliation trend. Thus, a sharp demarkation of one type from the other is not easy on the map. Veins of quartz and feldspar and, rarely, of feldspar and hornblende are also seen. In the latter, half an inch crystals of hornblend may be concentrated in the middle. In some of the places, epidote-rich veins have developed along joints and fractures. Also seen are streaks and patches of hornblende.

Microscopically, the rocks can be broadly classified into quartz diorites, amphibolites, metagabbros, biotite schists and gneisses, and granites, The latter are described in a separate section. The quartz diorites are hypidiomorphic and medium-grained, including the rocks that look coarse-grained in hand specimens. The large "crystals" of these are, actually, aggregates of light and dark minerals. The rocks are mainly composed of plagioclase, hornblende, biotite, and quartz, with minor ore (magnetite/ilmenite), sphene and, in some, clinopyroxene, apatite, zircon. The plagioclase, at places strained, is zoned andesine and shows selective alteration. The quartz is usually strained and may grow in vermicules around some plagioclase. Some of the biotite and horhblende may grow into large poikilitic patches. When pyroxene is present, it is always surrounded by hornblende which may look seived. In some, the pyroxene may be uralitized locally. At places, quartz may intergrow with biotite. Secondary epidote occurs in some of the rocks and, in rare cases, may be intimately associated with biotite, as if forming at the latter's expense

The amphibolites, as usual, are made of hornblende and plagioclase, with varying amounts of quartz, ore, and sphene. In some of the banded types, abundant sphene occurs along certain bands and none along others. The lighter bands may have coarser plagioclase than the darker bands, and may have abundant quartz. The metagabbros resemble the diorites in mineral composition but they usually do not have biotite. The plagioclase appears to be more calcic than in the diorites and the bluish-green hornblende (at places seived) looks to be after pyroxenes (both hypersthene and augite relics may occur). Close to Dewangar confluence, on the western bank of the river, are local outcrops of metaperidotite containing hornblende, (?) tremolite, relict grains of olivine, prochlorite, ore, and green spinel. The olivine has many fractures that may be filled with ore.

The biotite schists and gneisses are porphyroblastic on finer scale and are composed of quartz, biotite, plagioclase with, or without, sphene and hornblende. The plagioclase in the gneissose varieties appears to be as calcic as An_{50}. Many rocks are banded and some of the bands have a higher quantity of biotite.

Age and Correlation : The Deshai diorites appear to extend in a northeasterly direction for miles on both sides of the river. Matsushita (1965, p. 45) has shown them to extend up to Gilgit-Swat border to the northeast of Dewangar. Some of them resemble greately with the diorites to the south of Kalam and their age may also be Late Cretaceous. However, in the Bankhwar area, they appear to be terminating the volcanic rocks and their age may, thus, be post-volcanics (? Early Tertiary). The associated metasedimentary rocks might be as old as Palaeozoic. Detailed field work is necessary to study the contact relationships of the volcanic rocks with these and Kalam diorites before some conclusions on the age can be reached.

The Gabral Plutonites.

For the twelve miles distance to the north, and three miles to the northwest of Gabral, along the two major streams, different types of silicic intrusions have been noticed. Many of the rocks vary in texture and appearance, at places in short distances. For this reason, and for the extreme relief, time factor, and unreliable topographic maps, the various types of rocks could not be separately shown on the map. In the vicinity of Gabral village, the rocks intrude the volcanic rocks in the south. It is clear from intrusive relationship that the earliest of these intrusions are quartz diorites, followed by granites. Some of the diorites are darker in handspecimen, especially in the southern part. A few are smokey-looking and give a false impression of basic, or even ultrbasic, rocks. The granites are leucocratic in a few places.

The rocks are generally in the form of small dykes and bosses. Some are well-jointed, such as those in the north of Jabba where an excellent joint set strikes N 70°E and dips 45° NW. A few of the rocks are foliated and may contain thin amphibolite layers parallel to foliation. In rare cases, foliated parts "interlayer" with finer-grained, nonfoliated ones. The rocks contain inclusions of amphibolites, and darker diorites, in addition to the volcanic xenoliths common near Gabral. At places, abundant veins and dykes of granites have produced intrusive breccias and conglomerates. Quartz veins are everywhere but pegmatites have not been noted. The rocks are mainly quartz diorites with comparatively lesser granites and local granodiorites. Throughout the area, massive and hard granites with quartz phenocrysts occur, and appear to be the youngest rocks in the area. Nearly all of the rocks, in thin sections, are medium-grained, hypidiomorphic to allotriomorphic, equigranular to sub-equigranular. The quartz diorites are composed of plagioclase, quartz, hornblende, biotite, ore, apatite, and in some, sphene and/or zircon. In a few, hornblenbe is subordinate. In rare cases, bronzite and clinopyroxene also occur. The plagioclase of the rocks is usually zoned andesine which may be locally cloudy, especially along certain zones and cores. Sericite, clay and, in some, epidote are common alteration products. In a few, the inner parts of the plagioclase may be crowded with inclusions. Zoning may be oscillatory or normal. In rare cases, some albite twin lamellae have fine pericline twinning, absent in the alternate set. Myrmekitic intergrowths may locally be produced in some. The quartz is always undulose and often anhedral, it may rarely be poikilitic, a character more common in biotite and hornblende. In the pyroxene-bearing varieties, hornblende usually surrounds the pyroxene. The orthopyroxene may be altered on margins with production of abundant ore granules. In one case, muscovite associates biotite and seems secondary after the latter. Locally, the rocks contain lesser quantity of quartz and are dioritic in composition.

