THE GEOLOGY OF THE SHAH DHERI–KABAL AREA, SWAT

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ABSTRACT

This paper presents a geological map and petrography of about 20 square miles of the Shah Dheri-Kabal area in the Upper Swat. The previously undivided (? Precambrian) Hornblendic Group of Martin et al., 1962, which covers most of the area, has been divided into Homogeneous Amphibolites and Banded Gneisses, Dioritic Rocks, Alpine Ultramafic Rocks, and Quartz Diorites and Simple Pegmatites. With the exception of the amphibolites and gneisses, the rocks are considered to be connected with the Himalayan orogeny and may be Middle Cretaceous to Early Tertiary. The amphibolites, gneisses, and dioritic rocks have generally been metamorphosed to amphibolite grade; hornblende, epidote and, in some, garnet are very common. The group has a thrust-faulted contact with the rocks of the Lower Swat-Buner Schistose Group (Siluro-Devonian or possibly Ordovican), which cover the southernmost part of the area. These are represented by low grade eugeosynclinal sediments metamorphosed to phyllitic schists, marble, and greenschists.

The area is of some economic importance because of the occurrence of china clay, corundum, and magnetite (the latter to the north of the area investigated).

INTRODUCTION

This paper is an edited account of a M.Sc. thesis presented to the Department of Geology in August, 1970. It presents a preliminary geological map, together with detailed petrography and structure of the rocks, and a brief account of the economic potential. Mapping was carried out on Survey of Pakistan toposheet No. 43 B/1 on a scale of 1 inch=0.7 miles.

The area lies in the Upper Swat, about 12 miles northwest of Mingora. It is bounded on the east by the Swat River, on the west by the drainage divide between the districts of Dir and Swat, and on the north and south by 34° 50′ and 34° 45′ north, latitude, respectively. Access to the area is easily gained from Mingora by an

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all weather road; a fair weather road bifurcating from the main Peshawar-Mingora road near Landakai leads directly to the area. Jeapable tracks, streams, and foot-paths provide deeper penetration. The region has a moderate calimate with an annual rainfall of about 35 inches. With the exception of rainy season and shorter duration of hot summer days, field work can easily be carried out throughout the year.

The relief is moderate to high; the valley floor rises from 3,000 feet at Kabal to 4,000 at Tal, whilst the nearby peaks may reach 6,000 feet. The drainage, in general, is dendritic but some of the subsequent streams join the major consequents at right angles. The drainage texture is fine and the strams (mostly intermittent) are closely spaced. The banks of the main streams are covered by a thick cover of alluvium brought from the adjacent slopes down ravines fed by rain water. Moderate vegetation, dominanted by conifers, scrub and medium-sized trees, covers the area.

Previous Work.

Pascoe (1959) briefly described the rock types of Swat along the main road. The first general account of the geology of the Lower Swat-Buner area was presented in some detail by Martin, Siddiqui and King (1962). They divided the rocks ot the region into six units, namely:

1. The Upper Swat Hornblendic Group
2. The Lower Swat-Buner Schistose Group
3. The Swat Granitic Gneisses
4. The Swabi-Chamla Sedimentary Group
5. The Ambela Granite
6. The Shewa Formation.

Of these, the first two are exposed in the area under discussion. King (1964) further studied the metamorphic and granitic rocks of part of Lower Swat and considered that the granites were intruded as crystalline mush, syntectonically, during the Mesozoic (Post-Triassic) time.

Davies (1965) gave an account of the Upper Swat Hornblendic Group. Jan and Tahirkheli (1969) worked on the geology of lower part of Indus Kohistan of Swat and described this group in greater detail. According to these workers, the Hornblendic Group is composed of hornblende-bearing schists and gneisses, norites, diorites, periodotites, syenites, granites and pegmatites. Bakr and Jackson (1964) have tenatively placed the rocks, exposed south of Kalam along the Swat River, in the Precambrian.

Detailed investigations on Shah Dheri china clay have been carried out by Shah *et al.*(1964); Faruqi and Ahmad (1967); Moosvi *et al.* (1966) and Faruqi *et al.* (1970a, 1970b). Ashraf (1969) gave a short account of the geology of magnetite-bearing rocks north of Shah Dheri, and Jan *et al.* (1969) described briefly a corundum-bearing rock located 1½ miles southwest of Shah Dheri.

