

GEOLOGY AND MINERALS INVESTIGATION
OF THE
JAGLOT-BUNJI QUADRANGLE (43-I/10),
GILGIT-DIAMIR-SKARDU DISTRICTS,
NORTHERN AREAS
PAKISTAN

By

SAJID HUSSAIN SHAH
RAFIULLAH KHAN

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Northern Areas, Pakistan.

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ABSTRACT

The investigated area lies towards SE corner of the Kohistan Island Arc sequence, which is bordered by the Nanga-Parbat Haramosh massif of the Indian mass, having remobilized Kataclastic metamorphosed and granitized gneisses. Direct collision of the Indian mass occurred with the Eurasian mass, along the Nanga Parbat-Haramosh massif spur, thus dividing the Kohistan-Ladakh island arc in two parts - the Kohistan island arc and the Ladakh island arc. In the investigated area, the rocks of the Indian mass started subducting under the rocks of the Kohistan Island arc, during the Early Eocene, along a megashear - the Main Mantle Thrust (MMT). The MMT zone, in the investigated area, generally measures 200 m - 300 m in width. while in the Lichar surroundings it is truncated and disturbed by the Raikotx fault and also concealed under scree. The subduction of the Indian mass under the island arc, resulted in severe tectonism, thrusting, folding, formation of a cordillera type folded mountain chain alongwith profuse intrusion of subduction related granitoids in the island arc sequence.

The Cretaceous island arc volcanogenic rocks were intermixed with the Jurassic to Cretaceous flysch type intra arc metasediments, with subsequent multi-phase and diversified type magmatism of granitoids in the Kohistan island arc. The first phase of this magmatism commenced in Late Cretaceous (Albian) while its third and final stage, representing a swarm of acidic dykes and pegmatites, in the Indus-Gilgit confluence area,

occurred during Oligocene and even Miocene (Patterson and Windley, 1985). The earlier acidic intrusions were metamorphosed to orthogneisses.

Three Himalayan orogenic episodes from Late Paleocene to Pliocene/Pleistocene caused strong diastrophism, resulting in the formation of different sets of foliation and lineation and metamorphism.

Large deposit of white, saccharoidal marble is present in Thelichi area. Some metalliferous hornblendites and volcanics, mineralized pegmatites, scattered multi coloured sulphide deposits and placer gold showings, all make the investigated area economically significant.

INTRODUCTION

Purpose and Scope

The Geological Survey of Pakistan initiated the programme of the regional geological mapping and mineral investigation in the Northern Areas at a scale of 1:50,000.

The Northern Areas of Pakistan which include Gilgit, Diamir, Hunza and Baltistan regions consist of some of the highest mountain ranges and peaks of the world. The high relief, rugged topography and poor means of communication have been and still are the main hurdles in the way of systematic geological work in the Northern Area.

Location and Accessibility

The Bunji-Jaglot quadrangle is covered by the Survey of Pakistan topographic sheet No. 43 I/10. It is bounded by the latitudes 35° 30' to 35° 45' N and the longitudes 74° 30' to 74° 45' E.

The towns of Bunji and Jaglot lie in Diamir and Gilgit districts respectively. Jaglot is located on KKH about 50 kms southeast of Gilgit while Bunji lies along left bank of the Indus, on the Jaglot-Astor road about 50 kms from Gilgit and about 560 kms from Islamabad.

The all weather Karakoram Highway (KKH) which is the communication media between Gilgit, Chilas, Besham and Rawalpindi runs along the left bank of the Indus. The Indus River is crossable by the recently constructed hanging bridge near Bunji-Jaglot in the northern portion and Raikot bridge towards south of the quadrangle.

A fair weather jeepable road along the Astor River passes through Bunji and connects the town of Astor. Besides that road, most of the area is inaccessible except for few trails that traverses the area. The investigated area lies in the western extremity of the Great Himalayan ranges.

Physiography

The Bunji-Joglot area is characterised by extremely rugged topography and high relief. Reliefs of 2000-4000 meters are common. The mountain slopes are very steep. The highest peak in the mapped area is Chamuri 4597 m and is located in the southwest of the area. The lowest contour of 1310 m is located downstream at the junction of Sai Nala with the Indus near Bunji.

The mapped area has two principal rivers, the Indus and the Gilgit Rivers which flow from northeast towards south. The Astor River is the main tributary which flows from southeast towards northwest and joins the Indus River near Thelichi village. The Sai Nala and Damot Gah are other important tributaries of the Indus, which flow from northwest and join the Indus near Jaglot town, Thelichi Gah, Bunji Gah, Ramghat Gah and Lichar Gah are other important tributaries of the Indus which supply water for irrigation and other domestic purposes. The drainage pattern in the mapped area is parallel, subparallel and dendritic.

The Bunji-Jaglot area has been glaciated. The major river valleys are V-shaped. There are many places particularly along the Indus valley, where Glacio-erosional and glacio-depositional features are commonly observed. These include moraines,

elliptical drumlins, roche moutonnee's etc. Some of the moraines at high altitudes, indicate that their deposition was followed by a period of swift erosion by the rejuvenated rivers during the Himalayan orogeny.

Climate, Vegetation and Habitation

The climate of the area varies from almost arid in the main Indus valley to subtropical in the watershed areas of its tributaries. The Indus valley is devoid of vegetation while its tributary valleys are thickly forested. The precipitation is mostly in the form of snow with some rainfall. The winters are cold and the summers are hot especially in the Indus valley and become fairly cool towards the watershed areas. The forest vegetation is in the form of pine and chalthoza, while the principal fruits grown are walnut, almond, mulberry, grapes, peach and apricot. Chalthoza, walnut and Salajeet (a natural organic compound used for medical purposes) are the principal market products of the area. Due to rough terrain and less cultivatable land, the population is sparsely distributed which mostly dwells in the major valleys and engaged in farming and local timber industry.

Previous work

Among the previous workers, Wadia (1932, 1952), Gansser (1964) and Bakr (1965) are the pioneer workers in the Northern Areas. They described the geology of the Nanga Parbat and adjacent areas. Ivanac et al. (1956) contributed to the geology of Punial and

and Baltistan areas in more detail. Later Desio (1974) and workers of Peshawar University in collaboration with some foreign agencies, contributed to the geology and geotectonics of the Northern areas and adjoining Kohistan and Malakand Agency. Their work makes the base for further research in the area.