The granites are composed of plagioclase, quartz, biotite, ore with, or without, sphene, hornblende, perthite and/or microcline. The rocks, in general, are very variable in handspecimens as well as in thin sections. The feldspar is usually cloudy. The plagioclase is often zoned and in the varieties with no potash feldspar, it is antiperthitic with a low quantity of the exsolved type. The perthite, when present, is usually orthoclase with strings of sodic plagioclase; microcline may not be perthitic. The biotite is locally chandged to chlorite, and the ilmenite to leucoxene. Quartz is usually undulose. The granodiorites resemble the quartz diorites in mineralogy except for having a small quantity of essential interstitial microcline.

Age and Correlation : The Gabral rocks extend into Dir in the west, they may be merging into Deshai diorites in the northeastern parts. Mineralogically, some of them (the diorites) are similar to those of Deshai, however, they generally lack the strong foliation which is so characteristic of the Deshai diorites. Thus, they are most probably younger than the Deshai ones. It has already been stated that the diorites clearly intrude the volcanic rocks near Gabral, and are themselves intruded by various types of granites. Therefore, it appears that the rocks may be spread over a broader range of Lower to Middle Tertiary period.

The Granitic Rocks.

Apart from the smaller granite intrusions described in the previous pages, large masses of granites occur in Bankhwar, Matiltan area, and Dewangar. The first two are of the size of stock and are so much similar in appearance and mineral composition that they may be the intrusions of the same magma. They are named by us as the Matiltan Granite. The last one, judging from the traverse of Matsushita (1965, p. 45) along Dewangar Pass, may be of batholithic dimension and is named as the Dewangar Granite.

The Matiltan Granite : These rocks are light-coloured, with a flesh-pink touch. They are well - jointed and, at places, foliated, especially in the Bankhwar where their foliation trends notheast, dipping northwest. Out of the many well-developed joint sets, the best one strikes N 35° - 60°E, with northwesterly dips. Along this joint set, the granite looks "bedded" from a distance due to well-developed transverse joints. Also, in Bankhwar, steep cliffs of great height are characteristic. The foliation appears to increase northwards. Some of the rocks are porphyritic, with two to three millimetres long, lenticular feldspars in a finer groundmass.

The exposures in Matiltan cover a larger area and extend up to Falakser. Around Matiltan, abundant granite intrusions are seen along the streams under a quartzite cover. Some of the intrusions seem to be marginally chilled. In Bankhwar and near Paloga, they clearly intrude the volcanic and dioritic rocks with sharp margins. At places, they are repeated in short distances. Xenoliths of amphibolites, quartzites, and diorites are common; more rarely, thin layers of the former two also occur. In Batandar Stream, where the main rocks are volcanic, abundant veins of granite, at places in network, seemingly extend from the adjacent pluton in Bankhwar. Veins of quartz and less common aplites, up to six inches thick, occur throughout. Along certain fractures, yellow epidote and feldspar fillings are also present.

The rocks are medium-grained, hypidiomorphic to allotriomorphic, equigranular to subequigranular. They are composed of plagioclase, quartz and perthite, with minor quantity of biotite, ore and, in some, traces of apatite, ziron, and muscovite. The plagioclase is weakly zoned oligoclase or albite, locally cloudy or saussuritized. Myrmekite may commonly develop in some. The perthites may be represented mainly by orthoclase or microcline although some of the rocks totally lack them. The quartz is strongly undulose and, in rare cases, is abnormally high in quantity. Some of the fine-grained and strongly foliated varieties are micro-augen-gneisses in which the mafic minerals float around feldspar. Epidote, sericite, sphene, and chlorite may be locally produced as secondary products. In rare cases, chlorite and epidote are intimately associated and appear to be pseudomorphic after (?) horndlende.

The Dewangar Granite: Towering exposures of granite, visible for many miles in the Ushu Valley, occur at Dewangar confluence. The rocks are strongly porphyritic and phenocrysts of zoned plagioclase reach 2.5 inches in length In general, the rocks are homogeneous grey but a few variants have a higher proportion of hornblende and look more like diorites. They are also porphyritic and, if they are not crystallized from the same magma, their phenocrysts may be due to metasomatism. The rocks are generally non-foliated or very locally foliated but, in some, the phenocrysts may be aligned in trains. They are very well-jointed in, at least, two directions, and breaking along these has produced very steep and high cliffs. The best example of this is seen at the stream confluence near Dewangar, where over 2,000 feet high cliff stands like a tower. They look to be the youngest rocks of the area and intrude the diorites and the amphibolites in the south. The stream channels have apparently been carved along the contact of this granite and Deshai Diorites. Some smaller intrusions in the latter resemble the groundmass material of the former; it is possible that intrusions along thin dykes may have been "filtered" such that the phenocrysts were not allowed to penetrate along dykes but the liquid was able to do so. Inclusions of amphibolites and diorites are common; so are veins of quartz and feldspar with, or without, hornblende.

