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THE GEOLOGY OF JANDUL VALLEY, WESTERN DIR.

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ABSTRACT

The geology of Jandul Valley consists of Palaeozoic metamorphic rocks oj amphibolite facies, intruded by igneous rocks in Jurassic-Cretaceous times. The plutonic rocks consist of an earlier phase of diorites, granodiorites, and granites and an apparently later phase of norites, hornblendites, pyroxenites and peridotites.

The Mesozoic magmatism was followed by volcanic activity in the Tertiary times. These, consisting of andesitic and dacitic tuffaceous rocks, are intimately inter-bedded with fossiliferous metasedimentary rocks of phyllite grade. This phase is characterized by the intrusion of porphyry dykes which were probably the main feedes at the time. This was followed by a phase of granite and diorite dyke intrusions. Next quartz and pegmatite veins formed, followed by a final stage of dolerite dyke intrusions. Extensive sporadic copper-mineralization is associated with the volcanism.

Structurally, the region is complexly folded and faulted. The main bodies of the intrusive and extrusive rocks seem to be located along a thrust zone. At least three tectonic stages are discernible in the area.

INTRODUCTION

Jandul Valley, in the southwest of Dir district, is situated between Latitude 34° 45′N to 35.0°N and longitude 71° 30′E to 71° 45′E., covering about 400 square miles. It is connected with the main road from Timurgara. The valley is bordered in the north by Barawal, in the south by Bajaur (Utmankhel Territory), in the east by Maidan Valley and in the west by Bajaur (Salarzai Territory) and Asmar Valleys (Afghnistan).

The eastern divide is inhabited by Mishwani tribes, the west by Salarzais, and the southern part by Utmankhel tribes.

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Jandul is a broad flat valley drained by Jandul Rud (River), flowing north-south for a distance of about twenty miles. Two miles south of Munda Qala it joins Bajaur Khawar that flows eastwards. Jandul Rud is made of two main tributary streams, the Kambat Khawar in the east and Miskini Khawar in the west. The confluence of these two streams is about one mile south of Mayar.

The altitude of the area varies from 4500 feet to 9000 feet above sea level. The broadly amphitheatrical aspect and relatively flat base of the valley suggests that it might have been carved originally as a glacial valley.

Mapping was done on a scale of one inch to 0.789 miles (1:50,000). No partinent geological literature is available about this whole region. Ahmad (1962) briefly reported on the copper mineralization in the area, and mentioned the occurrence of diorites, andesites and dacites. The present work is, therefore, the first detailed report on the geology of the area. The detailed structural geology of the area is not well-known. Work is still in progress in order to demarcate the intricately complex structural patterns of the area.

GEOLOGY

The geology of the region consists of four major stratigraphic units :

1. Palaeozoic rocks, probably Siluro-Devonian in age, of the southern and central parts. The rocks are classed in amphibolite facies, and consist of hornblende-plagioclase schists, epidote-hornblende-plagioclase schists and in small amounts of hornblende-garnet-plagioclase schists. This also includes the scattered sheets and lenses of metasediments included in the younger intrusive rocks and probably parts of the eastern gneissic belt.

2. The Mesozoic rocks, probably Jurassic-Cretaceous in age, in the east, west and northeastern parts of the valley, consist of diorites, granodiorites and granites. Closely associated with the diorites are small intrusions of pyroxenites, peridotites, and hornblendites in the southeast; hornblendites in the southwest, and norites in the east and north central parts of the valley. Most of these basic and ultrabasic intrusives are restricted to intensely sheared zones. The surrounding rocks usually show the development of quartz and pegmatite veins.

3. Tertiary volcanic rocks and porphyry dykes occur in the north and northwestern parts. These consist of andesite and dacite tuffs intimately interbedded with fossiliferous metasedimentary rocks, containing *Lockhartia* and other forams, some recent Gastropods and Fusilinid shells. These rocks are best developed in the north in Barawal area, where the total thickness of the volcanics and metasediments is more than ten thousand feet.

4. The Late Tertiary phase is of granite and diorite stocks, meladiorite dykes, quartz and pegmatite veins, and dolerite dykes, respectively. The porphyry dykes were probably the main feeders in the area.

1. Palaeozoic Rocks of Amphibolite Facies.

The amphibolite facies rocks are exposed in the south and central parts of the area with minor sheets and lenses included in the plutonic rocks. These rocks are distinctly banded and schistose. Their mineralogy is uniform, showing only local variations. They generally contain hornblende, plagioclase and quartz with small amounts of epidote, chlorite, calcite; zoisite, hypersthene, garnet, biotite; muscovite, sericite; and magnetite in different samples. The hornblende is dark green in colour and has broken down into epidote near contact zones, where epidote occurs as well-developed crystals in veins. Hypersthene, and garnets in amphibolites are only restricted to intensely deformed parts, where they reach high proportions. Micas are only locally developed and appear to result as products of the breakdown of hornblende.

In intensely sheared areas the banded structures in the amphibolites disappear, and the hornblende usually breaks down to epidote and iron-ore or almandine garnet. The garnet crytals occasionally form the bulk of the rock in small bands, which consist of almandine, plagioclase and quartz. Hypersthene rarely reaches as much as 13 percent of the total bulk. The almandine garnet-hypersthene zones are restricted along shear zones and they can be included in granulite facies which occurs in small exposures throughout the area.