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GEOLOGY

The investigated area comprises the rocks of Indian mass and the Kohistan island arc. The Indian mass consisting of the remobilized metasediments subducted northwardly under the Kohistan island arc along the MMT. The Kohistan island arc comprises of the metasediments, volcanogenic rocks and the granitoids.

Indian Mass Metasediments

The Indian plate located along the eastern side of the MMT, in the mapped area, is almost wholly covered by the metasediments. These metasediments include biotite gneiss, gneissic biotite schist and augen-gneiss. Locally granitization process is exhibited in these metasediments. Wadia (1932) described these metamorphosed and granitized rocks and correlated with the Archean rocks of the Rajputana and Singhum region of the Indian Shield. The Nanga Parbat-Haramosh massif comprising these granitized rocks of Precambrian age (Tahirkheli, 1982) is considered a kind of protuberance of the Indo-Pakistan plate inserted as a wedge into the Jurassic-Cretaceous island arc.

Augen gneiss:

The augen gneiss also known as the remobilized Nanga-Parbat gneiss (Tahirkheli, 1982, p. 17), is exposed in Hattu Pir area and also along upper reaches of the Ramghat Gah and Bunji Gah (Fig. 1).

The augen gneiss is gray, purple, and pink, weathers to

brown colour, coarse grained, well foliated, compact and banded. It has augens, lenses and lensoid pods of quartz and feldspar. These augens are aligned parallel to the foliation in a Zig-Zag and random manner. Mineral contents of augen gneiss are quartz, feldspar, biotite, muscovite (minor), garnet. Biotite varving is present around the augens. The remobilization and metasomatic granitization, in these augen-gneisses produced augmentation of quartz, feldspar and biotite, fine banding with zig-zag outlines. Microfolding of bands, recrystallization and partial melting due to remobilization phenomenon, is typical in these augen-gneisses. Gneissic schist and biotite gneiss:

The gneissic biotite schist and biotite gneiss are widespread in the Indian mass. They are grey to dark grey, weather to grey, generally fine to medium grained but locally coarse grained also, well foliated, banded and having small augens, lenses and pods of feldspar and quartz. Locally they exhibit lineation also. At places, thin white marble bands are interbedded with schists, and gneisses. Thin quartz veinlets traverse commonly parallel to foliation. Thin acidic dykes and pegmatites have been observed in these metasediments along the Skardu road. The amphibolite dykes are common along the Astore valley with colour index upto 90. Some pegmatites with quartz, k-feldspar laths, biotite, tourmaline and muscovite (minor) are also present. Gemstone-topaz, aquamarine, beryl, tourmaline have been mined from pegmatites of the Haramosh Range (NE of map). Sericitization and biotitization - augmentation and assemblage of

biotite along faults and shear zones is a common feature in the Astore valley. Banding in gneiss exhibit grey and white bands. Microfolding of bands, recrystallization and remobilization phenomenon is typical for these metasediments of the Indian mass.

The mineral contents of these metasediments are quartz, feldspar, biotite and sericite. Sericite is formed at the expense of biotite.

Meta-amphibolite dykes:

The meta-amphibolite dykes are exposed within the metasediments of the Indian mass, and mostly cover the Astore valley. They are greenish grey to black, friable fine grained, slightly foliated, locally garnetiferous and have hornblende from 80 - 90%.

Island Arc Metasediments

The Kohistan island arc metasediments are exposed in Bunji area, Damot Gah, Sabil Gah, north of Thelichi and Gor Gali area.

These metasediments cover the major part of the mapped area. These constitute flysch type metasediments deposited in the intra arc environments. All these metasediments are profusely intersected by sills, dykes, veinlets and pods of acidic, as well as, basic nature.

On basis of the field observations and petrogenesis these metasediments have broadly been classified in two major units (i) the pelitic metasediments and (ii) the calcareous metasediments. These calcareous and pelitic metasediments designated as the Thelichi Bed has been assigned Jurassic to Cretaceous age

(Tahirkheli, 1982, p. 25).

Pelitic metasediments:-

The pelitic metasediments cover major part of the Island arc metasediments. These are exposed in Damot Gah, Sai Nala, Bunji-Hosi area, Thelichi Gah and Gor Gali area (Fig. 1). These pelitic metasediments consist of para-amphibolite, para-gneiss, biotite schist, garnetiferous mica-schist, hornblendeschist, chlorite schist, migmatite, phyllite and thin marble beds. All these metasediment facies are interbedded with each other.

Para-amphibolite is well exposed in the Hosi area. Small exposures of garnet amphibolite are present in Thelichi and Gor Gali area. Para-amphibolite is grey to dark grey and black, fine grained, foliated, compact and consist dominantly of hornblende and feldspar in almost 80:20 ratio. The para-amphibolite in contact with the acidic dykes swarm changes to migmatite and lit-par-lit gneiss due to extensive intrusions of very thin stringers and veinlets of acidic nature along its foliation. Locally ptvgmatic folding, lineation and micro-varving have developed in amphibolite and migmatite.

Para-gneiss is well exposed between the KKH and Gor Gali (Fig.1). However, its small exposures are present in the rounded hillock just north of Thelichi, Hosi-Bunji area and in the vicinity of Astor-Indus Rivers confluence. Para gneiss is grey, fine to medium grained, thin banded and well-foliated. Banding developed due to parallel segregation of felsic and mafic minerals. In Gor Gali area, these metasediments are intersected

along a fault zone, by sills, dykes and irregular pods of basic pegmatite, thin hornblende and meta-volcanics. As these metasediments are located near the MMT zone, so the diastrophic forces caused intense shearing, crushing, epidotization and faulting, especially between Gor Gali and Indus-Astor Rivers confluence.

The schistose rocks consist of biotite schist, hornblende schist, calcareous schist, chlorite schist, garnet-mica schist, quartz schist, hornblende-biotite schist and green schist. The names prefix to schists are the diagnostic minerals. These schistose rocks are predominant along the lower Damot Gah and its tributaries, Sabil Gah; while in lesser proportions are also exposed elsewhere within the other pelitic metasediments. Chlorite schist is best exposed along the KKH, on left bank of the Sagatal nala. The schistose metasediments are green grey to dark grey and brownish grey, friable, fine grained, well-foliated, laminated and thin bedded. These metasediments weather generally to brown and dark grey depending on their mineral contents. Locally pygmatic folding, micro-varving crumpling thin banding are also found. Epidotization is common near the MMT zone. Quartz veinlets, pods and augen-like inclusions are found within these schistose metasediments both parallel and cross-cutting foliation. The schistose rocks along left bank of the Thelichi Gah have alternate hard and soft beds due to interbedding of hornblende schist and biotite-chlorite schist respectively.

