*Geol. Bull. Univ. Peshawar, Vol.* 4, 1969, *pp.* 1-13

# THE GEOLOGY OF THE LOWER PART OF INDUS KOHISTAN (SWAT), WEST PAKISTAN

M. QASIM JAN AND R. A. KHAN TAHIRKHELI

## ABSTRACT

*An area of over 450 square miles in Indus Kohistan, Swat, has been mapped and the detailed petrography of the rocks is presented. The area investigated is bounded by latitudes 35° 15′ to the north, and 34° 45′ to the south, by the Indus River to the east, and by the drainage divide of the Indus and Swat Rivers to the west. The predominant rocks in the southeast and south belong to the Lower Swat-Buner Schistose Group (Siluro-Devonian or possibly Ordovician). The Schistose Group is commonly represented by low grade quartzites, quartz-mica schists, amphibolites, marbles, calcareous schists, phyllitic schists, graphitic schists, and greenschists. These were intruded by ultramafic rocks (pyroxenites and dunites near Jijal; serpentinites near Alpurai, Jijal etc.) during the earlier phases of the Himalayan orogeny (middle to late Cretaceous). During later orogenic phases (early Tertiary), the area was intruded by the abundant Swat Granites and Granite Gneisses (generally leucocratic, two feldspar-bearing rocks) and pegmatites, and minor gneissic granodiorites near Shang and Dubair. These events were followed by overthrusting of the (?Precambrian) Upper Swat Hornblendic Group which covers the northern and northwestern part of the investigated area. The Hornblendic Group is represented mostly by diorites, metadiorites, hypersthene gabbros, and garnet-amphibole gneisses.*

## INTRODUCTION

The Department of Geology, University of Peshawar, conducted a field mapping programme during June and July 1968, and May 1969, to investigate the geology of the previously unmapped area of Swat Kohistan. The basic purpose of this work was to prepare a preliminary geological map and to provide some knowledge about the various rock types exposed in the area. Traverses were carried out along the Indus Valley Road and major stream courses, and about 300 rock samples were collected for further investigation. From these, some sixty thin sections have been cut. Mapping was carried out on toposheets (No. 43-A, 43-B, and 43-E, scale 1″=3.798 miles enlarged to 1″=1 mile) of the Survey of Pakistan Department. The accompanying map is thus based on limited information for such a complex area and will require additions and revisions, especially in the areas lying far from the main road and streams.

*Location and Access:* The area investigated lies roughly between the drainage divide of the Indus and Swat Rivers to the west, and the Indus River to the east. The northern and southern limits of the area do not extend beyond latitudes 35° 15′ and 34° 45′, respectively. Construction of the Indus Valley Road is in progress and the area is accessible by motor vehicles in fair weather. From this road, access on foot is possible deeper into the area along streams and footpaths.

*Topography and Drainage:* The terrain in general is very rugged and the relief is very high. The main valley floor is less than 2200 feet, south of Kayal village, whereas the nearby peaks may reach 10,000-12,000 feet. The valley slopes are thus very steep, and are mainly V-shaped, many of them separated by long acute ridges. The drainage in general is dendritic, but some of the subsequent streams join the major consequents at right angles, locally producing a trellised pattern.

*Rainfall and Vegetation:* Rainfall is moderate in the south but scanty towards the north. Dubair (taken as average) has a rainfall of about 20-25 inches per year, whereas Patan gets only ten inches. The valley is characterized by hot summers and cold winters. Summer maximum temperatures may be above 110°F and winter minima below freezing point. Much of the precipitation during winter months is in the form of snow on high peaks, many of which, and some high valleys, are glaciated.

Vegetation is sparse; common plants below 4000-5000 feet are broad-leaved *Quercus ilex* (oak), *Juglans regia* (walnut), *Aesculus indica* (bankhor), etc., and narrow-leaved trees of *Pinus* species. *Cedrus deodara* (deodar), *Abies pindrow* (palunder), *Abies webbiana* (silver fir), *Pinus gerardiana* (chalghoza), *Pinus wallichiana* (blue pine) and *Juniperus communis* (juniper), etc. are typical of higher elevations.