REGIONAL GEOLOGY

The Himalayas terminate in syntaxial bends, both in the east and west, caused by the northwards directed spurs of the Indian shield (Wadia, 1966). The rocks of the Upper Swat, probably, are a southwestwards continuation of the Himalayas west of the Balakot syntaxis. Hayden (1915) thinks that the belt of igneous and metamorphic rocks running through the outer mountains of Dir and Swat is a continuation of that found in Hazara — which most people consider Himalayan. Gansser (1964, p. 8) writes: "......the Hazara ranges, which form the western continuation of the main Himalayas west of the syntaxis, continue southwestwards although the whole range diminish greatly in magnitude. West of the Indus, and just north of the Trans-Indus Salt Range, only a narrow belt is left below the southern branch of the Afghan Hindukush." The authors can not follow from Gansser's account whether this southern branch of the Afghan Hindukush extends up to Swat or not. The northwestern part of Dir, however, appears to be a part of the Karakorum-Hindukush System.

As previously stated, Martin *et al.* (1962) divided the rocks of the Lower Swat-Buner region into six units. They suggested that a thrust fault enabled the Upper Swat Hornblendic Group to override the Schistose Group. Jan and Tahirkheli (1969), working in Kohistan area, added two more units, one above and the other below the Swat Granitic Gneisses.

a. Shang Granodiorite Gneiss
b. (3. Granitic Gneisses)
c. Jijal Ultramafics

The Hornblendic Group occupies the northern part of the region and forms a wide belt of country to the vicinity of Kalam where a thick formation of green and red mottled volcanic rocks is encountered. The group extends with a northeasterly trend, from Jandul in Dir to near Chilas in Gilgit. It is composed of norites, metadiorites, granitic rocks, peridotites, and minor metasedimentary amphibolites.Norites occupy the northern three-fourths portion of it. The Schistose Group, together with granitic rocks, occupies most of the Lower Swat and Buner region. These eugeosynclinal metasediments are considered to be Siluro-Devonian(Stauffer, 1967) along with the rocks of the Malakand Agency and northeatern part of Swat district. The common rocks are phyllites, greenschists, amphibolites, quartzites and siliceous schists, mica schists, calcareous schists and marbles.

LOCAL GEOLOGICAL SETTING

The area under discussion contains, mainly, the rocks of the Hornblendic Group and a part of the Schistose Group. The former is represented by metasedimentary rocks (banded gneisses), amphibolites, metadiorites, metagabbro, pegmatites, ultramafic and granitic rocks, and the latter by chloritic schist, chloritoid schists, talc-garnet schists, quartz-mica-carbonate schists and marble. The writers have tried to mark various units within the Hornblendic Group. The sequence of the rocks is as follows:

Alluvium		Quaternary
The Lower Swat-Buner Schistose Group		Siluro-Devonian
The Upper Swat Hornblendic Group:		
Quartz diorites and pegmatite	)	
Ultramafic Rocks	)	
Dioritic Rocks and Hornblende Pegmatites	)	(?) Precambrian
Homogeneous amphibolites and banded amphibole gneisses	)	

STRUCTURE

The Hornblendic Group extends for at least 160 miles from western Dir to near Chilas, Gilgit Agency. South to north, the Group extends for about 60 miles up to the vicinity of Kalam. The general trend of the rocks throughout this area is from northeast-southwest to east-west, with a general dip towards northwest to north. To the south, the group is bounded by the Schistose Group. Martin *et al.* (1962, p. 10) write: "......in the Lower Swat-Buner area there seem to be zones of folding ......Just north of the Swat River, the folding trends largely northeastwards...... South of the Swat River, and to the divide between Swat and Buner, the fold direction trends northwestwards. In the south, the folding trends again predominantly northeastwards, although a more easterly trend is seen in Buner, before the trend in the area, as a whole, swings into the northerly direction......" They also conclude: "the regional strike changes from west-southwest in the west and south, to northerly in the northeast and east. This coincides with the proximity of the main Himalayan re-entrant at Balakot to the east. The regional dip is to the northwest, which is also the direction of the dip of the minor fault planes and axial planes of the folding which are parallel to the regional trend."

The contact between the Hornblendic and the Schistose Groups is considered by Martin *et al.* (1962) and Davies (1965) to be a thrust plane. Jan and Tahirkheli (1969) thought that the Hornblendic Group may either be generated in situ or thrust faulted over the Schistose Group. They, however, prefer the second alternative in explaining some of the contact featurs. The contact between the two groups, in fact, is very puzzling; there is considerable feldspathization of the Schistose Group and chloritization of the Hornblendic Group. The rocks near the contact are greenish, whitish and brown in colour and are fractured and weathered. Besides, at places, the contact is covered by alluvium.