Migmatite and lit-par-lit gneiss are found within the meta-

sediments due to the acidic intrusions in which thin stringers of acidic nature penetrated the host metasediments profusely, parallel to its foliation. Later distrophic forces produced harmonic micro and macro-folding and the zigzag type pygmatic folding. These migmatites and lit-par-lit gneiss are exposed in Sabil Gah, Hosi area and lower Damot Gah. Towards west of Damot, along the left bank of Damot Gah, the haphazard granitic intrusions occurred so common, that the parent meta-sediments remained only as big xenoliths and screens with different orientation due to flowage of granitic melt.

Slate and phyllite are exposed along the upper Damot Gah, on southern flank of the marble bed. They are grey, fine grained, foliated, thin laminated, and also show lineation trend.

Thin marble beds are exposed in Bargin Gah, Upper Damot Gah and Bunji NLI shooting point. These marble beds are white to cream coloured with bluish tinge, coarse to very coarse grained and saccharoidal. The marble bed of the Bunji shooting point is 5 m. thick, interbedded with biotite schist. It is mineralized containing garnet, phlogopite, green and bluish green mica, galena and bluish green asbestos.

Calcareous metasediments:

These metasediments are exposed along the KKH northwest of Thelichi and extend westward towards upper Damot Gah (Fig. 1). Previously Wadia (1932) and Gansser (1964) considered these calcareous metasediments as extension of the Salkhala Series of Precambrian age, but the new tectonic model of the northern part

of Pakistan and also its higher proportion of carbonate association, all negate the old concept. The new tectonic model emplaces the Jurassic-Cretaceous Kohistan island arc sequence between the Precambrian Indian mass and the Eurasian plates. The dominant rock unit is white to cream coloured, saccharoidal marble, while impurities as argillaceous and argillaceous marble and calcareous schist exist along its flanks and near the KKH. The marble is coarse grained, pure, slightly banded and sparsely jointed. This marble bed is about one km thick at its exposure near Thelichi, while its north-westward extension along the strike, in upper Damot Gah pinches out and remain only 50 m and 10 m thick beds. The 10 m. thick bed has faulted contact with the adjacent volcanics. This marble bed exposure towards NW of Thelichi, forms a tight plunging syncline, with steep dips to 60 to 80°, and plunge towards east, and therefore, has maximum thickness of over 2 km.

Volcanogenics

These volcanogenics mark almost the base of the island arc and originated as thick oceanic crust within the oceanic intra arc subduction related metasediments and considered a part of the Rakaposhi volcanic complex (Tahirkheli, 1982). Their eruption took place in multiphase episodes hence interbedded with the entrapped pelitic and calcareous metasediments. These volcanogenics include the bedded volcanics, massive amphibolite and the tuffaceous slate. On basis of fossil discovery in the entrapped metasediments, these volcanics and volcanosediments

have been assigned Lower Cretaceous age (Tahirkheli, 1982, p.26).

Intermediate and basic Volcanics:

These banded intermediate and basic volcanogenic rocks are exposed along the KKH between Jaglot and Thelichi, and extend westwards across Damot Gah. Small exposures of these rocks are also observed along Thelichi Gah and Gor Gali nala. These volcano sediments are well banded. These include andesite, basalt, amphibolite, dacite, but the predominant rocks is andesite. The entrapped interbedded sediments include soft, friable, biotite schist, brown calcareous bands and thin white marble bands. These banded volcanics with entrapped sediments are exposed as large elongated screens within diorite in Thelichi area and have sporadic mineralization of lead and zinc (Shah, 1980). The banded volcanics are also interbedded with the tuffaceous slate and chlorite schist along the KKH on left bank of the Sagatal nala.

Andesite and dolerite are grey to dark grey, usually with greenish tinge, weather to brown, usually fine grained and sparsely jointed. Hornblende, feldspar, epidote and garnet are the major minerals of these rocks. Locally limonitization is present. At places recrystallization of feldspar and hornblende occurred due to metasomatic effects.

Basalt is dark grey to black, tough, very fine grained, splits to hackly fracture and usually have columnar jointing pattern.

Dacite is grey, fine to medium grained, well jointed and have feldspar, hornblende and biotite.

Amphibolite is green and dark greenish grey with blue tinge, fine to medium grained, tough and having fine acicular crystals of hornblende. The mineral content being feldspar, hornblende, and biotite (minor).

These bedded volcanics are cut across by basic and acidic dykes and pegmatites. These dykes and pegmatites have produced metasomatic recrystallization effects in these volcanics.

These incompetent banded volcanosediments alongwith the interlayered competent quartz diorite sills, are intensely folded, in the area towards west of the KKH opposite Bunji. This folding is the result of strong diastrophic forces acting from the MMT zone.

Massive amphibolite:

Massive amphibolite bodies are exposed in the area between the Ramghat Gah and the Bunji Gah (Fig. 1). Small unmappable exposures are also present near the Astore River bridge. They are greenish grey to black, fine to medium grained, massive. The mineral content being plagioclase feldspar, hornblende, epidote and secondary chlorite. Due to vicinity with the MMT zone, these amphibolite bodies are highly sheared and epidotized.

Tuffaceous slate:

Tuffaceous slate is exposed along the KKH towards west of the Sagatal nala (Fig. 1). It is associated with grey bedded volcanics and green chlorite schist. The slate is grey to

greenish grey, fine grained, medium bedded, well foliated and thin laminated. Both the tuffaceous slate and chlorite schist exhibit lineation. The slate breaks in medium thick slabs.

Kohistan Arc Batholith

Ladakh granodiorite of Bakr (1965) has been redesignated as Kohistan-Ladakh granitic belt (Jan et al: 1981). Patterson et al. (1985) renamed it as the Kohistan arc batholith because of its presence in the Kohistan island arc sequence.