The average composition of the amphibolites as deduced from microscopic study, approaches that of diorites which have intruded the amphibolites.

The amphibolite facies in the southern parts trends east-west and is well-developed south of the Bajaur Khawar in the Utmankhel territory. These rocks extend westwards into the Bajaur area, where they pass into Mohmand tribal region in the south. They are well-developed west of Mayar, where they are in contact with the diorites. The amphibolites are also exposed in Wuch Khawar on Matakai hill and also near Rustum Banda, north of Munda Qala. Further north of these localities they are also seen again near Jabagai where they are intruded by a small stock of granite gneiss, just along the main road. A small outcrop of these rocks is seen east of Barwa, where they are in contact with diorites and gneisses. The southern contact of these rocks is extermely sheared and it seems that they might have been displaced over great distances, and are extremely tightly folded.

The general strike of the amphibolite changes from east-west in the southern parts to northeast-southwest in the north and central eastern parts of the area, suggesting that these rocks may be exposed in the core of an anticlinal structure. The contacts of amphibolites with intrusives are highly variable in nature, grading from sharp, well-defined to transitional ones. The contact zone, west of Mayar near Zaro-Derai is transitional, where for about half a mile there is a continuous alternation of bands of amphibolites and diorites. Near the contacts epidote is formed profusely and epidote veins in all direction are commonly seen. The epidote is formed at the expense of hornblende and decreases in amounts away from the contacts. The change from hornblende to epidote has resulted in the release of iron and titanium oxides, which occur as small veins of magnetite and ilmenite.

Near Matakai Hill the amphibolite facies rocks are dark coloured, medium grained, banded schists and gneisses. The bands consist of alternating layers of hornblende, and plagioclase and quartz. The rocks strike east-west and have a vertical dip. There is a continuous coarsening effect, from the bottom of the hill towards the top. Here well-developed hornblende porphyroblasts are seen. There is also a continuous darkening effect due to an increase in the hornblende content near the top. Microfolding also increases near the top, due to the proximity of the contact. On the western slope of Matakai Hill, a well marked two feet thick, red, occasionally porphyritic band of quartzite occurs. The contact of the amphibolites with granite is exposed near the western slopes of the hill in a small stream near Ghakbai. It is a sharp contact with a shear zone in the hornblend-schist, about 50 feet thick. Some schist near the contact is granitized. About 150 feet away from the contact two parallel veins of hornblendite occur in the granite. It seem to be a result of partial assimilation of the country rocks. East of Matakai hill, across the stream, the trend of the amphibolites changes to northeast. Here well-developed veins of epidote-rock occur along shear planes, probably as a result of retrograde effect of the granite body.

The Manrugai outcrop is a tightly folded anticlinal structure. The hornblende schist here grades into hornblende - garnet gneiss, which is very tightly folded. Further south towards Munda, the hornblende-garnet gneisses pass into hornblende-plagioclase-quartz gneisses, which locally show distinct development of hornblende veins, whose frequency increases southwards. The small hornblende veins consist of pure hornblende mineral in the center, hornblende, plagioclase and plagioclase, quartz in their marginal parts respectively. The plagioclase quartz paragenesis finally passes into coarse grained granular leuco-granitic veins. These leucogranites vary in size from a few inches to bodies of large dimensions about a mile in diameter. The whole area in this vicinity is very disturbed and the structures are rather complicated. Most of the gneisses here are tightly folded and sheared at places. The fold axes are in the dip-plane of the foliations and the axial planes are parallel to the general strike. Further south of Manrugai, near Pashatai, these gneisses abruptly pass into a massive body of hornblendite, about one by three miles in dimension, and consisting of pure hornblende.

East of Mayar, near Charmang, a large outcrop of amphibolites is exposed. It has been intruded by granitic rocks in the middle, as a result of which a lot of hornblende has been released in the form of veins. The granite itself is highly sheared, porphyritic gneissose, profusely intersected by quartz and pegmatite veins throughout. The amphibolites consist of hornblende, plagioclase and quartz and are in contact with diorites in the southeast and with granite in the southwest. The northern contact with diorites has not yet been marked. The intensive shearing, folding and faulting is suggestive of partial remobilization of these rocks. Differentiation between the intrusive granitic rocks from the ones granitized in situ is very difficult. This complex relationship, which prevails all over the eastern divide strongly suggests that most of the apparently intrusive gneissose rocks may be a result of metamorphism. Near the contacts the gneisses have bands of well developed garnet zone, locally passing into a granulite facies paragenesis.

Northeast of the Barwa-Satbar line are isolated outcrops of the amphibolites, generally trending northeast-southwest with steep dips. These outcrops are in contact with porphyritic augen gneisses, which are usually very coarse-grained and light in colour. The grain-size of these gneissose rocks becomes finer northwards. The amphibolites in this zone are intensively deformed and stretched, and east of Kambat they are profusely intruded by porphyry dykes with copper mineralization. In this region, biotite also appears at certain horizons in the schists, and usually, when biotite appears, there is very little or no hornblende in the schists. These schists contain biotite, chlorite, pyrite, quartz and feldspar. Along the sheared contacts in this area, the hornblende has broken down into epidote, which is very extensively developed locally.