It seems that the rocks along the contact are midway between the two groups. On one hand (in the area under discussion, especially) they are apparently well-bedded, schistose and carry quartz-rich layers, on the other hand they have hornblende and chlorite, and are coarser grained—resembling the altered rocks of the Hornblendic Group. This type of zone is not confined to only one place but occurs all along the contact of the two groups and, at places, many tens of feet thick. In Kandia River valley, in the upper part of Swat Kohistan (Jan, Ibid.), where a many square miles large body of low grade schists is surrounded by noritic rocks, a similar contact phenomenon is seen. Nowhere can be seen a clear and sharp contact. It is possible that this zone, either, is a part of the Schistose Group (that has been crushed, fractured and metamorphosed due to thrusting), or of the Hornblendic Group (that has undergone retrograde metamosphism along the contact). There still remains another possibility, i.e. the Hornblendic Group is intrusive in situ and this zone is a contact phenomenon. Field evidence, differences in grades of metamorphism of the two groups, and the occurrence of almandine-talc schist (along the contact in the area under discussion) support the idea of thrusting.

Jan (personal communication) thinks that the contact between the two groups may be a faulted one, however, it is not clear whether it is a thrust or not. Besides, considering the immense volume of the Hornblendic Group in Kohistan (Dir, Swat and Hazara areas), it seems more likely that the group has not been brought from very far in the north. Martin *et al.* (1962, p. 10) have shown the faults to be pre-granite in age, although there is no clear evidence for this. However, the faults, according to them, "probably predate the folding of the region since they are also folded." Jan (personal communication) thinks that the granitic rocks within the Hornblendic Group are quite different from the granitic gneisses occurring in the Schistose Group. The latter, apparently, terminate near the contact with the Hornblendic Group — suggesting that the thrusting post-dates the intrusion of the Swat Granitic Gneisses.

Minor faults of local nature, probably associated with the major faulting, occur near Kotlai and Suigalai khwars, and some other places. The fault near Kotlai khwar may be many miles long. With the exception of microfolds and a few local folds, there is no evidence of major folding. In the banded gneisses, the bands may continue parallel to the strike for a considerable distance. Several regular and imperfect joint systems have developed in the rocks. In the Schistose Group, one joint system strikes roughly parallel to the strike of the beds with moderate dip towards the north; a penetrative parting has been developed in these, possibly parallel to the original stratification. Cleavage is fairly well-developed in the phyllites and is cut by cross fractures which cause the rocks to crumble. The ultramafic and other intrusions are generally parallel to the foliation and/or bedding. When traced for a considerable distance, these bodies may change in thickness.

THE UPPER SWAT HORNBLENDIC GROUP

Introduction.

The so called Hornblendic Group was first named by Martin *et al.* (1962) because of the abundance and ubiquity of hornblende. The rocks range from hornblende-bearing schists and gneisses to diorites and even quartz-diorites and granites. A pale green epidote and a pink garnet are also common. In addition, the group contains a number of more basic rocks such as norites and peridotites. Davies (1965) also reported the presence of syenite. The rocks are cut by thin pegmatites with large crystals of hornblende. A distinct foliation is commonly developed by a preferred orientation of various minerals. Regional studies of the group by Jan (Ibid.) have revealed that the southern portion of the group is rich in amphibole but for the major part the rocks are noritic and pyroxenes are the major mafic minerals. For this reason, it may not be adequate to call it Hornblendic Group.

Jan and Tahirkheli (1969) divided the group into two major parts in Indus Kohistan, Swat. Most of the rocks are gneissose amphibolites composed of hornblende, plagioclase, clinozoisite, quartz, garnet, opaque minerals and minor rutile. These are flanked on the southeast by coarse-grained, banded gneisses composed of pink garnet, plagioclase, hornblende and minor quantites of clinozoisite, quartz, rutile and ore. A few also have muscovite. Some of the banded ones are very rich in either garnet or hornblende, some times making more than 80% of the rocks. Jan and Tahirkheli considered the latter to be basic igneous rocks metamorphosed to almandine-amphibolite facies grade. Siddiqui (personal communication) consideres that most of the rocks of the Hornblendic Group are norites metamorphosed to granulites.

Martin *et al.* placed the Hornblendic Group below the Siluro-Devonian rocks of the Lower Swat-Buner Schistose Group. Bakr and Jackson (1964) have tentatively placed the rocks of the group along the Swat River in the Precambrian. Jan (Ibid.) thinks that the Hornblendic Group is not entirely a Precambrian mass. There might be some justification to consider the banded amphibolites as Precambrian or Palaeozoic (?metasediments), but the diorite and other rocks are younger in age and probably connected with the Himalayan orogeny. The diorites and norites may have intruded during the earliest phases of orogeny (? Middle to Late Cretaceous) shortly followed by the alpine peridotites (? Middle to Late Cretaceous), and the still younger granitic rocks (? Early Tertiary). There, however, is no positive evidence for this.

