GEOLOGY OF BAJAUR AND NORTHERN PART OF MOHMAND

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ABSTRACT

Geological investigation in about 1000 sq. km. of area in Bajaur and Ambhar Utmankhel reveal that the area falls in the western tip of Kohistan with the Main Mantal Thrust (MMT) running roughly east-west, following the course of Bajaur Khwar. The area is overlain by the tectonic slices which moved from NW to SE.

The area exposes igneous and metamorphic rocks. Nawagai Limestone of (?) Silurian-Devonian age lies to the south-west. The pelitic sediments include amphibolites, epidote chlorite schists, phyllitic schists, piemontite schists, talc carbonate schists, graphite schists and slates. Extensive distribution of garnet schists is observed in the Shamozai area, lying to the south-east.

The igneous masses comprise granites and diorites; ultrabasic and volcanic rocks. The granitic and dioritic rocks are not considered to be comagmatic. The intrusion of diorites started sometimes in the Late Cretaceous, while the whole magmatism ended with the last phase of granitic stocks and dykes in Middle Eocene. The late Upper Cretaceous to Eocene-Oligocene ultrabasic phases of serpentinite, peridotite and pyroxenite/hornblendite lie "interbedded" with the metasediments. Eocene to Oligocene volcanic rocks of andesitic, rhyolitic and tuffaceous compositions are also present.

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Poor mineralization of copper, promising mineralizations of manganese, soapstone and chromite alongwith large deposit of marble are the noteworthy prospects in the area.

INTRODUCTION

The area Investigated lies between latitudes 34°36′ to 34°56′ N and longitudes 71°15′ to 71°35′E, covering about 1000 sq. km. It comprises a major portion of Bajaur and a part of Mohmand Agency—the Ambhar Utmankhel. The area is connected to Jandul (Dir) in the east through Khar—Munda road while in the west the Khar—Nawagai road passes on to Mohmand Agency.

The broad amphitheatrical valley of Khar is bordered by Afghanistan in the north and west, Jandul in the east and Mohmand Agency in the south. It is drained by the west-east flowing Bajaur Khwar that joins the Jandul Rud at Mian Kili. Most of the major tributaries have a north-westerly geometric fashion and have seasonal flow of water. The altitude varies from about 915 m. above mean sea level to 3060 m, with Kemoor (2436); Lakrosar (2811) and Lawatai (3060) as the prominent peaks which get some snow in winters. Kaga, Mukha and Ghakhai Kandao are some of the small passes that serve as communication routes to Afghanistan.

The difficult terrains in the north and north-west and that of Kemoor in the south have got some forestation with a decreasing tendency. The plains are sufficiently fertile but due to lack of irrigation water only single-season crops like wheat, barly, opinium and mustered are cultivated. The area is moderately populated. Mamun, Salarzai, Charmungi, Tarkani and Utmankhel are the main tribes of which the former two extend into Darra Hinduraj of Afghanistan. Nawagai, Loe-sam, Khar, Jar, Inayat Kili, Lar and Bar Khalozo, Badan and Damadola are some of the major villages.

The present work is the first geological account of the area. Some literature is available about the adjoining Jandul valley. Ahmad (1962) briefly described the copper mineralization from Kambat He also reported the occurrence of diorites, andesites and dacites. Detailed geological informations regarding Jandul comes from Kakar, Badshah and Khan (1971). Some erroneous information about Utmankhel area comes from Saif (1971). Most of his "limestones" now make up the metasediments and volcanics.