Besides these major outcrops of amphibolites, small lenses and sheets of these rocks are to be found everywhere included in the plutonic and volcanic rocks. Generally, these bands of rocks have a different paragenesis from the hornblende and epidote schists. Some of these sheets contain well-developed tremolite needles, while others consist predominantly of biotite-chlorite-quartz paragenesis. Some of these rocks may be remnants of larger bodies, which have been completely granitized, while others, distinctly, are products of subsequent-retrograde metamorphism of the amphibolites which were intruded by the igneous rocks. The frequency and size of the inclusions in the igneous rocks suggests that they are part of the sunken blocks and roof-pendants, which were stoped by the magma at the time of intrusion.

MESOZOIC PLUTONIC IGNEOUS ROCKS

The Mesozoic rocks are probably Jurassic-Cretaceous in age and have a typically plutonic igneous aspect. These rocks have intrusive relationship with the amphibolites and may be partially magmatic and partially palingenetic in origin. They are tentatively divided into two groups, intruded at different intervals. The first, apparently older group, consists of diorites and granites intruded into the amphibolite rocks, and a second younger group, which has intruded the diorites, consists of norites, peridotites, pyroxenites, and hornblendites. It is possible that the time interval, between the formation of these two groups, might not have been very considerable, and in fact the two groups may be overlapping in time. However, for a clearer understanding of the general relationships of these rocks, it is proper to treat them as two distinct groups.

1. A. Diorites.

Diorites are the most extensively developed rocks in the whole of this region and they cover almost 70% of the total area. They extend west and north-westwards over great distances and pass into Afghanistan, there covering probably most of the Kunar, Asmar and Ningrahar regions. The diorites extend in the south to Bajaur and Mohmand territories gradually grading into biotite and tourmaline granites. These rocks may be spread over an area of about a thousand square miles.

The divide, separating Jandul from Barawal Valleys, is all dioritic, passing eastwards into Maidan and from there to Dir. These diorites probably extend eastwards over hundreds of miles right across Dir, and Swat Kohistan. They may be extensions of the axial batholithic belt of the Himalayas (Jan, 1969; Matsushita, 1965).

Two varieties of diorites are differentiated in the field as light and dark coloured ones. The light coloured diorites predominate in the eastern part of the area, and the dark-coloured ones in western part. The light coloured diorites are usually pyroxene-free. In this type hornblende is generally altered as a result of which sphene and ilmenite crystals are formed. Plagioclase in the light coloured gniessose rocks is usually completely altered up to the core.

The dark coloured diorites are usually pyroxene-bearing. They contain a higher proportion of hornblende and larger flakes of biotite. The plagioclase is generally more calcic and quartz decreases in amount up to 5 percent.

Texturally the diorites are medium- to coarse-grained, hypidiomorphic granular or coarse-grained gneissose. Every transition from granular to gneissose character is observed. The gneissic varieties, however, are more abundant near the contact zone.

These rocks are generally made up of plagioclase, hornblende, pyroxene and quartz. Other minor and accessory minerals are biotite, sphene, garnet, apatite and epidote, occuring as one and occasionally more minerals in the same rock body.

Plagioclase is generally andesine. It is more sodic in light coloured varieties and becomes calcic (An 50) in dark coloured varieties. The plagioclase is usually twinned and sometimes zoned. The twin lamellae are ocassionally bent. In the light coloured diorite gneisses the plagioclase is completely altered to kaoline and rarely to epidote, chlorite or sericite. As the plagioclase tends to become more calcic in darker coloured diorites the amount of quartz correspondingly decreases, pyroxene appears, and hornblende increases in proportion.

Hornblende is the next most abundant mineral in diorite after plagioclase. The primary hornblende crystals are light-green to deep-green pleochroic. Myrmekitic intergrowths of plagioclase and hornbleude have been observed in some sections. In pyroxene-free diorites the hornblende is generally altered. Sphene, ilmenite are seen to have developed as a result of alteration. Occasionally secondary hornblende is also formed at the expense of pyroxene. Complete pseudomorphs of hornblende after pyroxene are commonly seen in such cases.

Pyroxene is a common mineral in the dark coloured diorites. Both orthopyroxene and clinopyroxene occur. The orthopyroxenes are generally hypersthene and bronzite and the clinopyroxenes are augite and/or diopside. Hypersthene is always partially or completely surrounded by augite at the margins. The orthopyroxenes have ore inclusions in the form of ore-dust while in clinopyroxenes exsolved lemellae are common. The orthopyroxenes generally have a strong tendency towards replacement by hornblende. Chlorite, talc, and serpentine are the commoner alteration products of pyroxenes along cracks and fractures. Chlorite is, however, more common.

Quartz occurs in diorites usually as anhedral grains between the interstices of plagioclase and hornblende. However, small grains of quartz embedded in plagioclase, hornblende and biotite are not uncommon. Quartz tends to increase in grain-size in some localities and as a result the rocks assume a porphyritic aspect. Some diorites grade into granodiorites with increase in the amount of quartz. The proportion of diorites and granodiorites, however, has not been ascertained.