Homogeneous Amphibolites and Banded Amphibole Gneisses.

In the area under discussion, amphibolites and banded gneisses are closely associated. The latter are more common in the northern part. They are foliated and composed essentially of hornblende, plagioclase and epidote. Some are highly weathered, giving rise to a spongy appearance due to greater stability of some minerals towards chemical weathering; others are highly fractured and jointed, a few of which are rendered into huge blocks. Concentration of various minerals in more or less distinct bands in those amphibolites is more common which are asociated with banded gneisses. Some of them contain medium-grained porphyroblasts of garnet in a finer matrix. In the banded gneisses, dark and light coloured bands, at places plunge-shaped, are conspicuous. In some, these bands run parallel to each other for a considerable distance, in others they are irregular and diminish at a short distance. Alteration is more pronounced along the contacts of the bands. They are intruded by coarse pegmatites containing hornblende, feldspar and garnet, and thin veins of feldspar and quartz. Veins of epidote, garnet, and magnesite (the latter near the contact with the ultramafic rocks) are also common.

Under the microscope, the rocks are medium-grained, gneissose, hypidiomorphic to allotriomorphic. Based on visual estimates of mode of seven sections, they are composed of hornblende (53 %), epidote (20.6 %), plagioclase (19 %), quartz (5 %), ore (1.7 %); and minor rutile and chlorite. The proportions of these minerals greatly vary from section to section, and any mineral may be totally absent. Hornblende is 3-8 mm long, anhedral to sub-hedral, pale green to pale yellow pleochroic, and has brownish iron oxide along fractures, cleavages and grain boundaries. Some grains have abundant inclusions of feldspar, epidote and ore; the latter being concentrated as fine dust in the middle of some grains. Martin *et al.* (1962) have noted that hornblende may be rimmed by mica. Most of the plagioclase has been altered into clayey and micaceous material.

Epidote is, generally, in inverse proportion to hornblende and plagioclase combined. It has anomalous birefringence, and some is in distinct secondary granules embedded in the plagioclase. A little of it may grow into myrmekitic texture with quartz; other may grow in large poikiloblasts around which small grains of hornblende, epidote and quartz twist. The large grains may also be twisted and bent due to stresses. Quartz is in the form of minute 'interstitial' grains with undulose extinction. Iron ore (magnetite) occurs in distinct grains and inclusions. One section contains both oxide (opaque) and sulphide of iron. The forn alteration to deep red (?) hematite and the latter is always rimmed a by opaque oxide of secondary origin. Yellowish to reddish-brown d occur in only one section in minor quantity. Chlorite is faint green only some of it is fibrous, and much of it appears to be secondary. S‹ contain pink garnet and in a few it is very high in proportion, pa certain bands.

In two localities (one and a half miles southwest, and two mile: Dheri), corundum also occurs in amphibolite and chlortic schist, res latter is composed of chlorite, (?) talc, muscovite and hornblende. V fine crystals of black tourmaline also occur. In the former, the corun surrounded by a light green alteration rim (of ? margarite, etc.), pa fractures run close to them.

Dioritic Rocks.

Numerous dioritic intrusions (? Cretaceous), mostly altered a phosed, occur in the southern part of the area. They are from a hundred feet thick and may extend for many miles. Their trend ch due to faulting; however, in general, they are in accordance with the r the Hornblendic Group. They are variable in texture and colour i from dark meladiorites to leucodiorites. Both physical and chemica made it difficult to get fresh samples of many of these rocks, parti contact with the Schistose Group where they are highly chloritiz schistose. At places, the rocks are very fractured and abundant epi tion is seen along such fractures. Inclusions of amphibolites are com these rocks.

The rocks are medium-grained, gneissose and hypidiomorpl Hornblende and plagioclase make 30 to 40 % each, but some ha proportion of one or the other. Plagioclase is generally altered to clay material or saussuritized; some is completely epidotized. The f (andesine) is in subhedral grains with albite twinning. The margin: ever, are also saussuritized and thus have corroded appearance. So have fractures along which are seen minute granules of ore and epido is in subhedral to anhedral grains, some times twinned. Some of it h with abundant ore inclusions which may be due to metamorphism. blende may be chloritzed on margins. Epidote is also present in v ranging from 4 to 60%. It is colourless to pale and some is in poikil generally makes less than 5% as minute, anhedral grains between lar undulose and some is fractured. Traces of opaque minerals are 1 sections. In one case, it is ilmenite altered to leucoxene on margins.