The area is basically igneous and metamorphic in nature. Some limestone and dolomite exist in the south-western parts of the area. Andesite, subordinate dacites, dioritic and granitic rocks, amphibolitized gabbro, dolerite and ultramafics make up the bulk of igneous masses. Most of these are partly metamorphosed. Among the metamorphic rocks, amphibolites, banded amphibilites, epidote schists, phyllitic schists, graphitic schists, piemontite schists, slates and marbles are present. Garnet schists are abundantly exposed to the southeast beyond the mapped area and constitute the main divide of Arang and Barang—Shamozai. Limestone and dolomite, besides constituting a unit in the southwest, also occur as lenses and pockets in the metasediments. Quartz veins and pegmatite bodies, probably both of igneous and metamorphic origin, sparsely exist throughout the area. A few hydrothermal quartz veins at Gabarai and Inayat Kili bear copper mineralization. Some manganese mineralization is present along the contact of a doleritic intrusion in the thin hedded, grey dolomitic limestone at Ashgar-Charmung. At certain places in Nawagai area, Ambhar Utmankhel and Targhao, low to medium commercial grade soapstone exists in the chloritic schist. The talcosic schist in the Amankot area of Barang bear low to medium quality emerald mineralization. Some transported boulders and pebbles of ultramafics carry stringers and veins of chromite. A sizeable boulder of magnetite was observed roughly 2 km to the north-west of Gumbatai. Huge deposits of white marble (dolomitic in composition) exist in the hills exposed to the north of Gumbatai. Workable deposits of green zebra marble (carbonate-chlorite schist) exist at Pampokha.

GEOLOGY

The various rock types present in the area may be classed as metasediments and sediments of Palaeozic age; dioritic rocks of Mesozoic; ultramafics and volcanics of Tertiary; granitic and doleritic dykes and sills, pegmatite bodies and quartz veins of Late Tertiary period. These rocks may be briefly described as under :

Palaeozoic rocks

Metasediments. These include metasediments, epidote-chlorite schists, phyllitic schists, slates, talc-carbonate schists, graphitic schists and piemontite schists. These have a general E-W trend, however, in Mamun area they have adopted a NW-SE tendency. In the Ambhar Utmankhel area, especially towards

south, the rocks attain a NE-SW trend. In the northern half of the area the metasediments, especially the amphibolites, occupy the foothill regions, while in the southern parts these constitute certain ridges. These are also exposed in the form of scattered sheets and lenses in the rest of the country rocks. These have been intruded by granitic, doleritic and ultramafic bodies and also invaded by volcanics. The isolated hillocks, like that of Trakai, are mainly composed of amphibolite whereas the Bajaur-Ambhar Utmankhel divide is made of interbedded metasediments and volcanics.

The contact relationships of the metasedimentary rocks are variable throughout the area. Their contact with the dioritic mass in the eastern Mamun area is well-defined in general whereas in the area to the north of Sarkari-Qila it is transitional. At this locality an alternation of bands of amphibolites and dioritic rocks is observed. Layers and bands of hornblendites are also present at this place. At Shinai and Takht Kandao the contact zone is partly sheared and very disturbed. Along the Kitkot—Gabarai—Mukha—Kaga line thinly bedded argillaceous limestones lie interbedded with light green calcareous slaty rock (questionably tuffs) and prophyritic volcanics.

The amphibolite facies rocks, especially the banded ones, are exposed in eastern Mamun foot-hill regions and at the limbs of the ridges exposed to the north of Khar-Jar-Mian Kili road. These are also exposed at Trakai, Baba-Ziarat in the plains of Khar and at certain ridges around Kuhai, Kharashah and Kharai in Ambhar Utmankhel.

Amphibolites are both banded and non-banded and it is thought that these are not related genetically. The former are believed to have developed partly after banded tuffaceous rocks and partly after sediments. The non-banded ones found in the transported boulders in the Wuchkarai Khwar at Kitkot are believed to be meta-igneous, most probably metagabbroic. Few sections cut from such boulders generally contain porphyroblastic amphibole and clinopyroxene with a ground matter consisting of plagioclase, hornblende, epidote, quartz, chlorite, white mica, carbonate, sphene and opaque minerals. The bigger crystals of amphibole are yellow green weakly pleochroic and are surrounded by a more strongly pleochroic brown hornblende. Hornblende is found growing as a result of metamorphism. The relics of clinopyroxene are fractured and altered.

The banded amphibolites have a vague uniformity in composition. They are fine to medium-grained and contain plagioclase, hornblende, quartz and small amounts of epidote, chlorite, and some biotite, muscovite, sericite and rarely garnet and opaque ore, probably magnetite. Micas and epidote may have developed after hornblende. Enrichment of epidote in the form of veins and streaks is some times observed in the amphibolites.