Biotite is a minor mineral that occurs ubiquitously in almost all diorites. In the pyroxene-free diorites biotite occurs as small laths of a yellow to yellowish-brown pleochroic character. In the pyroxene-bearing diorites it is deep red-brown to dark brown pleochroic. Occasionally, alternating lamellae of biotite and chlorite are to be seen.

Epidote is the commonest secondary mineral and it reaches its maximum development near the contact zones where it occurs as a vein mineral along fractures. A small proportion of primary epidote is also observed in diorites. In its secondary character it is associated with plagioclase and hornblende. Occasionally rims of epidote are formed around small grains of ilmenite in these rocks.

The commonest accessory minerals are sphene, magnetite, ilmenite, leucoxene, apatite and garnet. Sphene is generally associated with hornblende and magnetite and leucoxene with ilmenite. Both ilmenite and magnetite are products of the breakdown of hornblende. Apatite and garnet are very rare in diorites. The proportion of garnet increases near the contact zone, and locally it become major mineral.

Near the contacts the diorites are always predminantly gneissose and become granular away from the contacts. The contact relations vary from sharp to transitional. The gradation zone, near transitional contacts, is usually very large with alternating amphibolite and diorite bands. The contact zone in such cases may be as much as one mile thick. Along the contacts hornblende has broken down to epidote releasing magnetite and ilmenite. The magnetite occurs as small veins in the country rocks, while ilmenite is almost exclusively restricted to quartz veins, which are profusely developed near the contact zones.

About 50 years back the natives used this magnetite for smelting iron. The magnetite was usually obtained from sands in certain streams, where it is highly concentrated locally. The natives also made use of the dark hornblende, and mistook it for iron-stone. Strangely enough they did succeed in getting some iron out of it. It is probably because of the high degree of alteration which locally changes the aspect of the mono-mineralic rock, as a result of which iron and titanium oxides are formed. The resultant iron from smelting hornblende was a high strenght steel.

In the southeastern and southcentral parts where the diorites are in contact with amphibolites, large bodies of hornblendites have formed in the diorite. In the north-central parts these diorites are profusely intruded by andesite and dacite porphyries in Tertiary times. The eastern diorites and granodiorites have some well-developed shear zones, with profuse development of quartz and pegmatite veins. Northwest of Barwa, in a north-west trending shear zone occur quartz and pegmatite veins, each about two feet thick, at the interval of almost every ten feet. North of Barwa the rocks are highly gneissose and grade into granites which contain quartz, feldspar and biotite. The pegmatite veins also have a similar composition. The frequency of the pegmatite veins increases northwards. About two miles east of Barwa the country rock is overshadowed by the pegmatite-quartz vein swarms. The quartz veins are usually later than the pegmatites which themselves are cut by dolerite dykes, some of which are quite large in size. The whole structural pattern in this region is extermely complicated and small faults can be seen at intervals of every ten yards. Further north near the contact with amphibolites the diorites tend to become finer grained.

In the southeast near Rustum Banda the dioritic rocks are extermely sheared and augen gneisses consisting of plagioclase and hornblende have formed. The transition from diorite to granodiorite and grantite from place to place is a characteristic feature of the area.

2. A. Granites.

In the field granites are either coarse-grained granitoid or gneissose in structure. The crystals in granitoid granites are usually anhedral, while those in gneissose varieties may be anhedral or subhedral in form. The granular varieties are usually found in the middle of the main granitic bodies, while at the margins near contact zones gneisses are well-developed. In few localities injection gneisses are also seen.

These granitic rocks have a uniform mineral composition, consisting of feldspars, quartz, and hornblende. Minor and accessory minerals are epidote, garnet, sphene, micas, apatite, rutile and leucoxene occuring separately in different varieties. The feldspars are orthoclase and microcline with albite or oligoclase. Both the K-feldspar and plagioclase are kaolinzed to a certain degree, more so in the gneissose varieties. Occasionally they are also altered to epidote and sericite. Quartz occurs in granites upto 25-30 %, however, some varieties may contain as much as 50%. It generally occurs in the inter-spaces as anhedral or subhedral grains, with a typically wavy extinction. Small grains of quartz are also seen embedded in feldspar and occasionally in hornblende. Hornblende is the commonest ferromagnesian mineral in these granites and makes up to four percent of the bulk of the rock. It is usually green to dark bluish green in colour. Small grains of sphene, magnetite and rarely biotite are usually closely associated with hornblende. Micas are rare in these granites, but when present, they are generally in very small amounts. They are commonly biotite or muscovite, and occur as small strained laths, tappering at one end. This character gives them a fan shaped aspect. Occasionally magnetite is also found associated with biotite, in which case its colour deepens from pale brown to deep brown.

Epidote always occurs as a secondary mineral, as pale yellowish to pale greenish pleochroic crystals at the margins of hornblende or plagioclase in granites. Garnets are rarely seen as small, sub-rounded, fractured crystals. Along these fractures iron oxide is usually formed. Sphene, apatite, rutile and leucoxene are the main accessory minerals. One or two of these minerals are usually found in the same rock. Magnetite is also common but it is usually observed as a product of breakdown of other ferromagnesian minerals in granites. It occurs as dark opaque grains associated with hornblende and sphene or, rarely, with biotite and leucoxene.