The rocks are composed of plagioclase, perthite, quartz, and minor proportion of hornblende, ore, biotite, sphene, apatite and zircon. Both of the feldspars may occur as phenocrysts; the plagioclase, usually, forms larger crystals. The perthite is mostly microcline type but some may be orthoclase. The plagioclase is strongly zoned and, in some, over a dozen oscillatory zones may be present. For this reason, accurate composition can not be determined. In the larger crystals, zoning can be clearly seen even in handspecimens. Some of the rocks have antiperthitic plagioclase. The plagioclase may be locally cloudy; and myrmekitic at places.

Age and Correlation : Both of the granites intrude the Deshai Diorites. The Matiltan Granite is also intrusive into the volcanic rocks, however, the latter are nowhere in contact with the granites of Dewangar. Deshai diorites, as said previously, are prabably younger than the volcanic rocks and are considered by us to be Early Tertiary. Therefore, a Middle Tertiary age is assigned to the granitic rocks. General lack of foliation in Dewangar Granite may suggest a younger age for them than for the Matiltan Granite which, at places, is foliated. We are not aware of any granites in Swat, Dir, and Indus Valley which can be correlated with those of Dewangar.

Quaternary Deposits.

Unconsolidated deposits of glacial and alluvial origin occur along the main valleys throughout the area. The alluvial deposits are generally thin and limited in occurrence although some of the fans in Gabral and Ushu valleys are fairly large. Glacial deposits are especially abundant to the north of Mankial in the major valleys. We have not concentrated on their study and the readers are referred to the excellent work of Porter (1970), and that of Matsushita (1965).

STRUCTURAL GEOLOGY

The Swat Kohistan, probably, comprises the northwestern extension of the Himalayan mountains and the area is structurally very complex. Shear zones, minor faults and folds are common throughout. Folding is better exhibited by the Kalam Group. The contact of the volcanic rocks with the Kalam Group is very complex; small blocks and beds of quartzites, rarely phyllite, occur in the volcanic rocks and appear to be structurally emplaced. The latttr also show changes in dip and are folded. The general trend of the Kalam Group is northeast - southwest, with northwesterly dip. Locally, there are changes in strike and dip, especially in the phyllites to the southwest of Kalam. At a few places, the quartzites have been domed up seemingly by granites, near Matiltan. The contact of the quartzites and the overlying phyllites seems to be normal, however, Matsushita (1965, p. 41) has suggested a northeast - southwest fault between the two in the Ushu-Kalam area.

The contact between the rocks of the Basic Complex and Kalam Group appears to be intrusive although it may be locally faulted. Presence of porphyritic dykes in the latter, xenoliths of quartzite in the former, and development of a clinoamphibole in the metasediments near the intrusions favour this idea. The lower contact of the complex with the Lower Swat-Buner Schistose Group is considered to be a thrust plane by Martin *et al.* (1962). The contact was not studied during the present investigation, as it is outside the area, however, Jan and Tahirkheli (1969), Rehman and Zeb (1970) have agreed that the contact might be a faulted one, although clear evidences are lacking.

The rocks of the Basic Complex extend over a large area between Nanga Parbat and eastern Afghanistan. These rocks are considered to be orogenic in nature; in the east they occur in the Himalayan (mainly Tertiary orogenic) belt and in the west in the Hindukush (mainly Mesozoic orogenic) belt. The norites and some diorites of the complex exhibit well-developed foliation in most parts. The foliation of these rocks trends east-west to northeast-southwest in the southern part, gradually becoming northerly, and, in the northern part, north-westerly. The dips of the foliation planes, similarly, change from northwest to southwest (see foliation map.) Local variations due to shearing, faulting, and microfolding occur. In Dilram stream, two miles south of Peshmal, the diorites have six she arzones within a distance of 800 feet; the rocks are brecciated and granulated, at places up to ten feet in thickness. Near Pardesha, $3\frac{1}{2}$ miles to the west of Madyan, a hornblende pegmatite, along a shear zone, has been changed into flaser rock with ovoid plagioclase in a fine-grained, crushed groundmass.

The norites and diorites of the Basic Complex, as said previously, have many sets of well-developed joints. Poles of more than 1050 readings of joints were plotted on Schmidt's stereonet (Fig. 8 and 9). The joint systems appear to be radial; no distinct direction of forces emerges. Three possible explanations can be : 1) the forces responsible for the joints were many directional during various times, 2) the joints in the rocks may have been produced by an uprising magma at depth. It may be the latter intrusions of the norite magma itself into the earlier, solidified norites, or of some other magma that has not been exposed yet by erosion, or 3) the joints may be due to the combination of the first two factors.

The foliation in the Deshai Diorites has been shown to trend northeast on the east, and northwest on the western side of Ushu Gol (Matsushita, 1965). The two sides were thus regarded to be faulted. According to our observations at a few places on the western bank, the trend of the foliation as well as of the metasedimentary beds appear to be like those on the east, except for abundant local variations due to many intrusions, especially in the southwest of Dewangar confluence. However, the amphibolites, schists, and diorites of the western