These granitoids covering maximum part of the island arc, were intruded during Late Cretaceous to Oligocene and even Miocene, in three different episodes (Patterson and Windley, 1985). The first phase intrusion comprising the deformed diorite, tonalite and basic rocks took place during Late Cretaceous (102 ± 12 to 75 Ma). The second phase intrusion related to Andean type subduction and comprising Hb-gabbro to granite but abundantly granodiorite took place during Paleocene-Eocene (65 ± 2Ma to 40 ± 6Ma). The third and final phase of intrusion related to crystal melting and comprising aplite-pegmatite, leucogranite and sheated granite took place during Oligocene and even Miocene (34 ± 14 Ma to 29 ± 8 Ma).

Hornblendite:

These elongated and oval-shape small intrusive bodies, mostly aligned along the tectonic zones, are exposed near Shotiachuk, Bargin, along Gor Gali nala, Bunji Gah, Thelichi Gah, the KKH (opposite Lichar), and in the MMT zone along the (Astor road) (Fig.1).

These intrusive bodies have two different phase intrusions - the first earlier phase consists of green meta hornblendite and the second later phase of black hornblendite. Both these hornblendites have colour index 70-90.

The meta hornblendite is greenish grey, dark green to black green, coarse to very coarse grained, heavy and massive. They show recrystallization feature in Gor Gali nala probably due to the metasomatism of the diorite body. Here pods and lenses of green brown hornblendite (iron bearing) are present within diorite. The green meta hornblendite has secondary chlorite and sericite formed at the expense of hornblende and feldspar.

The small meta-hornblendite bodies are quite widespread within diorite in Thelichi Gah. The meta-hornblendite body along the KKH. is cut across by the later dykes, pods and lenses of black hornblendite, amphibolite, basic pegmatite and gneissic granite, with prominent epidotization and kaolinization.

The dark grey to black, very coarse grained hornblendite of later phase intruded within meta-hornblendite and diorite in the form of pods, lenses and dykes. The black hornblendite has predominant hornblende megacrysts minor feldspar and biotite. The black hornblendite in Bunji Gah, has hornblende, feldspar, green mica and hematite, probably due to its close proximity with the MMT zone.

The hornblendite bodies are commonly cut across by the later volcanic dykes - basalt, andesite and amphibolite, along with acidic pegmatites, micro granite dykes, aplites and basic

pegmatites.

The hornblendite bodies originated both by metasomatism within the diorite, as well as tectonically brought from the mantle by high angle faults during convergence of the two plates.

The hornblendite body in the Gor Gali nala, has prominent slickensides along almost each crack, showing severe faulting therein.

The green metahornblendite bodies are usually metalliferous with silver white metal.

Being in close proximity with the MMT shear zone, hornblendites located in the Bunji Gah and the KKH, are profusely intersected by the acidic and basic dykes, therefore the original hornblendite masses remained only as big screens and xenoliths.

Ortho-gneiss :-

Small unmappable bodies of ortho-gneiss are wide spread, but those located in the Gor Gali nala and along KKH, opposite Lichar, are the mappable units (Fig. 1).

Granite gneiss is exposed as an almost circular body along the KKH. It is whitish to light grey, coarse grained. The grade of metamorphism increases gradually towards south i.e. towards the MMT.

It contains screens, big xenoliths, pods and thin linings of dark grey to black, fine grained, para-amphibolite. The existence of abundant thin linings of granite gneiss within amphibolite resulted the lit-par-lit gneiss with local pygmatic folding.

The mineral contents of granite gneiss are quartz, feldspar

minor biotite, garnet (locally in lit-par-lit gneiss portion) and hornblende. The hornblende crystals are not sharply at margins but blurred due to their metamorphism. It has sharp intrusive contact with the adjacent hornblendite.

Diorite gneiss is exposed as an oval body in Gor Gali nala. Diorite gneiss is grey, medium to coarse grained and foliated. It has transitional contact with diorite.

Diorite:

Diorite makes the major intrusive body in the investigated area. It is exposed from Raikot bridge in the south (out of map) to Thelichi Gah covering the highest Chamuri peak and extends further northwards in the form of big screens and apophyses (Fig.1). Towards north of Jaglot, diorite remains as the xenoliths and small pods, as intensely intersected by the later acidic dyke swarm. On the left bank of the Indus, it is also exposed in Ramghat and Bunji Gahs.

Diorite has two phases of intrusion. The earlier phase, exposed near the MMT zone (opposite Lichar) is well foliated, garnetiferous, sheared and epidotized, while the later phase is fresh, massive and unaltered.

Diorite is mostly grey and locally dark grey, and weathers to brown colour, medium to coarse grained, massive and usually unfoliated, tough, at places foliated. Between Gor Gali nala and Thelichi village, it is foliated and metamorphosed to gneiss.

Locally, diorite shows recrystallization, hybridization and segregation features resulting leucodiorite, hornblendite,

amphibolite and mela-diorite pods and screens with irregular and transitional marginal boundaries. Near Raikot bridge (in SW corner of map), diorite has inclusions of norite also.

Its mineral composition varies from leuco-to mela-diorite, with average composition being Na ~~37~~ plagioclase 60-70%, hornblende 25-30%, quartz upto 5%, garnet upto 5% and biotite (5-7%). Locally, garnet accumulated as clusters and aligned mostly along cracks and joints, in the diorite of earlier phase and is exposed along the KKH, opposite Lichar. Hornblende in mela-diorite is present usually in the form of small accicular crystals.

Diorite is intersected by dykes of both acidic and basic composition: granite apophyses have been observed in Damot Gah, while around Jaglot and Sai Nala diorite is immensely intersected by Swarms of acidic dykes. It has sharp intrusive contact with the metasediments and later intrusives.

Being in proximity to the MMT zone, diorite in southern portion of the investigated area, has severely been sheared and altered giving greenish hue because of chlorite and epidote, and also subjected to sulphateric action by the hydrothermal solutions.

Quartz diorite:

Quartz diorite is exposed on right bank of the Sai Nala, between Damot Gah and the KKH (Fig. 1).

It is dark grey, coarse to very coarse grained with megacrysts as well as small clusters of hornblende. It is massive, with colour index 30-40. Locally it shows recrystallization and

hybridization process resulting in small hornblende pods with irregular outlines.

The mineral composition reveals quartz (10-15%), Na-plagioclase (40-45%), hornblende (38-40%) and biotite (5-10%). Locally hornblende changes to epidote.