*Previous Work:* Although much has been written about the geology of the Himalayas, little of it contributes directly to the area under discussion. The main source of information hitherto is a paper containing geological and structural maps by Martin, Siddiqui and King (1962). They divide the rocks of the region immediately to the south into the following six units:

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 three are exposed in Swat Kohistan. In order to keep uniformity in nomenclature, the present authors have retained the names used by Martin *et al.*

In 1964, M. Abu Bakr of the G.S.P., and R.O. Jackson of the U.S. G.S. compiled the geological map of Pakistan but only the rocks exposed immediately to the south of the area investigated are shown on this map. Davies (1965) gives a brief account of the Upper Swat Hornblendic Group.

## FIELD RELATIONS AND PETROGRAPHY

The rocks of Swat Kohistan can readily be grouped into five broad units, as follows:

5. The Shang Granodiorite Gneiss
4. The Swat Granitic Gneisses
3. The Jijal Ultramafics
2. The Lower Swat - Buner Schistose Group
1. The Upper Swat Hornblendic Group

The relative ages of some of these groups are speculative because of lack of positive evidence.

### 1. The Upper Swat Hornblendic Group.

These rocks occur in the north and northwest of the area, with a general NE trend, and extend into Dir State to the west (Davies, 1965). The name 'Hornblendic Group' was applied to these rocks by Martin *et al.* (1962) because of the ubiquity and abundance of hornblende.

The rocks range in composition from garnet-amphibole schists to gneissic diorites, diorites, and quartz - hypersthene gabbros. Davies mentions the presence of associated granites and syenites, and Martin *et al.* report associated dunites. The present authors did not see such associates of the Hornblendic Group in Indus Kohistan.* The predominant rocks in this area are hornblende - gneisses, followed by less gneissic intermediate and basic rocks of plutonic character; less abundant metasediments are found to the south, north of Patan Village.

The Hornblendic Group is flanked to the south by a special group of rocks, the garnet-amphibole gneisses, described at the end of this section.

Foliation, compositional banding, and microfolding (in the more schistose rocks) are common. The rocks are cut by thin pegmatites and quartz veins. Most of the pegmatites are less than five feet thick and very coarse grained, containing different combinations of quartz, feldspar, hornblende and tourmaline, etc. Some pegmatites may carry perfectly euhedral crystals of hornblende up to nine inches long (Martin *et al.*, 1962). Garnet is commonly asociated with the quartz veins, especially the narrow ones.

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* Granitic rocks and peridotites occur north of the area.

The metamorphosed sediments of the Hornblendic Group are fine-grained schistose rocks that generally grade into gneissic and apparently plutonic non-gneissic rocks, although some may have sharp contacts with the latter. Many of them have well preserved sedimentary layering indicated by the changing composition of different layers, although this might be probably due to migmatization and/or metasomatism. Texturally the metasediments are porphyroblastic, and most of the grains exhibit some crystal faces, and parallel arrangement. Based on a study of three thin sections, they are composed of hornblende (45 per cent);* andesine - labradorite (25 per cent); clinozoisite (10 per cent); quartz (10 per cent); pinkish (? almandine) garnet (6 per cent); and minor rutile and opaque minerals, (one section only contains 5 per cent biotite). Much of the garnet is in "bands" or "pods", though some may be dispersed throughout the rock.

The gneisses are medium- to coarse - grained, ranging from normal hornblende diorites to metamorphosed amphibolites. They are composed of abundant hornblende, followed by plagioclase, quartz, pyrite and magnetite/ilmenite. Pyrite is rimmed by opaque iron oxide and hornblende has light green rims of more sodic amphibole. Hornblende may be rimmed by mica (Martin *et al.*, 1962, p. 2) in some cases. The rocks contain xenolithic inclusions that are metamorphosed to garnet-amphibole assemblages. As previously mentioned, weakly gneissic norites** are also associated with these rocks. These are medium-grained, sub-equigranular rocks composed of 55-60 per cent labradorite (with both albite and pericline twinning); 14-16 per cent each of strongly pleochroic hypersthene, and light green, weakly pleochroic diopsidic - augite (both with exsolved lamellae); 5 per cent each of quartz and iron ore; and minor hornblende. Some rocks may have up to 10 per cent quartz.