The epidote chlorite greenschists are exposed at Kamangara, Inayat Kili, Sara Mena, the Bajaur-Ambhar divide and certain ridges in Ambhar Utmankhel. These are medium-to fine-grained and have well-defined lineations except at certain places close to the contacts with intrusives where these are found altered with the lineation disturbed. At such places epidotization is more pronounced resultantly giving rise to the development of veins and patches of epidote in the rocks. These rocks contain quartz, chlorite, epidote, plagioclase, and some hornblende, carbonate, sericite and opaque ore. They sometimes show banding of epidote where some bands are darker than the others. The darker bands of epidote have more impurities.

Phyllitic schists are exposed at Batai and the surrounding Alizai area, the Amankot area of Barang (outside the mapped area) and certain ridges in Ambhar Utmankhel. Most of these have heterogeneous lithology and are found intruded by intrusives and may occur interbedded with limestone and volcanic rocks.

Among the slaty rocks two varities have been distinguished, the light green ones and the dark grey phyllitic slates. The light green slaty rocks are exposed at places like Kitkot, Gabarai and Mukha etc. These rocks are rather more fine-grained than the rest of the slates of the investigated area and are comparatively better cleaved. In general appearance these resemble the green rocks of Baraul valley, Dir, that lies close by, almost touching the northern Salarzai area of Bajaur. Starting in the western extremities of Baraul Valley, these rocks extend eastward upto Dir for more than 40 km. Red and maroon tuffaceous rocks of slaty characteristics run almost all along these rocks. From previous visits to that area, it was inferred that originally these rocks could be volcanic tuffs and ashes. Khan (this volume) has arrived at similar conclusions.

Striking lithological similarities between the rocks of the two areas and the presence of some tuffaceous rocks in some parts of Bajaur (Nawagai area) reveal that the light green slaty rocks exposed in Bajaur are most probably

volcanic in origin. The dark grey slates are exposed at certain ridges in Alizai and Barang and posses quartz veins and pegmatites.

The talc-chlorite schists have restricted occurrences and are exposed at certain places at Gumbatai, Batomena and Shinai of Ambhar Utmankhel, Nawagai and Doda of Bajaur, Amankot of Barang and in Targhao. The talc-carbonate schists rarely carry chromium minerals which generally exists in the form of fuchsite. At Amankot the rocks have developed emerald. At Gumbatai, Doda and Targhao low to medium quality soapstone has developed in these rocks.

Piemontite schists exist in some ridges in the Alizai Area. Thin sections cut from the rocks collected in Batai and Sara-Mena Khwars are fine-grained schistose and contain quartz, plagioclase and peimontite with subordinate sericite, chlorite/margarite and some opaque ore. Plagioclase is locally porphyroblastic and may be albite (Jan, pers. comm.).

Graphitic schists are exposed just in the north east of Pampokha in Ambhar Utmankhel. These are highly weathered and mainly contain quartz, micas and carbonaceous material. A rather more extensive occurrence of graphite schists of black colour was observed along Targhao-Kandu-Gadamar line. This formation, which could not be checked properly for certain reasons, may posses graphite deposits.

Marbles constitute certain horizones in Doda-Nawagai area of Bajaur and at Pampokha and Gumbatai of Ambhar Utmankhel. These also occur as lenses and bands in Kamangara and Paikhan areas. The marbles at Gumbatai are homogeneous in Character. These are white in colour, dolomitized and are thick - bedded to massive. At Doda-Nawagai and Pampokha the marbles are basically carbonate-chlorite rocks which have developed schistose to gneissose structure. These are thin-bedded to massive and polished samples have a zebra like pattern with green streps.