The largest single body of granite intrusion in amphibolites is near Jabagai, about three miles east of Mayar. It is a wedge-shaped body, convex towards the south, with apophysies running in the form of small thin tongues into the amphibolites. The granite is light coloured, coarse-grained, gneissose, and is cut by quartz and pegmatite veins, profusely developed in the central part of the body.

Another granitic body is near Matakai hill which grades into hornblende-garnet-plagioclase gneisses near the contacts, and into leucogranite in the north. This rock body is gneissic and is intensely folded and faulted.

Northeast of Kambat there are some coarse-grained biotite-granites, but they have no sharp contacts with the surrounding amphibolites and diorites. They are transitional in character and grade into diorites and granodiorites in the north and south. They may be well-developed in the east in Maidan Valley, but that area is not yet covered geologically.

Other small dykes and veins of leucogranites commonly occur in diorites. These are probably of Tertiary age and may be differentiates from the lavas of that epoch. Other granitic bodies are described under the Tertiary rock group where they belong.

B: The second group of rocks closely associated with the diorites, and granites, is probably somewhat later in age. It includes peridotite, pyroxenites, hornblendites and norites. The contacts of the peridotites, pyroxenites, and hornblendites are almost sharply defined against diorites complexes in which they occur and suggest a later period of formation. Norites on the other hand seem to be almost contemporaneous with the diorites and they lack sharply defined contacts. However, it seems probable that the ultrabasic rocks might be contemporaneous or a little younger than the dioritic complex in which they occur.

1. B. Ultrabasic Rocks.

Peridotites and pyroxenites occur in the form of a folded sheet at the bottom of Tora Tiga (Black hill) about two miles southeast of Barwa. At the core of this fold there is a lense-shaped diorite and hornblendite body, surrounded by about 50 feet thick band of pyroxenite. The peridotite occurs at the outer margins. Only that portion of the peridotite, which constitutes the lower limb of the fold is visible. The upper limb is completely hornblendized.

The peridotite, exposed near the road side, is a dark green, weathered rock. It is covered by alluvium in the south and is in sharp contact with the pyroxenite in the north. Peridotite-bodies of similar character have also been reported 10 miles to the east near Timurgarah and further east in Swat Kohistan by Jan *et al.* (1969). The very small size of this peridotite body makes it very difficult to establish whether or not it belongs to the alpine-type group. It is interesting to note that the peridotite in this part occurs at the nose of a very big fold pitching in a southwesterly direction.

The pyroxenite body is relatively well-developed as compared to the peridotite. It is massive and green in colour. It trends roughly east-west for some distance, then takes a very sharp turn and follows southeasterly trend. It is sharply terminated near the road side and is covered with alluvium. In thin section the pyroxenites are coarse-grained hypidiomorphic and consist of augite and hypersthene. Hornblende may be present upto 10%. Accessory minerals associated with pyroxenes are sphene, ilmenite, and rarely pyrite which is probably of secondary origin. Olivine may be present in small amounts The Hypersthene present is distinctly pleochroic, usually surrounded by augite and hornblende coronas. Alteration of pyroxenes to serpentine and talc along lines of fracture is common. Southwards, the percentage of olivine increases and reaches up to about 30—40%, whence the peridotite zone starts. Texturally the peridotites are very similar to the pyroxenites.

Pyroxenites are also known to occur further east a few miles southeast of Timurgarah and also in Swat Kohistan. Westwards in Afghanistan in Kunar region peridotite and pyroxenite bodies occur sporadically as small sheets and lenses. Southwards in Bajaur and Mohmand tribal areas, these rocks are also known to occur as small bodies. In Mohmand tribal region rocks are associated with dunites and chromites, which assume extensive dimensions in Utmankhel territary between Tangi and Harichand. Correlation of these ultrabasics over the whole region suggests that they are part of the great Himalayan-Alpine ultrabasic complexes that extend from Hindubagh northwards for more than a thousand miles. If this assumption is correct then all the ultrabasic bodies found in these regions will belong to Jurassic or Cretaceous period.

2. B. Hornblendites.

Hornblendites are extensively formed in the southern parts of this area. They generally occur at the end part of the diorite complexes, specially near their contact zones with the amphibolite. The largest body occurs east of Munda in the diorites, with which it has sharp contacts. Another body costitutes the Tora Tiga (Black hill) complex, where it is associated with pyroxenites and peridotites. The third largest body is in the south-central part, between Tabai and Chinghaz banda, north of Babukara Khawar. Recently, another hornblendite body was reported by R. Nawaz (personal communication, 1972) roughly two by three miles in dimensions near Rabat about 20 miles north-east of this area in amphibotites, with transitional contacts. Small veins and lenses are commonly found all over the eastern flank, near the contact zones. Small veins of hornblende mineral are commonly found associated with norites in Swat (Jan and Mian, 1971).

Two different kinds of hornblendites can be differentiated on the basis of size all over this region. Those of a smaller size, occuring in the form of veins and lenses, probably as prodncts of metamorphic differentiation near the contact zones of the amphibolite. The second group of hornblendites are bodies of large dimensions, approximately six to ten square miles, which have sharp contacts with the diorites. These bodies seem to have directly crystallized from extremely dilute hydrous solutions under high pressures.