*Associated garnet-amphibole gneisses:* Massive, generally coarse-grained and gneissic rocks of the almandine-amphibolite facies are well exposed along the southern limits of the Hornblendic Group; the best exposures are southwest of Patan Village. Concentration of various minerals in distinct bands is very characteristic of these rocks. In hand specimen, they appear to be composed of about equal amounts of garnet, amphibole, and white minerals, with subordinate muscovite in some, towards the south. Some of these rocks are non-porphyroblastic, others have large crystals of garnet (up to 2 inches across, and sometimes aligned in trains), surrounded by a narrow rim or corona of felsic or mafic minerals. Veins of calcite, epidote, and quartz are common along fractures. Thin veins of garnet and rare intrusions of pegmatite also occur.

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* All percentages in this paper are based on visual estimates.

** Recent investigations to the north of the area suggest that hypersthene-gabbros (norites) are predominant.

Pink garnet, calcic plagioclase, and hornblende make more than 80 per cent of the rocks in thin section. The remainder consists of clinozoisite, quartz, rutile, and iron ore in decreasing quantity. Chlorite and extensive epidote appear after garnet, hornblende and plagioclase in many of these rocks. The muscovite-bearing rocks have more clinozoisite and less garnet than the rest. Muscovite, as coarse flakes, generally forms less than 15 per cent. The rocks vary in texture from fine- to coarse - grained, gneissic to non-gneissic. One of the sub-equigranular amphibole-rich parts has crystals of hornblende 3 inches long. The grain size may change gradationally or abruptly across a plane.

Some of these rocks are very rich in one mineral, and there are "sheets" up to 120 feet thick that contain more than 80 per cent garnet or amphibole. Similarly, there are pods (up to several feet across) of hornblende and/or garnet, incorporated in normal garnet - hornblende - felsic assemblages. A garnet - rich rock in thin section has 80 per cent garnet, 10 per cent each of plagioclase and hornblende, and minor iron ore. A hornblende - rich rock contains only 18 per cent of pink garnet and traces of ore and rutile, besides predominant hornblende.

The mineralogy and abrupt variations in texture and composition of the garnet-amphibole gneisses within themselves indicate that they were a series of basic intrusions that have been metamorphosed to their present assemblages.

Martin *et al.* (1962) think that the Hornblendic Group is older than the Swat-Buner Schistose Group. The latter, according to them, is younger than the Salkhala Series (Precambrian), and older than the Chamla quartzites (? Devonian). Bakr and Jackson (1964) have tentatively placed the rocks, exposed south of Kalam along the Swat River, in the Precambrian. These rocks are part of the Hornblendic Group under discussion.

**2. The Lower Swat-Buner Schistose Group.**

Most of the rocks south of Jijal village belong to this group of, generally, low grade metasediments. Martin *et al.* divide them into five subdivisions, namely: 1) Siliceous Schists, (2) Amphibolite Horizon, (3) Marbles and Calcareous Schists, (4) Phyllitic Schists, and (5) Greenschists. The present authors have not extended this subdivision in the north, where the above sequence is seen in the area. Common rocks east of Churlandai village are pyrite-bearing quartz-mica schists and quartzites (probably equivalent to the Siliceous Schists of Martin *et al.*), whilst those to the west of Alpurai village are greenschists and associated serpentinites. Between these types are marbles (some containing fuchsite and tourmaline) and calcareous schists, and phyllites, with minor but persistent quartzites and quartz-mica schists (like those to the east), and graphitic schists.

The rocks are strongly schistose, medium - to fine-grained, and some are banded. Banding is particularly well displayed by the quartz-mica schists. Some of the rocks, especially the greenschists, are very deformed, faulted and micro-folded. The most common rocks are quartz-mica (biotite/muscovite) schists, quartz-mica-garnet(-ore) schists, quartz-chlorite-albite schists, quartz-carbonate-(mica-ore) schists, quartz-carbonate-garnet-mica schists, carbonate-talc schists, marbles, quartz-chlorite schists, epidote-albite schists, actinolite-talc-quartz schists, and fine-grained phyllitic schists, some of which also have garnet and/or graphite. Martin *et al.* have also found kyanite in some of the calcareous rocks. An interesting member of the group is a metaconglomerate ($\leqslant$300 feet thick) exposed in Chaman Nala, and to the south of Bhesham Qala. It has a fine-grained phyllitic matrix, enclosing boulders (up to one foot long) and pebbles of igneous and metamorphic rocks, elongated parallel to the schistosity. These may be interlayered with thin, equigranular schistose rocks.