Sedimentary Rocks, (''*Nawagai Limestone Group*''). The rocks are exposed all along the Lakaro-Nawagai type section and are named as "Nawagai Limestone Group" after an important locality (lat. 34° 40′ N, Long. 70° 17′ E). The unit occupies limited space in the south-western parts of the mapped area but extends over fairly vast distances in the

adjoining Mohmand Agency and further west into Afghanistan. The limestone has enormous thickness measurable in thousands of meters. Its contact with the metasediments is faulted. A large fault line scarp is developed in the ridges situated to the west of Lakaro Plain beyond the mapped area. The unit has a general NW-SE trend. Local folding and faulting is very common. Besides these disturbances the limestone has been intruded by a large number of intrusions which comprise porphyritic acid rocks, dolerites and ultrabasics. About one kilometer east of Nawagai the unit is overshadowed by swarms of intrusives.

The limestone is fine-grained, medium- to thick-bedded and unfossiliferous. The unit comprises light to dark grey limestones and dolomitic-limestones. Locally light grey to white dolomites which may be medium-to coarse-grained and recrystallized, are encountered. At places the dolomitic-limestones are silicious in composition. Recrystallization, especially in some contact zones, is a common phenomenon. It is more pronounced in the lenses and pockets of carbonate rocks sporadically found enveloped in the metasediments which lie interbedded with the volcanics. Such observations were made at Gumbatai and along Kuhai-Paikhan sections in Ambhar Utmankhel and at Kamangara area in Bajaur.

At present sufficient data is not available to assign exact age to Nawagai limestone. It's relationship with the ultramafic intrusives suggests that the unit is older than Tertiary. Similarly in the absence of any acidic intrusious, the limestone appears younger than the granites and diorites of the so far suspected Jurassic-Tertiary age. However as indicative from its faulted contact it may be stated that the "Nawagai Limestone" could infact be older than the diorites of Jurassic-Tertiary times but for the simple reason to have been tectonically brought from distant places at some later stage, has no diorite or granitic intrusion. Tentatively the unit is corelated with the Banna Fornation of Allai area in Hazara Kohistan which is placed by Tahirkheli (this volume) in the Besham Group occupying the northern marginal area of the Indo-Pakistan plate.

Mesozoic—Tertairy Rocks

These include the diorites, granodiorites, granites, hornblendites and serpentinites of the area. According to Kakar *et al.* (1971), the rocks of typically plutonic aspect in Jandul Valley are probably Jurassic-Cretaceous in age

and may be partially magmatic and partially palingenetic in origin. These rocks were grouped into an apparently older group of granites and diorites intruded in the amphibolites and a comparatively younger group of norites, peridotites, pyroxenites and hornblendites intruded in the farmer ones. It has also been stated that the two groups may be overlapping in time.

It is believed that Bajaur and Jandul are closely related for their geological history, however in author's opinion the time interval between the formation of the granitic/dioritic and the ultrabasic phases of magmatism appears quite considerable. We have a number of basic and ultrabasic intrusions in the sedimentry rocks of the area but as concern the dioritic rocks, no intrusions are found intruding the carbonate rocks. Also we have basic and volcanic intrusions in the dioritic rocks but not vice-versa. It is believed that infact the basic and ultrabasic rocks are not only much younger than the dioritic rocks but actually find a quite younger stratigraphic position close to that of the early volcanic phases in the area.

The various plutonic rocks of the areas may be briefly described as under:

Dioritic Rocks. These are the dominating rocks of the Salarzai area and are also exposed arround Gat, Kotkai, Asghar and other areas of Bajaur Valley. These also make certain ridges in Arang that falls beyond the investigated area. Gabbroic rocks, as known from stream boulders in Kitkot Khwar, exist in the upper reaches of the stream. Granites are present at Baba Ziarat, Inayat Kili, Badan and Damadola. No dioritic rocks were noticed in Ambhar Utmankhel.

The Salarzai diorites differ from those exposed in the rest of the area. These extend into Jandul and further east into Dir to find their continuation with the basic complex of Swat Kohistan. These may be the extension of the axial batholithic belt of the Himalayas. (Matsushita, 1965; Jan 1969; Jan and Mian 1971; and Kakar, Badshah and Khan, 1971).