Near Jabagai, where the granite has intruded the amphibolites, there is an extensive development of hornblende veins and lenses in the schists. The same feature is observed near the contacts of amphibolites and diorite gneisses, south of Manrugai and near Asman Banda. The frequency of these veins and lenses increases gradually southwards, where they are found as bodies of large dimensions. The small veins are usually from a few centimetus to a few feet thick, and generally consist of pure hornblende at the centre, grading into hornblende-plagioclase bands towards the outer magins. Finally the hornblende disappears, and the seggregated bands consist exclusively of plagioclase, feldspar and quartz in the outer most parts. This feature is characterstic all over the region, specially in areas which are gneissose in character.

The large hornblendite bodies, characteristically concentrated in the south-east and central parts, are definitely intrusive in nature, at least partially. In thin section the hornblende crystals are usually coarse-grained, hypidiomorphic, green to brownish green in colour. Along the direction of elongation of the hornblende magnetite and or ilmenite both have developed as rod-shaped crystals. Patches of kaolinized plagioclase are present in very small amounts. Chlorite and talc are also present along fractures in the crystals.

The dioritic magma, from which the hornblendites have separated, was very rich in water. Within the main hornblendite bodies, there is a profuse development of hornblende pegmatites, in which the hornblende crystals are oriented across the length of the pegmatite veins suggesting extremely high hydrostatic pressures. Some of the hornblende crystals are as large as one foot in size.

As pointed out earlier, the natives mistook these dark bodies for iron stones, and about a century ago, they smelted some black sands in open furnaces of a very primitive kind, for the extraction of iron. Massive hornblende rock was also extensively used for this purpose. The iron was extractable probably because these bodies have undergone alteration and weathering at places, resulting in the release of iron oxides. Veins of magnetite and ilmenite are also commoly found in and around the contact zones, where the hornblende of the amphibolites has been altered to epidote, releasing silica, titania and iron oxide in the process. Silica is generally crystallized as quartz veins which generally contain ilmenite crystals as small veinlets a few centimeters thick.

The hornblende pegmatites tend to be most well-developed in the southern most parts of these bodies. From the size of the hornblende crystals and the abundance of pegmatite veins, it appears that the fluids were freely moving and the supply of elements was un-hindered for a long time. These bodies probably crystallized at a relatively quieter tactonic phase, following the intrusion of the main granite-diorite complexes.

3. B. Norites.

The largest single norite body is found north of Mayar at Gambir hill. It is topographically distinct for its dark brown colour and relatively rough, prominent, craigy surface, caused by the swarm of andesite-dacite porphyry dyke rocks that cut it in an east-west direction. These dykes seem to be the main feeders of the Suraighat volcanics in the north. The norites are covered by alluvial fans in the east, south, and west, and in the north they grade into porphyritic dioritic rocks, without any observable distinct contacts.

Another smaller outcrop of noritic gneisses is seen west of Gambir hill on the spur near Mian Banda. These norites differ from the Gambir norites in their distinctly gneissic aspect.

Four other small norite bodies are seen east of Manrugai, along what appears to be a Shear zone of intensely deformed gneisses. The main outcrops are exposed near Chargo Kili, and Rasul Banda. These norites are surrounded by dioritic gneisses and garnet gneisses. The norites are very sheared and have well-developed gneissose structure.

In the field norites are best distinguished by their rust brown weathered surfaces. They are lighter coloured as compared to the melanocratic diorites. The plagioclase has a typical pale-yellowish tint.

Most of the norite bodies are course-grained, holocrystalline, hypidiomorphic and subequigranular. However, some norites located along shear zones have well-developed gneissose structure.

The norites contain plagioclase, orthopyroxene, clinopyroxene, hornblende and biotite. Quartz, magnetite, rutile and ilmenite occur as minor and accessory minerals in different norites.

The plagioclase is labradorite. It is very fresh and fractured, Twinning is common and ocassionally the twin lamellae are bent. Zonning is also common in plagioclase, the composition of zones usually varies from An 50 to An 66 from the outer margins to the core, occasionally, inclusions of a similar plagioclase grains are formed in larger crystals. These are generally differently oriented. Other inclusions of dark opaque minerals are commonly seen as small prismatic bodies parallel to the cleavage faces. Small inclusions of biotite are also not uncommon in the plagioclases.

Ortho- and clinopyroxenes are the characteristic ferromagnesion minerals. Orthopyroxene are hypersthene and bronzite and clinopyroxene are augite and/or diopside. The relationship of hypersthene and augite, by far the most abundant, are not well defined. Hypersthene embedded in augite, hypersthene encircling augite, are the common textural relationship. It appears that hypersthene probably started crystallizing a little earlier than augite, although the bulk of the minerals crystallized more or less at the same time. All the pyroxenes in norites indicate various stages of the exsolution of iron oxide and titanium oxide. These exsolved minerals occur in various stages of development in pyroxene matrix; varying from scattered dust to well-developed lamellar forms oriented parallel to the cleavages. In orthopyroxene these inclusions have a reddish colour while in clinopyroxene they are dark brown. Small inclusions of plagioclase and biotite are also seen in pyroxenes.