Quartz diorite is intersected by different dolerite dykes (measuring upto 3 metres in thickness each), muscovite-granite dykes and pegmatites. Both the dolerite dykes and quartz diorite are folded with E-W fold axes due to their minor plasticity. The quartz diorite has been crushed by 1 m. thick fault.

The quartz diorite has sharp intrusive contact with the metasediments. Its contact with the adjacent volcanosediments is interfingered and intensely folded due to strong diastrophic forces acting from the MMT zone.

Granodiorite:

Granodiorite is exposed as oval shaped elongated intrusion, covering the peak area, between Sai Nala and Shotichuk nala. Small granodiorite body is also exposed towards south of the Gor village (Fig. 1). It is light grey weathers to bluish grey, medium to coarse grained, massive, with colour index 15 to 20. It has sparsely spaced joints. Its mineral composition shows K-feldspar 20-25%, Plagioclase feldspar 35-50%, quartz 20-30%, biotite 10-15% and hornblende 2-5%.

Granodiorite is intersected by immense light grey to white dykes of granite and aplite, which are about 1.5 metre thick.

It has sharp intrusive contact with the adjacent intrusives

and metasedimentary rocks.

Granite:

Granite is exposed as thin linear bodies, along the Damot Gah and its tributaries.

It is whitish to light grey, weathers to light brown, medium to coarse grained, massive and jointed which are sparsely spaced. Its colour index is 10-15. The weathering produces pothole exfoliation and sub-rounded appearance.

Its mineral composition is quartz 20-35%, K-feldspar 45-65%, Plagioclase 5-10%, muscovite 3-8%, biotite 5-10% and hornblende 2-5%.

Towards SW of Damot, granite apophyses and dykes intersected the parent metasediments so profusely to render them only big xenoliths and screens with disturbed foliation trend.

Granite has sharp intrusive contact with the adjacent intrusives and metasedimentary rocks.

Acidic dykes swarm :-

The acidic dykes swarm are quite common around Jaglot, along both banks of the Indus and Gilgit Rivers and also along the Sai Nala. However, some linear acidic dykes also traverse their respective country rocks in other parts of the map. The dykes swarm exhibit the nature of stringers, veins, dykes, sills, pods with irregular zigzag outlines. They intruded the migmatite, gneiss and diorite so profusely and randomly that the pre-existing rocks remain only as xenoliths, screens and pods. These dykes also intersect each other. Their thickness varies from mere stringers

to almost four metres and their length upto tens of metres. The general trend of this dykes swarm is NE-SW, with dip towards NW. The acidic dykes swarm comprise of micro-granite, micro-granodiorite, aplite, quartz-feldspar veins and pegmatites.

Micro-granite, aplite and microgranodiorite are light grey, fine to medium grained, with various thickness and extent and having varying proportions of their mineral contents. Pegmatites are white, coarse to very coarse grained and show varying trends. These pegmatites are of two types - intrusive and recrystallized (Shah et al. 1986). The intrusive pegmatites cut across the country rocks sharply, as directly emanating from the magma chamber, while the recrystallized ones are the product of metasomatism - the result of volatile and hot gaseous solutions interacting the country rocks from where they pass through.

Mineralogically, the pegmatites have quartz, K-feldspar (microcline, orthoclase) laths, perthite, biotite + muscovite, while locally they contain tourmaline, garnet, epidote, and radioactive minerals. These minerals display their varying proportions within the pegmatites.

These swarm type dykes resulted from partial melting of the continental crust due to subduction process (Pettersson and Windley, 1986).

Basic dykes/sills;

The basic dykes and sills are quite common throughout the mapped area, but prominent in Barmas area, Damot Gah, Bunji Gah and along the KKH.

The basic dykes include andesite, basalt and dolerite.

The basaltic intrusions are dark grey to black, while the andesitic intrusions are generally dark green, fine to medium grained, tough, locally epidotized. Andesite usually show composition of feldspar, hornblende, biotite (minor), while basalt is cryptocrystalline and not identifiable without the optic aid. The basaltic dykes are common in upper Damot Gah.

Dolerites are grey to dark grey, fine grained, well jointed and tough. In Barmas area they are locally garnetiferous epidotized, limonitized, and biotite bearing. Here the dolerite is cut across by thin pegmatites, thus producing the coarse grained quartz, feldspar, garnet and muscovite within dolerite due to metasomatism. In Barmas area, locally, the dolerite dykes are folded with fold axis dipping at 10° towards south.

Unconsolidated Sediments

Molasse deposits:

These Pliocene deposits of terrestrial origin are located along the Indus valley, mostly as unmappable units, between Lichar and Thelichi villages.

They are generally grey, green and Khaki coloured, fine to medium grained, not very compact with fragments of silt, sand and grit and occasional pebbles thus making it a "loose conglomerate".

These molasses are present in the form of small patches surrounded by the later terraces and moraine deposits.

Moraine and glaciofluvial deposits:

Moraine and glaciofluvial deposits are widespread in the investigated area. These are the remnants of the Pleistocene glaciation and scattered along the main valleys, as well as, on the peaks as high as 1884 m. These high altitude glaciation remnants, suggest abrupt cutting and erosion by the rejuvenated Himalayan rivers during the Himalayan orogeny. Glaciation resulted moraine locally tillite, drumlins, glacio-fluvial deposits, glacio-erosional features and glacial lakes.

The moraines generally have the weathered colour of their parent denuded rocks. The valley moraines are generally buff, grey, yellow and pink, while the high altitude moraines are usually green. The buff and yellow colour is generally due to the schists and other metasediments, while green colour probably due to the rocks imparting green colour viz. basic volcanics and plutonics. The yellow, pink and various other shades within moraines are also probably due to the sulphateric action along the weak zones.

Moraines are loose, unsorted with silt to boulder size fragments and angular to sub-angular fragmental shape.

Locally, the moraines are transformed to compact tillite, which are not large enough to become mappable units.

Moraines in the form of oval and elliptical drumlins are present at various localities viz. Chakarkot Das, Damot village and north of Astor bridge. The principal axes of these drumlins are generally aligned in the direction of glacier flow. At Chakarkot-

Das, an esker is also present between two drumlins.

Due to glacial erosion, rounded elliptical hillocks are produced around Thelichi village. These rounded hillocks are also fault aligned. Towards north of the extinct glacial lake, between Lichar and Thelichi, small rounded heaps of loose glacial material are present.