The Salarzai Diorites have a comparatively higher colour index than the others and are medium- to coarse-grained, hypidiomorphic, sub-equigranular. Close to the contacts with amphibolites these rocks have developed gneissose structure. In general these rocks contain plagioclase, hornblende, quartz and some pyroxene. Biotite and epidote are common accessories. Apatite, sphene

and garnet occur as minor constituents. Plagioclase falls in the andesine range, mormally having 45% anorthite content. It is generally twinned, rarely zoned and may be epidotized, sericitized and/or saussuritized. Some of the twin lamellae are more altered than the others. Quartz inclusions may be present in the plagioclase. Hornblende is light green to deep green pleochroic and is partly or completely altered to chlorite and or sphene/magnetite. In some cases hornblende pseudomorphs have developed after pyroxenes. Chlorite is the common alteration product of pyroxene. Quartz and ore inclusions and exsolved lamellae are present in pyroxene. Chlorite and biotite also sometime form lamellar structure. Epidote is an accessory mineral, however it increases at places and attains its maxima at the contact regions. Similarly the percentage of quartz increases gradually towards the off-shoots protions of the dioritic rocks whereby the diorites merge into granodiorites.

Granitic Rocks. These include granites and granodiorites which occupy the distant ends of the dioritic mass and also make certain exposures in the western parts of the area. Granitic rocks are exposed around Zagai, Gat, Tangai and other areas. Rocks at these places are granitoid in texture. Medium grained foliated/gneissose rocks which are also present in the area are either developed at the contact regions or may be found in the form of injected bodies at different places. These foliated rocks crop out about one km to the north-west of Shagomian; along Banda-Baichina line and in some zones at the contact regions in Mamun and Charmung.

A subordinate amount of leucogranites may be seen around Bakaro in Mamun and at Maram Ghundai in Alizai. The leucocratic variety is rather more kaolinized than the rest of the granites in the area. All the granitic rocks, almost throughout the area, carry quartz and pegmatite veins.

Gradual gradation from granites to granodiorites is a common phenomenon, but keeping aside the minor deviations in texture and composition these rocks have almost a similar mineralogy. These consits of alkali feldspars (orthoclase and microcline); plagioclase that could be albite and oligoclase; hornblende and subordinate biotite. Epidote, chlorite, apatite, tremolite, garnet, sphene, rutile, leucoxene and iron ore are the various minor constituents which exist either separately or in different combinatios in different rocks. Feldspars are generally kaolinized and saussuritized. Epidote could be the result of more than one generation that is, primary and as a produet of saussu-

ritization. Hornblende usually occurs is association with opaque ore, micas and sphene. Biotite is generally chloritized. Quartz which attains a higher percentage in granites is anhedral and usually shows strong undulose extinction. Besides occuring in the interstices it may be seen in the form of inclusions in hornblende and sometimes in feldspars.

General discussion on the Kohistan ganitic zone. In the overall regional context it may be stated that the granites and diorites in themselves are not the result of one generation. The medium-grained diorites in the eastern Bajaur and the adjoining Jandul, Baraul, Maidan-Dir appear different and older than the coarse grained granites of the region. The latter are not associated with diorites but generally crop out as separate conspicuous bodies in certain areas like Kakzai and Charmung-Bajaur; Jabagai-Jandul; Warai-Dir and Malakand, etc.

The author believes that even the granites in the region are not comagmatic. The leucocratic granites of Malakand, Warai, Jandual and Bajaur; the foliated granites of Bajaur and Jandul etc., the well-bedded gneissose, rather cleaved granites of Chakdara and Shamozai Utmankehl tribal territory; the alkaline granites of Warsak, Shewa-Swabi, Ambela are quite different from one another in many respects. These rocks cannot simply be classed under one group.

The gneissose cleaved/foliated granites have undergone a diastrophism from which the others escaped and are therefore belived older than the ganitoid granites. The Swat-Buner granitic gneisses were considered to be Mesozoic (King, 1964). Similarly the coarse-grained granites have been intruded by fine-grained porphyritic ?alkaline granites for instance at Malakand. The auther while working on the geology of Benton Tunnel, Malakand during January, 78 noted an about 5 meters thick injected body of fine-grained porphyritic granite, with albite and riebeckite, in the older coarse-grained leucogranites of Malakand. Based on K-Ar age determination the alkaline granite of Warsak and Koga are respectively 41 and 50 million years old (Kempe, 1973).