Jan and Tahirkheli (1969), and Jan (Ibid.) have reported abundant hypersthene gabbros (norites) from Kohistan area but the writers did not find any norite in their area. However, at least one rock is gabbroic in composition. The sample is from a small intrusive body, associated with the gneisses, in the north of the area. It is composed of labradorite (partially altered, some twisted and/or zoned), hornblende (pale brown to brownish green), clinopyroxene (pale green diallage or diopsidic-augite), epidote (partially developed after plagioclase, some intergrown with quartz) and traces of iron oxide. Some of the pyroxene is ophitic in texture and many of the large grains are schillerized.

Hornblnde-bearing and very coarse-grained pegmatites (genetically related to dioritic rocks, probably) occur at many places. They may be concordant or discordant and not more than ten feet in thickness. Hornblende and plagioclase are the major constituents of these, although some also have abundant garnet and minor (?) epidote. In these, the crystals of hornblende may be many inches long. Martin *et al.* (1962) reported similar pegmatites with hornblende crystals up to nine inches long. Jan (Ibid.) has seen some pegmatites in Hazara Kohistan that contain over a foot long crystals of hornblende.

Ultramafic Rocks.

Peridotites occur along the Ramogai stream, near Tighak village, in at least three mappable outcrops. Characteristics such as irregular form, lack of systematic change in mineralogical composition, absence of contact metamorphism in the surrounding rocks, and presence of cataclastic texture support the idea that they are of alpine type. Areas covered by peridotites are distinct; at some places they are highly serpentinized, sheared, and many have a greyish-green colour. They appear to be steeply dipping sheets or lenses, emplaced concordantly or discordantly along the structural weaknesses of the enclosing rocks. Surface waters have produced greater serpentinization along numerous joints and contacts. Highly sheared and altered peridotites develop curved masses (rounded nodules), with core of less altered peridotite surrounded by a waxy shell of serpentine.

The rocks range from partially serpentinized peridotites to serpentinites. The former are composed of anhedral grains of olivine ± (?) orthopyroxene; the rocks are thus named dunites and (?) harzburgites. The cataclastic texture of these indicates deformation of the mineral grains during emplacement. The olivine grains are rimmed by (?) talc and serpentine. Thin veins of magnetite and serpentine run within the grains. Pyroxene (? enstatite) has been noted in two sections. It is pinkish in one and greenish to pink neutral (? altered) in the other; cleaved and has an optic axial angle of 70°-80°. When altered, it does not contain abundant ore like olivine. In one section, some of it looks to grow in ophitic patches around olivine, although serpentinization has obliterated a clear picture. In general, it shows lesser alteration than olivine.

In most cases, pyroxene and olivine (the latter in particular) have very irregular margins because of high alteration. There appears to be a radial growth of fractures in some of the pyroxene surrounding highly altered olivine. This might suggest that the olivine grains increased in volume because of alteration. In the pyroxene-bearing rocks, most of the ore is secondary. There, also, is a green spinal which, in some cases, forms a myrmekitic intergrowth with the ferromagnesian minerals. Serpentine and minor (?) talc make more than 50% of these rocks.

The highly altered rocks are composed mostly of fibrolamellar grains of serpentine, with relict grains of olivine up to three per cent. Less altered parts of olivine grains are generally surrounded by a partial or complete rim of iddingsite. Magnesite, colourless to pinkish pleochroic due either to impurities, surface colour or thickness of slide, is present in some; in one section it is up to 18%. Ore, up to 30%, also occurs. In one section containing patches of carbonate, iron oxide forms a network of 'veins'. In another, some of it is in distinct aggregates, and in grains tending to develop herring bone texture; other occurs in small granules arranged in trains.

Quartz Diorites.

Small intrusions of quartz diorite (? Tertiary) are abundant in the northern part of the area. They are generally concordant bodies trending east-west. The largest of these, on which lies the village of Shah Dheri, is half a mile long and 800 feet wide. Some of the outcrops are gneissic, a few look banded. Most have undergone physical and chemical weathering, both solution and spheroidal weathering have rendered the rocks friable and sandy. Quartz and feldspar veins and pegmatites, mostly thin and short, are very common. The Swat clay is a product of partial decomposition of the feldspathic bands in these rocks. Some of the quartz diorites have xenoliths of the enclosing rocks, thus proving their intrusive nature. Effects of contact metamorphism, however, are not very pronounced.