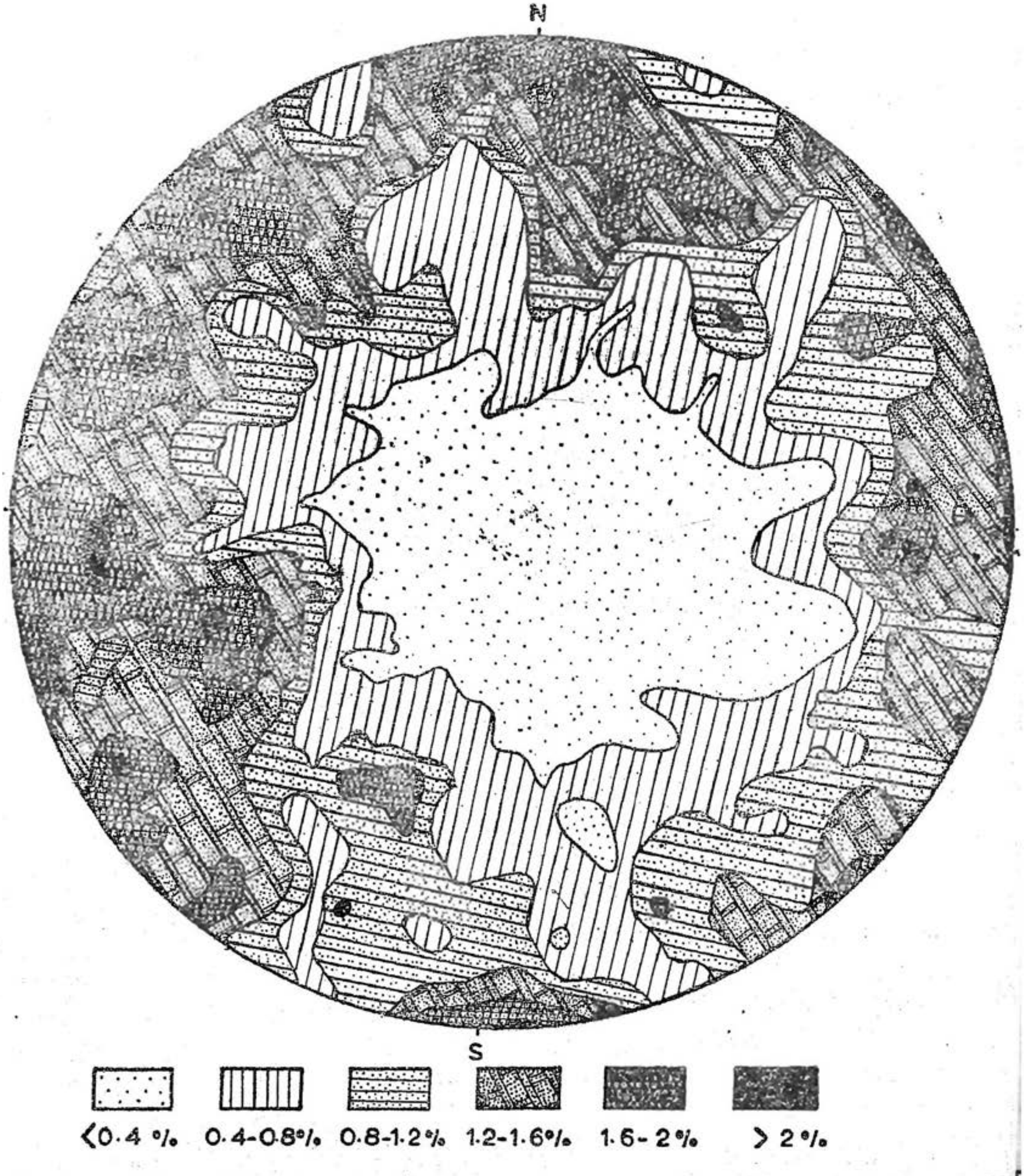
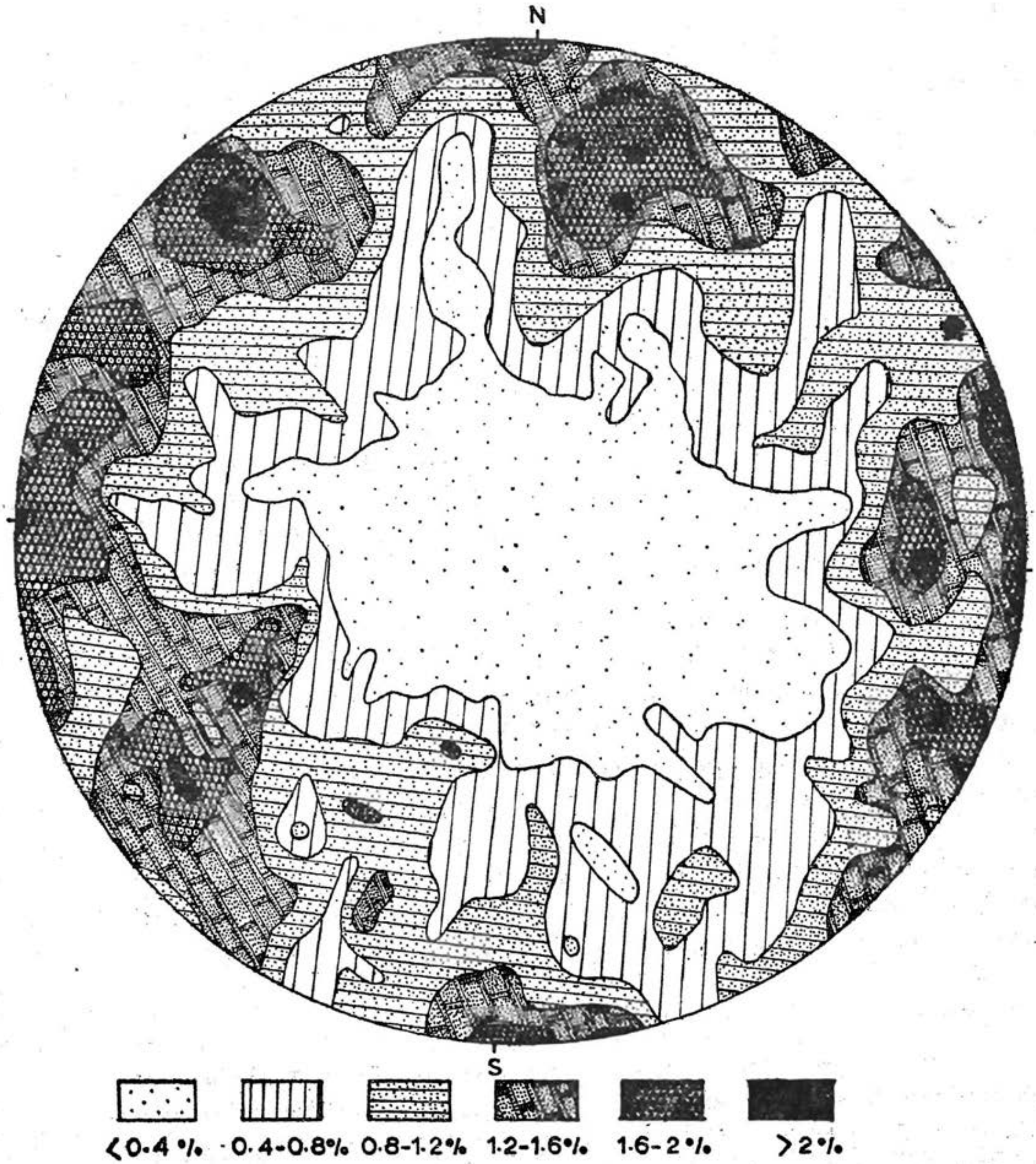