Through Rb-Sr method, Desio *et al.* (1964) reported granites of seven different ages from Karakuram and Hindukhsh. These granites belong to Lower Triassic; Upper Triassic; Upper Jurassic, and Upper Cretaceous, Oligocene, Miocene and Pliocene.

Jan and Tahirkheli (1969) think that the Swat granites and granite-gneisses were intruded during the latter orogenic phases (Early Tertiary). Tahirkhali (this volume) believes the granites of Malakand and Dewangar (Swat) to be of post collision period, most probably Upper Miocene to Pliocene. According to Jan (1977) the quartz diorites and most granites of Swat Kohistan to the south of Kalam seem to be ?Creto-Eocene. Khan (this volume) reports a granitic stock at Mian Banda-Baraul in the mixed series of metasediments and volcanics of Lower to Middle Eocene age. It shows that the granitic activity of the area, at least for its last phases, took place sometimes in late Middle Eocene.

In the light of the above observations it is concluded at the present that the diorites and granites are not genetically related and that the granites are younger than the diorites of the region. Also the granites are believed to be not comagmatic in origion. The latter-phased granites are younger than Middle Eocene and are contemporaneous with the early volcanic phases, while the whole activity within the region most probably started somewhere in Triassic and that in the investigated area in late Upper Cretaceous with the formation of diorites.

Ultrabasic Rocks. These include serpentinites, peridotites and hornblendites. These exist in the south-western and southern parts of the area. Although they have restricted occurrences in the mapped area, they cover serveral hundered square km in the southern Ambhar and Laman Utmankhel territories of Mohmands. Reconnaissance through different parts of Mohmands has shown that the ultrabasics constitute one of the dominating rock-types of the region. These are believed to be confined to a specific east-west extending tectonic belt that emerges somewhere in the western parts of Ambhar and find their eastward extension up to Dargai-Malakand right across the Utmankhel, Prang Ghar and Skhakot territories for more than a hundred km. Besides in the main belt, sporadic occurrences of ultrabasics, such as the ones in the mapped area, have been noted in upper Gandao, Kudda khel and Safi-Qandhari areas of Mohmand Agency.

Kakar et al, (1971) have reported peridotite from Tora Tiga (Black hill) in Jandul, Dir. Jan et al. (1969) have reported peridotite bodies at Timargara, Dir and further east in Swat Kohistan. Rehman and Zeb (1970) mentioned such intrusions from Shah-Dheri Kabal and Jan and Tahirkheli (1969) reported ultramafic rocks from Jijal—Indus Kohistan and Alpurai.

Krishnan (1956) states that the peridotites be alpline-type and Middle to Late Cretaceous equivalents of other alphine peridotites of Himalayas. According to Kakar et al. (1971), correlation of these ultrabasics over the whole region suggests that they are part of great Himalayan-alpine ultrabasic complexes that extend from Hindubagh (now Muslimbagh) northward for more than a thousand miles and accordingly if this assumption holds true then all the ultrabasics bodies in the region will belong to Jurassic or Cretaceous period.

Jan (1977) mentioned ultramafic rocks from the Jijal Complex which according to him includes the alpine-type ultramafics and the granet granulites. These ultramafics, he says, were probably intruded in the granulites as crystalline mushes after both had undergone a high-grade metamorphism and were uplifted tectonically during the Himalayan orogeny.

The author believes that the ultrabasics with a number of intrusions in the "Nawagai limestone" must be quite younger than those tectonic activities which, besides other changes, caused large scale faulting and brought the sedimentary rocks (limestone) in direct contact with the metasediments and granitic rocks. In the granitic/dioritic masses which are thought Late Cretaceous to Late-Middle Eocene in age, ultramafic rocks, locally serpentinized and asbestiform, have been noted at certain places like Lighunai. Enough field work has not yet been carried out on such occurrences to know wrether these ultramafic bodies represent xenoliths, intrusions or tectonic bodies in the granites. At other places, like Benton tunnel-Malakand, granitic intrusions have been noticed in the meta-hornblendites. It is therefore believed that the ultrabasic activity prevailed over a considerable span of time with the last phases close to or contemporaneous with the late granitic and volcanic activities of the region and thus may be tentatively assigned a Late-Cretaceous to Early Tertiary (Eocene-Oligocene) age.