They are medium-grained, hypidiomorphic and subequigranular. Plagioclase, making about 60% of the rocks, is mostly altered to kaolin and only a few grains show faint albite twinning. In some, secondary epidote has also developed after this. Quartz (24%) is undulose in extinction, fractured, and does not show sharp boundaries. It occurs mostly in disseminated grains but some of it forms graphic intergrowth with feldspar (? orthoclase). Biotite (14%) occurs in small grains, more abundant along fractures. It is deep brown to brown pleochroic but some is chloritized green.

Simple pegmatities, generally less than ten feet thick and genetically related, probably, to quartz diorite, occur in the area, particularly towards the north. A few aplites with even-grained minerals that rarely exceed 2 mm in size, also occur. They appear very fine-grained in contrast to pegmatites which are very coarse-grained and variable in texture. Along Manja khwar occurs a huge pegmatite body with a width of 30 to 40 feet and cutting the intruded rocks irregularly. Like others, it is composed of quartz, feldspar and muscovite. The body is highly fractured, weathered, and contains xenoliths of altered hornblende.

THE LOWER SWAT-BUNER SCHISTOSE GROUP

Introduction.

This group was also first studied by Martin *et al.* (1962). It lies to the southeast of the Hornblendic Group and occupies most of the Lower Swat, Buner, the western part of Chakesar and the northeastern part of the Mardan district. Martin *et al.* divided this group into:

5. Greenschists
4. Phyllitic Schists
3. Marble and Calcareous Schists
2. Amphibolite Horizon
1. Siliceous Schists

Jan and Tahirkheli (1969), however, have not extended this subdivision in the lower part of Indus Kohistan of Swat. According to these workers, the common rocks of the group are quartzites, quartz-mica schists, quartz-mica-granet schists, quartz-chlorite–albite schists, quartz-carbonate schists, marble and calcareous schists, and amphibolites, etc. Jan and Tahirkheli also mention the presence of metaconglomerates exposed at two places in Indus Kohistan, Swat. Martin *et al.* place them below the Chamla Quartzites of the (?) Devonian age. Bakr and Jackson (1964) give these rocks a Siluro-Devonian or possibly Ordovician age. Jan and Kempe (Ibid., p. 67) think that the metaconglomerates of the Kohistan area might be the equivalents of the Tanaki Boulder Beds of the Silurian age.

The group covers only the southernmost part of the area mapped. The rocks appear to be eugeosynclinal sediments that were metamorphosed to low grade assemblages during the course of the Himalayan orogeny. They are parallel to the northeastern trend of the Hornblendic Group, but locally they have different trends due probably to deformation along the faulted contact. Although not shown on the map, the rocks exposed can be divided into two subgroups: (a) phyllitic schists and associated marble, and (b) greenshchists.

Phyllitic Schists and Marble.

Along Suigalai stream, vertical erosion has exposed a part of the phyllitic schists underlying the greenschists. In lower part, they come in contact with crystalline limestone. They are greyish, fine-grained and schistose. Joints and fractures are common and so are microfolds. Very fine and thin veins of quartz twist in the latter; the thickness of the individual veins varying in different parts of a single microfold. Some quartz also occurs in unfolded veins, up to two inches thick, and in boudins and rounded masses. The marble is brownish in colour and poorly bedded. It is cut by calcite and quartz veins and a few epidote and (?) chlorite veins. Many of the rocks are composed mainly of carbonate, however, some also have other minerals in abundance.

Greenschists.

The common assemblages of greenschists present are: chloritic schist, carbonate-mica-quzrtz schist and assemblages of somewhat higher grade containing chloritoid. The rocks are generally soft, cleaved and differentially weathered. Mechanical deformation is much stronger than chemical weathering; joints and fractures are thus common. Cracks and (?) open cavities produced by folding have been filled by veinlets and boudins of quartz. The rocks are fine-grained and greenish but some are brownish due to weathering. Near the contact with the Hornblendic Group, some are so much feldspathised that their separation is difficult. Also, at some places near the contact, talc schist carrying abundant porphyroblasts of garnet are associated.

Chlorite makes about 92% of the chloritic schist. It is fibrous, pale green and pleochroic, with negative optic sign. Reddish brown rutile (7%) is concentrated in 'bands'. Traces of ore are also present. The carbonate-mica-quartz schist is composed of about 20% each of biotite/chlorite, sericitic muscovite, and quartz. Its other constituents are siderite (25%) and graphite (15%). The micaceous minerals, generally, are in very small grains parallel to the schistosity. Graphite is disseminated in fine dust and siderite has abundant reddish iron oxide in association. It appears from the section that most of the minerals tend to concentrate in distinct streaks.