The glaciofluvial deposits are found towards downstream side of the moraine, at Jaglot town, south of Bunji and Barmas village. These glaciofluvial deposits are unstratified to partially stratified and have big boulders which are sub-angular to sub-rounded, with other components as sand, gravel, and cobbles. These deposits are mostly covered by alluvium.

Terraces, scree, loose sand and alluvium:

These loose fragmental deposits cover vast area along the river and stream valleys and the hill slopes.

Terraces present along the valleys are well stratified, sorted and their fragments range in dimensions from clay, silt and sand to gravel and cobbles. Their gravels and cobbles are rounded to sub-rounded. Generally terraces have buff clay and grey sand. Mostly the terraces are laid horizontally but locally have oblique stratification due to turbulent currents, as observed at Astor bridge, Partab bridge and some other localities along the Indus.

The thickness of terraces vary at different places. The terrace exposed along the Indus, at its junction with the Bunji Gah, is about 80 metres thick.

These huge river terraces are probably the result of damming of the river Indus by the avalanches and landslides from time to time. Mostly the terraces overlie the molasse and the moraine, with exception of that exposed along left bank of the Indus upstreamwards of the Bunji bridge which underlies the moraine, probably due to recent faulting.

Loose scree along the mountain slopes is widespread throughout the area. It is well developed over the friable metasediments, along the Astor and the Indus valleys. The prominent places are the Mushkin and Dorian areas along the Astor valley and the Lichar-Astor bridge area along the Indus.

These scree deposits conceal the geological and structural details underneath, especially, along the left bank of the Indus between Lichar and Astor bridge, where the vast scree covers the MMT zone.

Prominent grey, loose sand deposit is located at the Indus-Gilgit Rivers confluence area. However, small sand deposits are also scattered elsewhere along the Indus valley, and near the extinct glacial lake at the Chakarkot Das. These sand deposits cover the terraces and moraine.

Alluvium patches, covering the terraces and moraines, are widespread along the valleys of the rivers and their tributaries. These thin alluvial covers are fertile and well productive.

GEOTECTONIC HISTORY

During the Late Palaeozoic most of the continental masses were joined to form one great super continent called Pangaea

(Searle, 1991). During Carboniferous to Early Permian (300 to 250 Ma), Pangaea began to break up into several smaller plates due to the divergent movements of the plates. A major new ocean called Tethys was created, dividing the Eurasian continental mass in the north from the Gondwana continent in the south (Smith et al. 1981, in Searle 1991, p.8). In between these two mega continental masses, were numerous smaller continental fragments viz. Iran microcontinent, Afghan and Lut blocks. Along the northern margin of the Tethys a number of parallel volcanic arcs viz. Kohistan-Ladakh-and Dras-volcanic arcs, developed above north-dipping subduction zones during the Cretaceous and lower most Tertiary.

During the Late Cretaceous Indian plate began its rapid north west drift from the southern Hemisphere, at very fast rates of 15-20 cm/year.

The collision of Indian plate with Asia (in eastern Himalayas) is thought to have occurred approx. 50 Ma ago during the Early Eocene resulting closure of Tethys and therefore, the drifting speed decreased upto 5 cm/year (Searle, 1991, p. 9), and the Indian plate was welded onto the Karakoram. The Indian plate collided with the Karakoram terrane along the Indus suture zone (ISZ), tracing over 2000 km from Kohistan in the west to Tibet in the east. This Indus Suture Zone, in Pakistan, has been referred to as the Main Mantle Thrust zone (Tahirkheli and Jan, 1979). Below 700 km depth, the descending Indian plate is remelted and reabsorbed into mantle (Heather, 1979, p. 36)

Searle (1983 & 1986, in Searle 1991, p. 42) define three major stages of deformation in the western Himalaya (i) a pre-collision ophiolite obduction phase (75-60 Ma), (ii) a continental collision stage involving polyphase thrusting (50-25 Ma), and finally (iii) a post-collision, dominantly back-thrusting phase (15-0 Ma). At the Indus-Gilgit Rivers confluence, the swarm of leucogranitic dykes and pegmatites are the final stage of magmatism in the Kohistan arc sequence.

Neotectonic deformation has placed Nanga Parbat gneisses over the Quaternary unlithified glacial deposits along the Lichar thrust, on left bank of Indus, in Lichar area.

The Raikot fault zone truncates and offsets the earlier Main Mantle Thrust. Active geothermal springs with hydrothermally altered gouges occur along this neotectonic fault zone along the Karakoram Highway.

The Nanga Parbat Haramosh massif, having the remobilized kataclastic gneisses, thrust towards the Asian mass and thus divided the island arc terrane in two parts viz. the Kohistan and the Ladakh island arcs. The Jurassic to Early Cretaceous volcanic rocks are well exposed developed in Kohistan and western Ladakh arcs.

Metasediments deposited in the intra arc basin, during Jurassic to Cretaceous crop out throughout the Kohistan terrane, but are not widespread. These chlorite- and epidote-bearing, low grade metasediments are interbedded with the andesitic to rhyodacitic volcanics.

Following the collision of these island arc masses with the Asian mass, the island arc sequence was folded, thrust and intruded by subduction-related granitoids. Earlier intrusives were deformed, metamorphosed and were intruded by later granitoids, throughout the island arc.

The collision of the northern margin of the Indian plate, resulted in regional-scale metamorphism, magmatism and uplift in Kohistan, Ladakh and Karakoram, to the north of the Main Mantle Thrust. The upheaval of the mountain belt began in the late Neogene and is still occurring. (Desio, in Geodynamics of Pakistan, 1979. p. 111).

Astonishingly high uplift rates of upto 7 mm/year of the Nanga Parbat-Haramosh massif resulted in more than 10 km of uplift erosion since Miocene (Zeitler et al. 1985 & 1989, in Searle, 1991. p. 291). The swift upheaval of the trans-Himalayan ranges, resulted in the abrupt increase in the erosive power of the rivers, which ultimately deposited their huge transported material as thick river terraces. The high altitude moraine exposed at a height of 2467 m on right bank of the Indus, opposite Lichar, is result of swift downward cutting of the rejuvenated river Indus.