FIG. 8 CONTOUR DIAGRAM OF 1050 JOINTS FROM FATEHPUR TO PESHMAL. PLOTTED ON LOWER HEMISPHERE.



IG. 9. CONTOUR DIAGRAM OF 800 JOINTS FROM FATEHPUR TO PESHMAL, WHERE THE FOLIATION TREND IS FAIRLY CONSISTENT i.e., N 15° W TO N 45° E, PLOTTED ON LOWER HEMISPHERE.

bank do not extend on the eastern side which is occupied by diorites of different appearance and texture. It can thus be assumed that a fault runs along the stream to the south of Dewangar. Consequently, the western part of the valley having been shifted to the south as compared to its eastern part, by more than a mile. A similar situation is seen in the volcanic rocks near Paloga where the southern limit extends 1½ miles more on the western bank than on the eastern. However, it is also possible that this difference may be due to the intrusion of the granites, more on the eastern side. The age of the fault may be post volcanic and diorites, however, it appears to be older than the Dewangar Granite which has not been affected.

The volcanic rocks have been inturded by the diorites of Gabral, Deshai, and the Matiltan Granite. The latter, and the granites of Dewangar, also intrude the diorites. It is clear from Matsushita's account that the eastern tributary of Dewangar confluence flows along the contact of diorites and granite. Same may also be the case with the western tributary. Because of extreme relief, the contact between the volcanic rocks and the Basic Complex has not been carefully studied.

Matsushita and Huzita (1966) pointed out that "the geological structure of the Western Karakoram is characterized by the zonal arrangement of rock formasions .... the boundary between each zone is in some cases represented by a fault." We have noted a similar zonal arrangement in Swat Kohistan, although not as perfect as that of their area. The southern part of Swat Kohistan is occupied by the Basic Complex, extending to the east and west. North of this is the zone of metasedimentary and volcanic rocks extending up to (?) western Dir. Further north are zones of diorites (of Deshai and Gabral) and Dewangar Granite. All of the plutonic rocks, apparently, are connected with the Himalayan orogeny.

ECONOMIC GEOLOGY

In addition to preparing a base map, a main purpose of the work in Swat Kohistan was the search for economic minerals. A few days were also spent in the Indus Valley to investigate the potentials of the ultramafic rocks exposed near Jijal along the Indus River. Following is the result of the investigation:

(*a*) Building and Decorative Material.

Most of the Swat Kohistan is covered by plutonic igneous rocks of light to medium colour which are suitable for building purposes. Special mention can be made of the coarse grained, biotite-bearing diorites to the north of Laikot and in the Deshai area, and the coarse-grained mafic gneisses exposed in the stream to the east of Madyan and the surrounding parts. The former in particular are light coloured, homogeneous, massive, and will take a good polish.

In Deshai area, some of the diorites have developed an orbicular texture, with many, dark to lighter, shells. The shells are rounded to ovoid, reaching over a foot in length; the individual shells usually having radiating minerals. We think that these rocks can prove to be excellent material if cut into slabs for table tops and frontal decorations.