Volcanic Rocks. These make up one of the dominant rock-types of the investigated area and besides croping out at certain exposures along the Mohmand-Bajaur Agency border in the south, these are found best developed in the north and north-western parts constituting the Pak-Afghan divide. The volcanics of the area, in an arching fashion, make part of an extensively exposed regional volcanic belt that finds its westward extension into Afghanistan while

in the east it extends through the northern Mamun—Salarzai area of Bajaur to northern Jandul (Kakar *et al*, 1971) and Baraul valley of Dir (Khan, this volume). Further east and northeast volcanic rocks have been reported from certain parts of Dir and Swat Kohistan. (Tahirkheli and Jan, this volume; Martin *et al.*, 1962; and Jan and Mian, 1971). In Chitral volcanic rocks have been noted at certain localities like Lowari top and Kesu Gol—Gahret and other places.

The volcanics of the investigated area are hard, massive, fine-grained and porphyritic in general. Apart from minor exceptions, these rocks unlike the volcanics from other areas like Baraul-Dir and Kalam-Swat, do not display strong tendency of colour variation. They are mainly in light dark or greenish-grey colours. Small occurrences of reddish-brown, fine-grained porphyritic volcanics at Sarlara Kandao and maroon, green and grey rocks of doubtedly volcanic origin at Nawagai have also been noticed. The rocks at Nawagai are fine-grained, tuffaceous and are strongly sheared and jointed. Greenish "slaty" rocks of doubtful volcanic origin also occur near Kitkot.

Most of the volcanic rocks have developed cone shaped physiography, for instance those at Kemoor in the south and at Lawatai and Mir Ali Baba of Mamun area in the northern parts. Some of these might be volcanic necks Most of the rocks at these places have developed almost sharp contacts with the rest of the rocks like amphibolites, granites and diorites, and calcareous sediments. At few places, like the foot hill regions at Mukha and Gabarai, the contacts are interbedded. At the ridges along the Bajaur-Mohmand Agency boarder the volcanics lie interbedded with the metasediments and have acquired an eastwest trend in accordance with that of the metasediments.

For the major part, the volcanics are andesitic in composition, however some more silicious rocks of dacitic and rhyolitic compositions are also encountered in the area. Within the main masses of fine grained porphyritic volcanic flows, sparse occurrences of rocks with relatively coarser textures, have been noted. These may be feeder dykes and plugs or other similar thick flows. Volcanic breccia with a lot of lithic fragements is occassional in occurrence.

The volcanic rocks have fine-grained prophyritic texture in general. Some are fine-grained trachytoid while others are vesicular. Flow structures are also present. Rarely, the groundmass gives glassy texture. Few textures are micro-dioritic types and these may represent thick volcanic flows unless they are intrusive in nature. In majority of cases the rocks are altered. Plagioclase, amphibole and clino-pyroxene make the phenocrysts. These minerals may occur in different combinations in different rocks. The pyroxene is in relict form in a number of cases. The ground mass carries feldspars, epidote, hornblende, chlorite, sericite, calcite, magnetite, hematite, quartz, and in a few cases biotite and muscovite. In the comparatively less altered rocks plagioclase microlites are noticeable in the ground mass. Sets of tinny ovoids, present in certain rocks, are filled with epidote, chlorite (generally radial), quartz, carbonate in combinations like epidote chlorite; chlorite carbonate; quartz carbonate etc. Plagioclase is generally saussuritized and sericitized. The ferromagnesian minerals are generally chloritized. Pyroxenes are sometimes zoned. Secondary epidote has in some cases grown into large grains and may be accompanied by quartz. Sericite, chlorite and carbonate locally occur as patches and may be accompained by biotite which may be yellow green pleochroic. Quartz, in majority of cases, is resticted to the groundmass, however in certain samples from Shakro, Gabarai and Kitkot, which have dacitic composition, it is found as phenocrysts.