Most of the pyroxenes are partially or completely rimmed by hornblende. Well-developed corona structures are commonly observed aronnd hypersthene, which is usually surrounded by augite, followed by hornblende and finally chlorite at the outer most margins.

Alteration of these pyroxenes to chlorite is common. Talc and serpentine are also seen along cracks and fractures. The formation of a fringe of chlorite around pyroxene is more common in augite than hypersthene.

Hornblende is present in all norites in small amounts. It occurs as pale brown to green pleochroic crystals usually replacing pyroxene. Occasional myrmekitic growths of hornblende and plagioclase are observed. The hornblende of norites is relatively free of inclusians as compared to that of diorites. However, small inclusions of quartz and some ore-minerals are not uncommon.

Small accessory amounts of quartz, magnetite, rutile, and ilmenite are present in various samples. Deep brown, pleochroic, secondary biotite is occasionally seen to have formed around small crystals of magnetite.

3. TERTIARY VOLCANIC BELT.

This region underwent intensive volcanic activity in early Tertiary times. At the outbreak of the volcanic episode there were probably still some embayements of the Tethys sea in the north of the region, in which marine sediments were being deposited. These volcanic tuffaceous rocks are intimately intermixed with sedimentary rocks, both of which have now been slightly metamorphosed to greenschist facies. The best development of these rocks is to be seen north of the valley in Barawal area, however, a small part of the same sequence is exposed at the northwest corner of Jandul valley near Shahi.

The most outstanding topographic feature in this area is the Suraighat volcanic rock, which protrudes about 500 feet above the surface, in the form of a long cone-shaped cylinder, standing vertically in the diorites. This cone is well-crystallized, porphyritic, light-coloured and dioritic in composition, with large phenocrysts of plagioclase. Another small volcanic? vent is towards the northeast about two miles away from Suraighat, on the southern side of the Jandul-Barawal divide. The eastern margin of the Suraighat volcanics is very much sheared. The surrounding diorites in the neighbourhood of these volcanics are cut by swarms of quartz and pegmatite veins of a later stage. Quartz and pegmatite veins are to be seen almost at every ten feet interval. The western contact of these diorites is extensively cut by volcanic porphyry dykes, light brownish-gray in colour, with lenticular feldspar phenocrysts, and exteremely fine-grained groundmass. Most of these dykes strike east-west or northeast-southwest with steep northerly dips. They seem to follow fracture zones.

Three dyke phases have been differentiated. The earliest and minor phase, which is only occasionally seen as small dykes, or as xenoliths in the later porphyries, are pink in colour with small phenocrysts and a fine matrix. The second phase material is green in colour and similarly porphyritic. The last phase of porphyry dyke formation consists of light brownish grey rocks, which are also the most abundant of the three. This last phase is very well-developed as large, some what radial, swarm of dykes within about five miles radius of Suraighat hill. The porphyry dykes are more or less uniform in size about 30 feet thick, and stand out prominantly on hill slopes as craigy ribs running for miles without any significant change in trend. Their general trend in the north east is northeast-southwest, in the south it is east-west and in the northwest it is northwest-southeast, thus approximating to a radial pattern.

The greatest bulk of the volcanic rocks is best developed in Barawal, where the interbedded meta-volcanics and sediments are about 10 thousand feet thick, with a more or less uniform east-west strike. They pass westwards into Afghanistan, south of Asmar valley in Kunar, and eastwards into Dir and Dir Kohistan where it seems to pass into Kalam volcanics in northern Swat. These latter rocks were placed in Palaeozoic age group by Bak and Jackson (1964) and Sultan (1970), but the association of Tertiary fossiliferous beds with the volcanics in this part of the area has necessitated a thorough revision and study of the stratigraphic relations. The stratigraphic age correlation as made by Martin *et al* (1962) and others, about this region, needs also be revised in the light of the present discovery. The present authors think that the Tertiary volcanic belt may be far more extensive than hitherto thought of before. The zone of this volcanic activity seems to extend over about a hundred miles northwards. Small sheets and lenses of tuffaceous volcanic rocks have been observed near Gahret in Chitral in rocks of Eocene age. This confusion has arisen as a result of the slight metamorphism of rocks to greenschist facies. The region covering the vast expanse of epidote-chlorite schists in Dir, Chitral and Swat may in reality by partially or wholly volcanic.

The volcanic porphyry dyke phase is followed by intrusions of granite and pegmatite veins as well as a few dolerite dyke veins. Some meladiorite dykes cutting these porphyries are also seen in the north near Jabagai. These later phase dyke rocks probably fall within Upper Tertiary group. This phase is characterized by intense shearing and faulting. The volcanic belt just mentioned above seeems to follow a fault-line as these rocks are overlain by diorites of Jurassic-Cretaceous age near Dir. The final phase of this activity is characterized by the formation of quartz and pegmatite vein swarms and last of all quartz vein swarms with copper mineralization, containing pockets of chalcopyrite, and bornite. The pegmatite and quartz vein stage was accompanied by intense shearing movements.