Dundai Marble : Near the village of Dudnai, two miles to the north of Thakot bridge along the Indus Valley Road, local outcrops of marble are seen. They are grey or white (with a greenish touch of serpentine at places) beds of only a few feet thickness; the thickest one is 30-40 feet. Nearly all of them pinchout in short distances of a few hundred yards or less. Many of them are banded; besides grey and white, brownish and mixed-colour bands also occur. The rocks are generally uniform in texture but many are fractured and only small blocks (less than a foot-cube) can be extracted. However, in a five feet thick bed, which has fewer fractures, many cubic feet large blocks are extractable. Some of the marbles are micaceous and, in a few, iron oxide staining is seen along the fractures. Thus, it is clear that the marbles at Dundai are not of much economic interest although they can be locally used in chips and for decoration. The marble has been used in Thakot bridge. It will be worthwhile to search for more of these marbles in the adjacent parts of Hazara Kohistan, to the east of the Indus.

(*b*) **Abrasive Material.**

In the area between Patan and Jijal, along the Indus River, garnet gneisses are the most common rocks. Some of them have as much as 80% garnet, besides plagioclase and ferromagneisan minerals. A rock with 10% garnet is generally considered suitable for extracting abrasive garnet from. The high quantity of garnet in these rocks is thus encouraging and suggests that some of these rocks may be crushed and directly utilized for manufacturing low to medium quality abrasives. A few of these rocks are fairly weathered, fractured, with low crushing strength and not much energy will be used in grinding them. However, for quality improvement, purification will be needed. In many places of the world, where garnet is extracted for abrasive purposes, stress is laid on the size factor, *i.e.*, the individual garnet grnins should not be less than the size of a pea. In Swat, the garnet-bearing rocks have much smaller grains.

However, there are a few rocks in which the garnet porphyroblasts reach the size of a billiard ball.

Near Telegram at Ser, seven miles north of Mingora, huge grinding wheels for flouring food grains in the water mills are carved from garnet-mica schists. According to the locals, the quarry has been meeting the demand of most of the water mills of Upper Swat for the past seventy years; some are carreid as far away as Buner. The largest of the wheels reach 42 inches in diameter and 12 inches in thickness and can, reportedly, last for ten to fifteen years. This figure appears exagerated because the rock is soft and an average wheel would hardly last for ten years. An average wheel costs 70 to 80 rupees at site and is prepared by a single labourer in about ten days by the help of primitive tools. Compared to this, a wheel of hard, garnet gneisses imported from Afghanistan costs over 1000 rupees in Swat. The latter are more durable and contaminate the flour less, the contaminations from the former, however, would not hurt the the teeth so badly as from the latter.

It may be mentioned here that before 1965, most of the requirements of grinding wheels, especially in Punjab, used to be met from imported Vindhyan sandstone from Agra, India (Tahirkheli, personal communication). Its majormarket was located at Lahore and it is advisable to introduce the crushing wheels made in Swat. In Bishigram and elsewhere, the locals used to carve the wheels from more superior and durable noritic rocks but they have been abundoned these long ago, probably, due to more labour involved. Grinding wheels are also prepared near Ghaligai, Lower Swat, from garnet-mica schists which, apparently, are more resistant than those of Telegram.

(*c*) Refractory Material.

In the vicinity of Jijal and Dubair, Indus Valley, peridotites occur in a many square miles outcrop. Some of the rocks are made of nearly pure olivine. R. A. Khan Tahirkheli of the University of Peshawar has recently suggested the use of olivine-rich rocks for refractory purposes and if his recommendations are accepted, the Jijal rocks could also find such a use. The Mg_2SiO_4 content of the olivine in these rocks is in the range of 85 to 95 and the mineral is thus a high temperature member of the forsterite-fayalite solid solution series.

(*d*) Pegmatites.

Abundant, leucocratic pegmatites occur along the Indus Valley Road between Dubair and Thakot. They are mainly composed of feldspar with minor quantity of quartz and with a little, or no, micas. Samples have been collected from most of these to conduct laboratory tests for ascertaining their utilization in the ceramic industries. A few samples have to be sent to the domestic ceramic industries set up at Gujranwala and Gujrat to see their worth After receiving the result, more work will be conducted to isolate the wokable pegmatite bodies in the area, if any.

Some of the pegmatites in Swat Valley, around Bahrain, have locallized pockets and disseminations of vermiculite and or muscovite. The best of these occurs about 6 miles to the west of Bahrain near Arin; it was locally exploited many years age. This, as well as the others, according to our opinion, are not of economic importance at the moment. Tahirkheli (Personal communication) has also visited the outcrops near Arin and holds a similar opinion.

(*e*) **Talc of Thakot.**

In Lilai Tangai, about four miles northwest of Dundai, is a minor outcrop of soapstone at an elevation of about 5000 feet. It is white to green in colour, sheared, and squeezed. The exposure is 1½ feet or less thick, and about 15 feet long along the slope of the valley. Thirty feet above is another exposure, a continuation of the lower one, probably. The middle part is covered by overburdon. The upper part is more twisted and squeezed up; the marginal parts of the talc contain minor "layers" of other material. The outcrop is, unfortunately, too small although the quality appears to be good.

(*f*) **Metallic Minerals.**

Most of the terrain gelogically investigated is occupied by igneous rocks and this forms an ideal geolgical set-up for metallic mineralization. However, in the area we have investigated, no extensive mineralized bodies have been recorded. Yet, in some places, small pockets and thin veins of sulphides of iron and copper have been noted which do not seem to form a major ore body. Tahirkheli (1959) investigated the sulphide veins exposed near Jabba, Falakser stream. The ore minerals include galena and sphalerite, with small amounts of pyrite and chalcopyrite in west-trending fractures in diorites. The veins are variable in thickness and rarely reach a foot in width. He, thus, concluded, "..................... the narrow, discontinuous veins do not appear encouraging for further exploration and development."