STRUCTURE

The mapped area is structurally very important and lie in the active tectonically disturbed zone. The famous megashear zone namely the Main Mantle Thrust (MMT) passes through SE of

the mapped area. The area is structurally controlled by this megashear. The Indian plate is subducted under the Kohistan island arc (Tahirikheli, 1979) along this megashear.

Due to this active convergence of the Indian plate with the island arc, severe tectonic disturbances involved, resulting a number of faults and shearing, squeezing up and folding of the sediments between two plates forming a mountain chain, tectonic emplacement of the mantle material, hot springs along high-angle faults and sulphateric action along the weak zones.

Strike slip faults along the Astor valley are result of subduction of the Indian plate under the overriding island arc. In response to the bending down of the descending Indian plate, compressional region developed in the upper surface, resulting a large number of faults, which intensely crushed jagged and sheared the intervening rocks e.g. in the southern portion of the mapped area adjacent to the MMT zone. Some of the faults are high angle resulting evolution of a number of springs and oil seepages. These oil seepages are visible in Dirkil and Gor Galinala. Most of the hornblendites and amphibolites have been tectonically emplaced from mantle and are therefore, quite heavy and metalliferous. Sulphateric action, as result of ascending hydrothermal solutions happened along cracks and deep seated faults.

As result of the convergence. the intra arc oceanic metasediments were compressed forming a folded mountain chain or cordillera. An example of such cordillera is observed in the

folded metasediments and volcano sediments, between Thelichi Gah and Damot village. In Ramghat Gah, such folding also resulted in the formation of plunging syncline within the Indian plate metasediments which plunges towards west i.e. towards the MMT zone. Moreover, another plunging syncline developed in the Thelichi marble zone, plunging towards east i.e. towards the MMT.

As the subducting Indian plate collided with the Island arc mass, a flake (large thrust block) of the Indian plate tectonically overthrusts the Island arc mass, along the Raikot fault, extending from Hattu Pir to Lichar (Fig. 1) and further extends along the MMT towards Tato Gah and Gunar area (out of map). Such flakes have also been reported in the Eastern Alps (Heather, 1979, p. 65). This flake dips in opposite direction i.e. away from the MMT in contrast to the rest of the metasediments dipping towards the MMT. This thrust block concept negates the earlier idea of Lawrence et al. (1984), whereas, they interpreted that the MMT near Raikot becomes vertical and then overturns to become SSE dipping i.e., away from the MMT.

As result of the severe tectonism, a block of the Indian mass comprising of augen gneissic-schist, thrusts over the Quaternary moraine, along left bank of the Indus near Lichar village. This thrust block is the unique example of the active thrusts.

The augens within gneisses and schists developed in the Nanga Parbat Haramosh massif (Indian mass), due to tectonism and resultant dynamic metamorphism.

MAIN MANTLE THRUST ZONE (MMT)

The MMT zone in Pakistan, extends from Dir to Kargil and makes a big loop around the Haramosh range. This MMT along the Nanga Parbat-Haramosh massif spur divides the island arc mass in two zones viz. the Kohistan island arc and the Ladakh island arc. A portion of the MMT zone, lies in the investigated area, on its south eastern side.

The MMT is a megashear, along which the oceanic part of Indian plate subducted at low angle under the Kohistan island arc. This megashear has resulted in immense shearing, crushing, accompanied by strong sulphateric action and volcanic activity. The MMT zone along the Lichar Gah is a mixture of the rocks of both Indian and island arc masses, associated with immense faults, gouge and sulphateric action. The MMT zone exposed along left bank of the Astor River has immense volcanic activity of felsic nature, accompanied by innumerable faults and a metallic, dark grey to black, heavy, andesite plug, brought up probably from the mantle of the earth.

The MMT zone in the investigated area, generally measures from 200 m to 300 m in thickness, but between the Lichar village and Astor bridge along the left bank of the Indus, the MMT zone is much narrow and locally concealed under the scree.

ECONOMIC GEOLOGY

Metalliferous Hornblendite and volcanics

Small elongated and oval-shape meta-hornblendite bodies, mostly aligned along the tectonic zones, are exposed at different

localities e.g. Shotiachuk, Thelichi Gah, Gor Gali nala, Bunji Gah, Bargin and KKH (Opp. Lichar) (Fig. 1). The metalliferous volcanics are exposed along the Astor road, in the MMT zone.

These metalliferous bodies are of small dimensions, and have silver white nickel and cobalt showings (Tab. 1).

The metalliferous dark grey to black volcanic plug within the MMT zone and measure 30 x 200 m in size.

These metalliferous bodies are quite heavy and probably the part of the mantle. Their metallic contents are given in Table-1.

Pegmatites

The white acidic pegmatite bodies are quite abundant around the Indus-Gilgit Rivers confluence: at other places some linear pegmatite bodies are exposed (Fig. 1). Mostly they cut across the pre-existing rocks in haphazard manner.

The pegmatites have big laths of K-feldspar, quartz, biotite, muscovite, with minor amount of garnet (red), turmaline, epidote and some radioactive minerals (Shah, et al. 1986).

The pegmatites with dominant and big feldspar laths are worth mining for utilization in ceramic and glass industry.

Placer Gold

The rivers flowing in the Himalayas, Karakoram and Hindu-kush in Northern Pakistan, have rich placer gold, precious metals, rare earths and radioactive minerals. The Indus gravel-sand deposits were examined for their heavy mineral fraction and gold contents and terms as the "Leanest ore" (Zaki et al. 1975).

For this, spot sampling of the meander gravel and sand bar deposits from the surface, as well as rarely from a few feet depth, was taken by the conventional primitive "Nava" (sluicing) operations. The heavy minerals i.e. zircon, garnet, scheelite, ilmenite, rutile, rare earths and other silicate minerals were noted in the heavy fractions along gold. Out of 35 samples, taken from Thelichi-Jaglot-Partabpur area, the gold content in ounces-long tons of washed sand and gravel, varies from 0.0005 to 0.011 (Thelichi area), from nil to 0.0092 (Bunji-Jaglot area), from 0.0006 to 0.0034 (Partabpur-Sassi area), and 0.05 being the highest content in the Bunji-Jaglot high terrace deposit. The river channel gravel-sand, especially the high terrace deposits, may prove economical by using modern sophisticated dredging-washing-treatment equipment, instead of the conventional primitive "Nava" operation method employed by the local gold-washers. Furthermore these placers may also prove to be the "richest ore", keeping in view the present hiking rates of gold and other recoverable precious metals and minerals, which may justify the cost of mining placers and separation processes. Moreover, the monetary value of gold and engagement of our manpower may further prove it to be economical.