The Schistose Group is intruded by abundant pegmatites, squeezed lenses and veins of quartz, granite and granodiorite gneisses, and a few amphibole-bearing rocks. The latter are composed of hornblende and plagioclase, with minor iron ores (sulphides and oxides), quartz, and traces of sphene. Alteration in these has commonly lead to partial chloritization of the hornblende, saussuritization of the plagioclase, and oxidation of the ores. Intrusions of granites and pegmatites are so abundant in some places that they cannot be shown on the map as separate bodies. The quartz-mica schists on the contact of these intrusions are feldspathized (some have 60 per cent feldspar) and some may appear "gneissic". Some of the schists close to these intrusions may also contain sulphides, which on alteration impart a yellowish-green colour to the rocks.

Martin *et al.* (1962) place the rocks of the Lower Swat-Buner Schistose Group below the Chamla Quartzites of (?) Devonian age. According to them, the presence of fossil remains in the marbles indicates that the rocks are younger than similar rocks of the Precambrian Salkhala Series. Bakr and Jackson (1964) give these rocks a Siluro-Devonian or possibly Ordovician age.

### 3. The Jijal Ultramafics.

A NW trending and northerly dipping body of ultramafic rocks, over three miles wide and at least seven miles long, occurs between the villages of Serai and Chopra to the north, and Jijal and Jaba to the south. It separates the Hornblendic Group from the Schistose Group, but to the northwest is probably terminated by the Hornblendic Group, which from then on is in direct contact with the Schistose Group. Immediately to the south of the main ultramafic body are concordant sills and lenses of serpentinite, intruding the Schistose Group. The main mass is composed of massive, hard, brown to green pyroxenites, incorporating a smaller greenish, resinous body of dunite towards the upper part.

The rocks are medium-to coarse-grained, hypidiomorphic to allotriomorphic; some of the pyroxenites have ophitic textures. All the rocks, particularly the dunites, have cataclastic textures. Colourless to faintly pleochroic diopsidic augite is the most common mineral of the pyroxenites. It has rod-shaped inclusions of iron oxide and exsolved lamellae of another clinopyroxene. In some cases it is partially altered to serpentine along grain boundaries. In one section, completely serpentinized grains, apparently of pyroxene, are seen among unaltered grains. This selective alteration is not clearly understood. Hypersthene is also present in some of the pyroxenites. It is generally more altered than the associated clinopyroxene and, in one section, all of it (forming about four per cent of the rock) is altered to brownish material, with the exception of a few fresh, pleochroic cores. Some types carrying more hypersthene (up to 35 per cent) may form hypersthene-rich bands. In these, hypersthene has inclusions of iron ore and about one quarter is altered to talc or serpentine. Greenish pleochroic diallagic diopside takes the place of diopsidic augite in the hypersthene-rich rocks. Diopside is only slightly altered and contains abundant, thin exsolved lamellae. It is interesting that the hypersthene-bearing rocks carry minor amounts of interstitial garnet. Iron ore is a constant but minor accessory in all the pyroxenites.

The authors do not know of any alpine peridotite or pyroxenite containing hypersthene. On the other hand, the latter is common in pyroxene granulites. It is therefore considered that some of the pyroxenites of Swat Kohistan may have undergone metamorphism, whereby hypersthene - garnet - diopside assemblages were produced at the expense of the original pyroxenites. Another possibility, suggested by S.F.A. Siddiqui (personal communication, 1969), is that the Jijal ultramafics might derive from a basaltic magma.

The dunites are composed of Mg-rich olivine and minor ore (about 2 per cent). Most of the olivine grains are sheared, have undulose extinction, and a 2V of about 90°. Some of the sections are fresh with little or no serpentine, whereas others may be one third antigorite with minor exsolved ore. The alteration is selective and within one section some grains may be almost fresh whilst others are entirely altered. The alteration, however, is more intense along grain boundaries and shear planes.

It is evident from the thin sections that the pyroxenites and dunites have been only partially serpentinized. Large scale serpentinization is very selective, being more intense along sheared and deformed zones, and on mountain peaks and ridges. The latter were not seen closely, the observation being based on the greenish colour of the