The chloritoid schists (only two sections) are composed of chloritoid, micas and quartz, etc. Muscovite (10 to 30%) generally occurs in thin aggregates, somewhere bent. The platy grains show well developed schistosity. The main schistosity is crossed by later strain slip cleavage due to microfolding. Chloritoid forms 7% of one and 15% of the other section. Most of it is in the form of porphyroblasts, many of which are parallel to the schistosity but some are even at right angles to it. It contains quartz inclusions and, in some cases, is completely surrounded by fine muscovite. In one section, it is altered along fractures and margins to a brownish material. Quartz is the most dominant mineral, forming 75 and 40% of the two. It is undulose and, in one section, is concentrated in distinct streaks and patches. Biotite/chlorite make about 8% on the average and ore is up to 4%. The latter is magnetite (partly altered to hematite) occurring in the form of fine granules and dust, some in micro-folded streaks.

ALLUVIUM

Quaternary alluvium covers a large part of the land and the flat tops of the low hills, particularly on the eastern side along the Swat River. It consists of unconsolidated sediments of varying sizes on which moderate soil has developed. On the eastern side, the alluvium is generally composed of angular and rounded material; the former may be from the local sources, whereas, the latter is probably brought by the river from the area to the north. The various components of the alluvium seem to have been derived from different igneous and metamorphic rocks mostly belonging to the Hornblendic Group. Near the contact with alluvium the dioritic rocks show a high degree of alteration for some distance.

ECONOMIC GEOLOGY

The area is of some economic importance due to the occurrence of china clay, corundum, magnetite (the latter, actually, is just north of the area) and building material. The corundum-bearing rocks are at two places; one, about a mile and a half southwest, and the other, about two miles north of Shah Dheri. In the former locality, the mineral occurs in a greenish, massive body that is bordered by banded amphibolites to the north and a thin dioritic intrusion to the south (Jan, *et al.*, 1969). The rock is composed of pale green amphibole, garnet, and minor chlorite, corundum and alteration products. It is weathered, fractured and friable; the amphibole is granulated along fractures. The corundum is generally surrounded by a light green alteration rim (of ? margarite, etc.), particularly where fractures run close to them. It is disseminated in well-formed crystals which are translucent, purplish and often fractured. The corundum showing to the north of Shah Dheri has been mined from time to time by the local inhabitants. Here, the rock is chlorite - (?) talc schist, highly weathered and intruded by veins of quartz-feldspar pegmatite. In both localities, the mineral is not economical at this stage, however, if greater concentration is found in any of these horizons, the mineral can easily be extracted from the soft rocks for abrasive purposes.

The kaolinite deposits are exposed in the northeast of the area, extending from Taghna (to the east) up to Shah Dheri. The deposits have been divided into three main parts, the western, the middle, and the eastern (Faruqi and Ahmad, 1963; p. 58).

The first two are about half a mile long with average width of 800 and 600 feet respectively, while the western part is over half a mile long and 100 to 1000 feet wide. Whyte (1965, unpublished) has estimated about 258,700 tons of reserves; as the kaolinite recovered is only 40 to 50 % pure, only 120,000 tons are usable. According to Moosvi and others (1966), the total reserves (about 1.7 million tons) after benificiation come to about 255,000 tons with kaolinite content of 50%. The clay is a partial decomposition product of the feldspathic bands in quartz diorite. From the modal analysis, it is evident that the raw and washed kaolinite is an admixture of the plagioclase (abundant), kaolinite and some quartz (Faruqi and Ahmad, 1967). Minor constituents such as biotite, muscovite, hornblende, tourmaline, apatite and complex magnesium silicates are also present, some only in traces. The mineral composition of the washed samples shows that the major constituents are kaolinite (50 to 60 %), and feldspar (about 35 %). The impurities found in the original rocks, such as mica, iron compounds, etc., continue to be present in small quantities in the washed samples. Recently, Faruqi and others (1970a, 1970b) have compared this clay with those of the imported ones and found that it can, after washing, successfully replace the imported clays and thus can be used in ceramic industry. The government has decided to set up a small factory to process on this clay in the N.W.F.P. and the deposit is under extensive investigation by the geologists of the W.P.I.D.C.

Magnetite reserves of good quality have been reported to the north of the area. In 1969, Ashraf of the W.P.I.D.C. found some magnetite in the stream near Shah Dheri. Later, he located the mineral in amphibolites near Mari Banda. The associated rocks, according to Ashraf (1969) are amphibolites; and peridotites of various combinations of pyroxenes, olivine, plagioclase and hornblende. The magnetite occurs disseminated or in large bodies. Siddiqui (1969, personal communication) thinks that the amphibolite is a metamorphosed norite (to granulite) and the magnetite is a high temperature mineral of primary origin. No estimates of the reserves are available.