Sulphide Zones

Multi coloured sulphide deposits of various dimensions are exposed at various localities within the island arc (Fig. 1). The colours are commonly red, orange, pink, yellow and green.

These sulphide zones are result of sulphateric action. The ascending mineralized hydrothermal solutions traverse the country rocks along the weak zones viz. cracks and faults, and deposit their mineral contents in the oxidation zone. Their metallic contents are given in Table-2.

Lead-Zinc Mineralization

Thin veins and veinlets showing lead-zinc mineralization cut across the host volcanogenics with entrapped sediments as exposed in the Thelichi Gah and the adjoining Sagatal nala (Shah, 1980). These volcanogenics are exposed as large elongated screens within the intrusive rocks. Mining had been operated after the partition and soon after abandoned because of termination of the mineralized veins and other mining problems.

Further mining of the hydrothermal mineralized veins in dipward direction aided with geophysical survey, may again hit the Pb-Zn ore of probably economic significance.

Building Material

Marble :

A thick marble bed, folded into a plunging syncline, is exposed as an isolated and peculiar outcrop, along the KKH towards west of Thelichi. The marble and recrystallized limestone is white to cream coloured, saccharoidal, coarse grained to very coarse grained, folded with high, dips ranging from 60° to 85°. These carbonate beds are cliff forming and thickens to about one km. due to synclinal fold, near the KKH. Further, traced northwards along the strike in Damot Gah, it remains only as two

thin beds measuring 10 m and 50 m in thickness and tectonically emplaced. The probable reserves of this marble deposit are estimated to be 25 million metric tons per one metre depth.

A small marble bed is also exposed in Hosi area, on left bank of the Indus, near the NLI shooting point. This marble bed is white to cream coloured, saccharoidal and well mineralized.

Slate :

Tuffaceous slate is exposed along the KKH, towards west of the Sagatal nala, while argillaceous slate lies in the upper Damot Gah. Both these slates are mostly grey, fine grained, well-bedded, foliated, well-jointed and dip at high angles. Tuffaceous slate is medium bedded, while argillaceous slate is thin bedded. The deposits of both slates are quite huge, excavatable in large slates and can be mined economically.

Loose sand and gravel :

Loose sand and gravel terrace deposits cover an extensive area, along both banks of the Indus, between the Indus-Gilgit Rivers confluence in north and Thelichi surroundings in the south. Workable, open sand deposits are exposed at the Indus-Gilgit Rivers confluence and along the KKH towards south of Thelichi. Gravel terrace deposits with variable thickness and size are scattered throughout the Indus valley.

Mineral water :

The nourishing and healthy drinking mineral water is located in Sagatal nala and a spring on right bank of Sai nala-KKH junction. The water from these points had been tested and used

by the KKH builders, as well as, the authors and found much better for stomach and general health.

Oil seepages:

Oil seepages are found in the metasediments, along Dirkil nala and Gor Gali nala, where the major faults traverse them. These oil seepages have low content of floating oil.

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Table - 1: Metallometric analyses of selected hornblendites and volcanics
Jaglot-Bunji Quadrangle (43-I/10).

| S.No. | Sample No. | Type of rock | Locality | Cu ppm | Zn ppm | Pb ppm | Ni ppm | Co ppm | Mn ppm | Au ppm | Ag ppm | As ppm |
|-------|------------|------------------------------|----------------------------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|
| 1. | SR-7(b) | Hornblendite | Shotiachuk Gah | 77 | 68 | 20 | 20 | 100 | 333 | BDL | BDL | BDL |
| 2. | SR-44(a) | Hornblendite | Theliche Gah | 242 | 24 | DBL | 83 | 77 | 208 | BDL | BDL | BDL |
| 3. | SR-59 | Hornblendite | Shotiachuk (small nala) | 158 | 42 | 20 | 23 | 86 | 333 | BDL | BDL | BDL |
| 4. | SR-65 | Hypabassal rock | Bargin Gah | 44 | 53 | BDL | 14 | 57 | 333 | BDL | BDL | BDL |
| 5. | SR-69(b) | Dacite plug in MMT zone | Astore Road | 7 | 28 | 16 | 17 | 23 | 217 | BDL | BDL | BDL |
| 6. | SR-69(c) | Andesite plug in MMT Zone | Astore Road | 62 | 47 | 28 | 40 | 200 | 450 | BDL | BDL | BDL |
| 7. | SR-73 | Hornblendite | Bunji Gah | 34 | 27 | BDL | 17 | 57 | 283 | BDL | BDL | BDL |
| 8. | SR-132(b) | Hornblendite | KKH Opp. Lichar | 37 | 35 | BDL | 26 | 71 | 333 | BDL | BDL | BDL |

BDL = Below Detection Limit.

Table-2: Metallometric analyses of selected sulphide zones
Jaglot-Bunji quadrangle (43 -I/10).

| S.No. | Sample No. | Type of sample | Locality | Cu ppm | Zn ppm | Pb ppm | Ni ppm | Co ppm | Mn ppm | Au ppm | Ag ppm | As ppm |
|-------|------------|--------------------------|-------------------------------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|
| 1. | 31(b) | Surface of sulphide zone | NW of Thelichi Gah, KKH | 712 | 80 | 20 | 20 | 86 | 117 | BDL | BDL | BDL |
| 2. | 87(a) | -do- | KKH, Opp. Lichar | 40 | 37 | BDL | 9 | 43 | 83 | BDL | BDL | BDL |
| 3. | 87(d) | -do- | -do- | 14 | 15 | BDL | 11 | 43 | 267 | BDL | BDL | BDL |
| 4. | 98 | -do- | Thelichi Gah E. of village | 9 | 24 | BDL | 6 | 57 | 125 | BDL | BDL | BDL |

BDL = Below Detection Limit



GEOLOGY AND MINERALS INVESTIGATION
OF THE
JAGLOT-BUNJI QUADRANGLE (43-I/10),
GILGIT-DIAMIR-SKARDU DISTRICTS,
NORTHERN AREAS
PAKISTAN

By

SAJID HUSSAIN SHAH
RAFIULLAH KHAN

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