Some exploratory work has been done on the deposits in the past. The mineralization was studied by one of us (I. Mian) during the present investigation and it was found that the remaining veins get even narrower, up to 2 inches at most. The main metallic minerals noted were galena and pyrite associated with quartz and feldspar. The former makes about 20 to 25% of the veins in some cases. Rabnawaz Khan (personal communication) of the G. S. P., who has recently worked in detail on these, also holds a similar opinion.

The Jijal ultramafic rocks were also investigated for chromite mineralization. The mineral has been found in minor quantity, usually in the form of disseminations along certain thin bands. Laboratory work is in progress to study nickel and platinum contents in these rocks.

The Kohistan Basic Complex, which is dominated by norites, covers a large area in the Upper Swat and the adjoining districts. The complex is expected to contain large quantities of economic minerals because such rocks yield minerals of great importance, such as chromium, nickle, platinum, iron, and titanium, etc., in other parts of the world. We have not succeeded in finding any concentrations in the area investigated, yet we believe that the great mass extending between Dir and Hazara Kohistan should have economic minerls of metals. Their discovery is more dependent on geological work in the field, supplemented by detailed geochemical work for which the laboratories in the Department of Geology are not yet fully equipped. Jan and Tahirkheli (1969) have already reported the occurrence of a pyrrhotite, making about 7% of the surface area of a fifteen feet thick brecciated zone, two miles north of Patan along the Indus. Another, ten inches thick, sulphide body was reported in a road cut one mile east of Shang village. Both of the outcrops occur along the Indus Valley Road. The complex is being investigated from a petrological poinf of view by Jan and Kempe. Seven of the rock samples from a limited part ot the area along the Swat River were analysed for them by C. J. Elliot. V. K. Din, and A. J. Easton at the British Museum, Natural History, London. The range of trace elements (in parts per million) is as follows: Cr 25 to 350, Li 13 to 19, Ni 0 to 150, Cu 45 to 295, Zn 107 to 173, V 200 to 550, Zr 25 to 200, Y 0 to 50, Sr 700 to <1000, Ba 50 to 400, and, Rb 18 to 25. The trace elements appear to be concentrated in the structure of the ferromagnesian minerals, as revealed by the analyses of the individual minerals—hornblende, hypersthene, and clinopyroxene. Seven more rocks have been given for ascertaining nickel and platinum values to the Chemistry Department of University Peshawar.