Besides these, there are two very interesting kinds of granite bodies, probably also Tertiary in age, southeast of Shahi. One is a coarse-grained granular granite with pink quartz, green feldspar and biotite, and the other further southeast is a similar granite but it contoins blue quartz, green feldspar and dark-green hornblende. The biotite granite in thin section consists of well-developed perthites, and the biotite is exteremely strained and occurs as corrugated laths. The hornblende granite consists of bule-green hornblende and perthitic feldspars. In both these granites the quartz is strained with wavy extinction. The contacts of these small granite bodies are faulted. The biotite granite is in contact with phyllites, quartzites, and some calcareous bands which are fossiliferous containing *Lockhartia* and some recent Gastropods.

STRUCTUKE OF THE AREA

As mapping was carried out on a very small scale (1:50,000) most of the important structures could not be depicted without creating un-necessary confusion. The general trend over most of the region is northeast-southwest with a northerly dip. In the southwest os the area the direction of strike changes to east-west. The whole region can be interpreted as a large fold, whose axis runs parallel to the Bajaur stream, with a southwesterly pitch. Small folds are superimposed on this large structure and refolding is common. At least three phases of folding can be discerned in the area.

The whole area could also be interpreted as a large recumbent fold thrust southwards. The main thrust zone in the case would be somewhere further south. Also, considering the continuous repetition of Palaeozoic metamorphics, Mesozoic intusives and the Tertiary metavolcanic-sedimentary formtions over about 300 miles from Chitral south-wards upto Mohmand tribal territory, it is difficult to assert any definite conclusion at this stage.

The amphibolites in the cores of the folds have undergone maximum deformation and stretching, which have probably facilitated their metamorphism to genisses in the east. They are usually very tightly folded.

The plutonic rocks are also very much folded and faulted. There are two major shear zones in these rocks, along which pegmatite swarms are profusely developed. Every phase of deformation seems to be accompanied by pegmatite vein formation, and hence three clear cut pegmatite phases are discernible in the area. One such shear zone is at the extreme northeastern corner of the area, which trends northwest-southeast and then turns round Kambat where the trend becomes northeasteast-southwest. This shear zone probably delineates the lower limit of thrust along which the volcanics are developed. This zone falls directly in time with the great Farghana wrench fault similar to Herat and Khebin wrench. If this assumption is proved to be correct with further field work, over this whole region; it would become very easy to draw the line between the Hindukush and Himalayan orogenies in this part of the world, which have not been so far differentiated.

Most of the works, on regional geology in the northwestern parts of this country and Eastern Afghanistan, have put all the plutonic rock formations into Precambrian basement shield zones, and shown the same on the maps so far published. These are assumptions inherited from the times of Suess, and no one has so far challenged them. It is imperative, that while dealing with the structure and stratigtaphic age relations of the plutonites, the dimension and extent of the Tethyan orogency must not be under-estimated. The same applies also to unfossiliferous metasedimentary belts in this region, which all the geologists have presumed to be latest Ordorician or pre-Upper Carboniferous, a hypothesis totally baseless and untenable. The plutonic rocks in Upper Swat, for example, which were always interpreted as belonging to Precambrian or Palaeozic times, have come out to be only 67 million years old from K/A dating (Jan and Kempe, in press). Such a large part, in reality the whole of this region, is still geologically unknown that any speculation about the regional structures and age-relationships will not only be premature, but purely speculative.

5. ECONOMIC GEOLOGY.

From economic point of view, three types of mineral deposits are distinguished for convenience :

1. Precious stones: Among the precious or semi-precious stones of any value one could consider the possibilites of exploration of some parts for garnets, opaline silica, aquamarine, and rosy quartz. Although they are only locally developed, some of the garnet varieties are of a very high quality, though small in size, and can be locally exploited on a very small scale. Opaline silica is only found near Bazarzai, on a limited scale. Some very nice samples were dug out by the natives, but lack of proper techniques only resulted in the distruction of the veins near the surface. There are also indications of aquamarine about four miles west of Timurgarah, but the quality is very poor. Occasionally rosy quartz is also found in the streams of Miskini Khawar.

2. Refractory material of any importance lacks in the area. However, the super abundance of quartz veins do carry the potential for silica based industries. But the lack of other materials, like coal, limestone etc. would not make the project very economical. However, quartz can be exploited very cheaply, and sold outside, because of the very low cost of local labour.

3. There is ubiquitous copper mineralization all over the area, associated with porphyries. The copper minerals occur as chalcopyrite, bornite and malachite lenses in quartz veins and country rocks. One of the characteristic of these and pockets of copper minerals is their uniform north-south orientation, no matter which way the host rock trends. These lenses are usually about five inches by two inches, and are widespread all over this area in Dir, Swat and Chitral. The lead-zinc sulphide mineralization in granites in Ushu valley may belong to this phase of mineralization. If the ages of these rocks are definitely established as contemporaneous, the whole of this belt could be classified as a metallo-genetic province, which shall open new avenues for further exploration and reserch, in order to establish economically feasble deposits of copper, lead, and zinc etc. The present distribution of these minerals could only be used as tracers to great deposits at some depth and probably also near the surface.

In this particular region under discussion, however, there seems to be no worthwhile economic mineral deposits. The copper showings near Kambat were surveyed by electrical resistance methods, but they did not prove economical (Ahmad, 1962). The same applies to the northern valley of Barawal, and Bajaur Valleys along Jar and Khar roads, which can be presumed barren for all practical purposes, however, future detailed surveys may uncover some subsurface reserves of metallic minerals.

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