Petrography and field evidence suggest that these rocks are a continuation of the Utror volcanics which have been dated at Early Tertiary on the basis of fossil finds in Baraul valley (Khan, this volume).

STRUCTURE

The area investigated constitutes part of the Kohistan region located in the western corner of northern Pakistan. The Main Mantle Thrust (MMT), after traversing through northern Hazara and Swat passes through Bajaur Valley in EW direction. A significant bifurcation of the megashear is discernable in the western part of the valley. The rock- formations to the south of the thrust trend EW, whereas trends in the area to the north of the thrust are NE / NW. Auxilliary faults, as the one in Arang-Takht area, are present. There appears to be a system of wrench faults existing in the area. The assumption is supported by the fact that similarity in lithology is found repeated at intervals from south to north at Asghar, Gat-Gorigal and Mukha localities.

The system of ancillary wrench faults are related to the general northward movement of the Indian Mass. One such fault, where the sense of movement is right lateral, has been noted along Damadola- Badan- Shakro line in the eastern Mamun ridges. A few faults of smaller magnitude but of similar trend have been noted in Kamangara, Nawagai and Ambhar Utmankhel areas. A great scarp developed on the eastern face of the Nawagai limestone in Safi area by the SW the off-shoot of a big fault.

A significant feature noticed in the area is the dominant control of the structure upon topography. The major streams follow the dislocations along the thrust as well as the strike slip faults.

According to Kakar *et al.* (1971), the whole region, i.e. Jandul- Bajaur and adjacent areas, can be interpreted as a large fold, whose axis runs parallel to the Bajaur stream with a south westerly pitch. He also pointed out that the whole area could also be interpreted as a large recumbant fold thrusting southwards. The main thrust zone in this case should be located somewhere further south.

It is felt that in order to arrive at any definite conclusion detailed data is yet to be collected; however it can be stated that the area has undergone various phases of structural deformation wherein regional and local faulting and folding took place. It is believed that the present geological configuration of the area and its surroundings is built on those tectonic slices, blocks and tongues which moved from NW to SE during past diatrophism.

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GEOLOGICAL MAP OF BAJAUR AND PART OF MOHMAND AGENCY

AFGHANISTAN

LAWATAI 3060
JABAGAI 1827
KAGA
LAKRO SAR 2611
GABARAI
MUKHA
GATKAI
PASHAT
1972
SALARZAI
KITKOT
GAT
WAIALAI KHWAR
BADAN
2067
MAMUN
BAKARO
KUZ KHALOZO
GARIGAL 1861
BAJAUR
INAYAT KILI
KOTKAI
BAI CHINA
BANDA
KHAR
1093
BAJAUR KHWAR
CHARMUNG KHWAR
BAR KAMANGARA
LIAGHUNAI
SAKA MENA
TAKHT
SHINAI
2436
KEMOOR
NAWAGAI
AMBHAR UTMANKHEL
KUHAT
RAMPOKHA
1259
SHINWARI
KHARA SHAH
AND

34° 55′
34° 50′
34° 45′
34° 40′
1300000
1290000
1280000
1270000
1260000
71° 15′
71° 20′
71° 25′
71° 30′
71° 35′
3330000
3340000
3350000
3360000

INDEX

- ALLUVIUM — RECENT.
- DOLERITE — EOCENE — OLIGOCENE.
- VOLCANIC ROCKS — EOCENE — OLIGOCENE.
- HORNBLENDITE — UP. CRETACEOUS — EOCENE/OLIGOCENE.
- ULTRABASIC ROCKS — UP. CRETACEOUS — EOCENE/OLIGOCENE.
- DIORITES + GRANITES — UP. CRETACEOUS — MID. EOCENE.
- NAWAGAI LIMESTONE — PALAEOZOIC.
- AMPHIBOLITE — PALAEOZOIC.
- METASEDIMENTARY ROCKS — PALAEOZOIC.
- DIP / STRIKE
- FAULT
- PROBABLE CONTACT
- INTERNATIONAL BOUNDRY
- AGENCY BOUNDRY

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SCALE
0 1 2 3 4 5 6 7 K.M

RIAZ AHMAD