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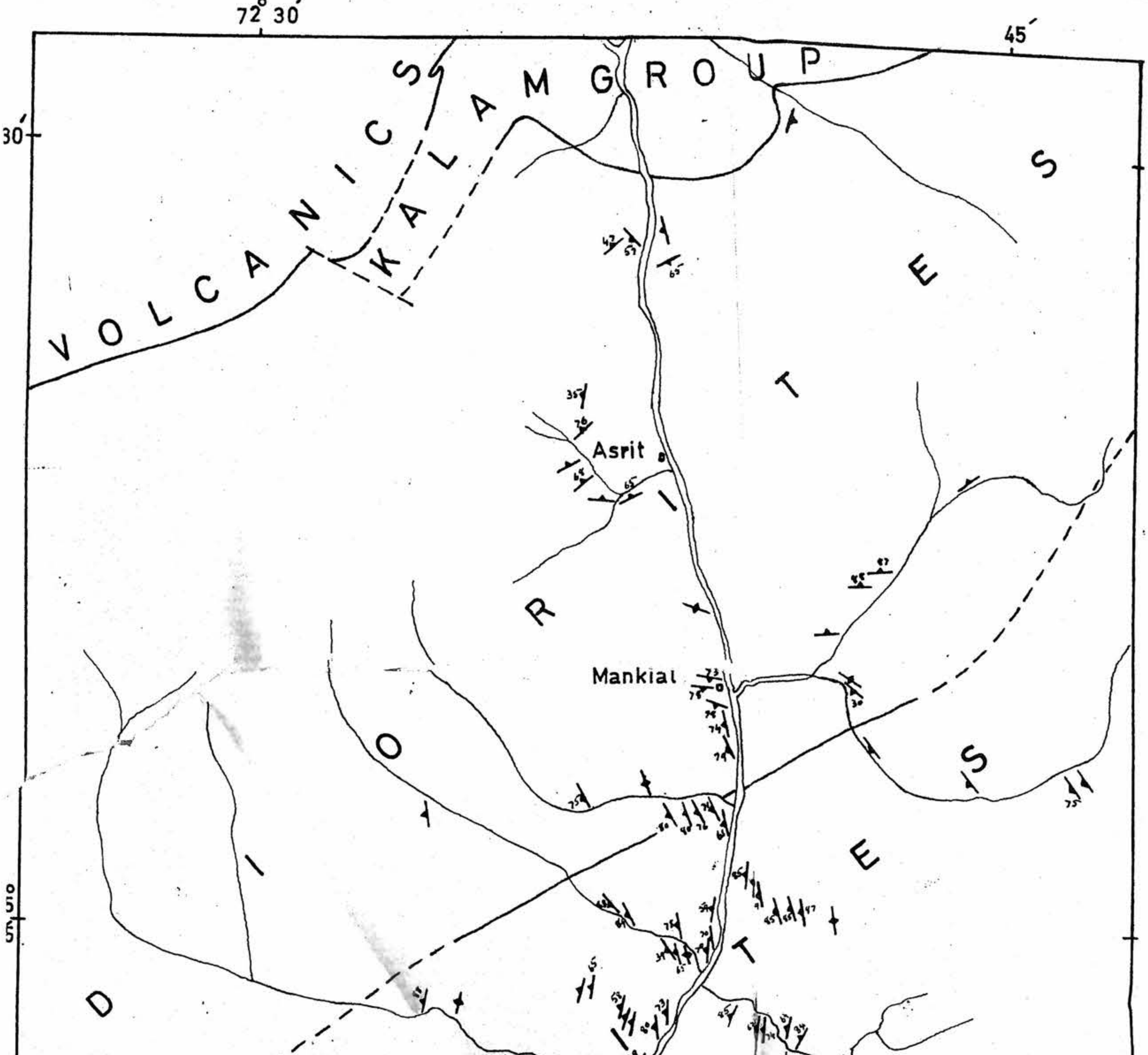
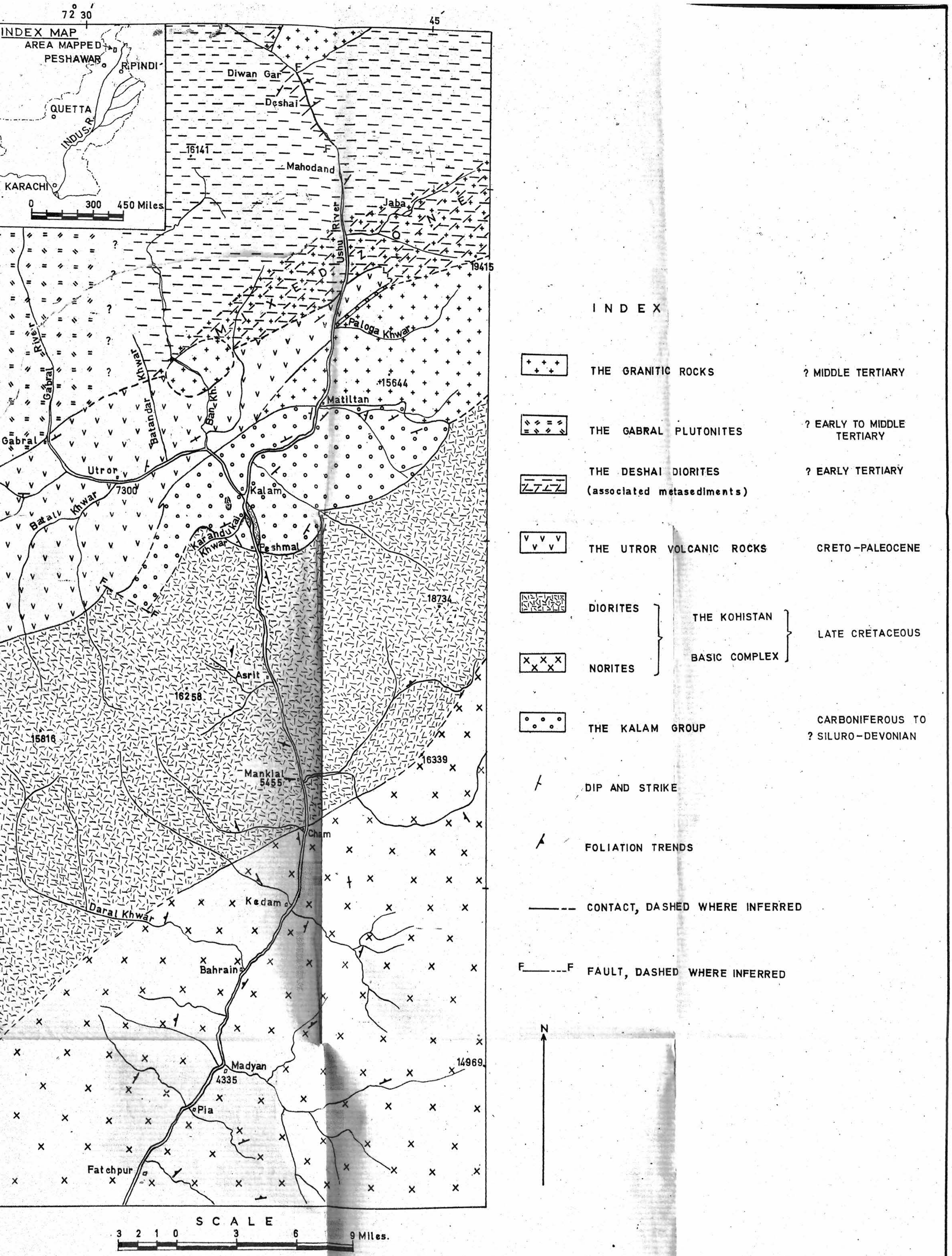


FOLIATION MAP OF BASIC COMPLEX SWAT KOHISTAN

(FAZAL AHMAD)



GEOLOGICAL MAP OF SWAT KOHISTAN

(FAZAL AHMAD)