Almost all of the rocks except the weathered ones,have been used locally as building sontes. Some of the serpentinites, banded gneisses (containing coloured bands due to varying proportions of amphibole, garnet and plagioclase, etc.) and the coarse, hornblende pegmatites may be used as decorative material.

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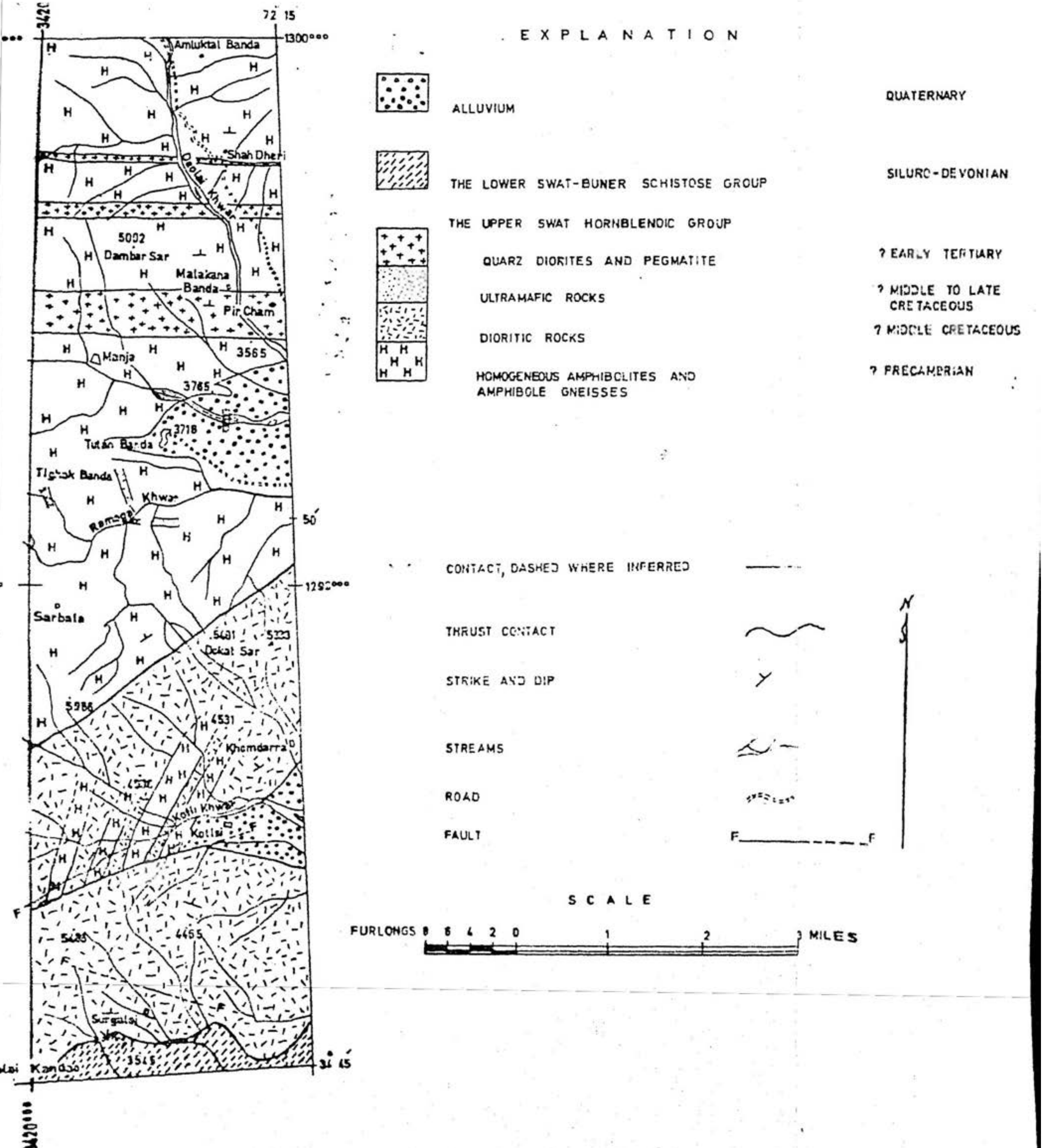

GEOLOGICAL MAP OF THE SHAH DHERI-KABAL AREA, SWAT.