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**GEOLOGY OF PARTS OF TRANS-HIMALAYAN REGION
IN GILGIT AND BALTISTAN, WEST PAKISTAN**

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GEOLOGY OF PARTS OF TRANS-HIMALAYAN REGION IN GILGIT AND BALTISTAN, WEST PAKISTAN

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ABSTRACT

Reconnaissance geological mapping at a scale 1 inch to 4 miles was carried out in the Trans-Himalayan region of Gilgit and Baltistan. The region contains three major mountain ranges, namely, the Kailas Range, the Karakoram Range, and the Hindura; Range. They are arcuate and parallel to each other with convexity northward. The region is underlain by a sequence of metasedimentary and sedimentary rocks, and several types and ages of igneous rocks. Metasedimentary and sedimentary sequence includes slate, quartzite, limestone, and gneiss of Permo-Carboniferous age. They are intruded or intercalated by

a group of rocks called Greenstone complex. All these rocks have been intruded by granodiorite and hornblende granite which are probably of Tertiary age. The salient structural features are the swinging of the strikes of rocks consequent on that of the ranges; and isoclinal folding of the Permo-Carboniferous rocks, in places, tending to re-cumbent folds. This swinging nature can be explained as due to the bending of all rock components around the syntaxis of the northwest Himalayas. Metamorphism of the Greenstone complex and Permo-Carboniferous rocks is widespread.

INTRODUCTION

Purpose and scope

Traverses to carry out reconnaissance geological mapping at a scale of 1 inch to 4 miles were done during the summer field seasons of 1951 and 1952, through the trans-Himalayan region of Gilgit and Baltistan. The region thus surveyed includes, within Gilgit, an area extending from Shimshal and eastern Haramosh to west of Yasin valley, and another area extending from Bunji to Skardu *via* Astor. In Baltistan, the area mapped extends from Skardu to Dogoro. The topographical sheets covering this region are 43 I, 42 L, 42 H, 42 D and 43 M.

Location and accessibility

Situated in the northeast corner of West Pakistan, Gilgit and Baltistan are Central government administered areas. Their northern boundary is with Afghanistan and China. The State of Chitral lies to the north-west and west; Swat State and Hazara District to the south (fig. 1).

Gilgit consists of the states of Hunza, Nagir, and Punial; Political Districts of Iskuman, Koh-i-Ghizar and Yasin; tribal territory of Darel; and some areas directly administered by the Political Agent, Gilgit and by the Additional Political Agent, Baltistan which include Gilgit town and vicinity, Astor, Chilas and Baltistan.

During summer the road from Balakot in Hazara District to Gilgit over the Babusar Pass is jeepable, while in winter, due to heavy snowfall, this cannot be used. The Pakistan International Airlines operate a regular air service from Rawalpindi to Gilgit and Skardu. A few miles of jeepable road exists inside Gilgit and Baltistan. Otherwise, pack animals are the only means of transport.

Climate and habitation

The climate is arid. The air being much rarefied, the weather is extreme, specially the winter is severely cold. During summer, the northern parts of Gilgit and Baltistan are pleasant.

Rainfall ranges from 3 to 5 inches in Gilgit, and zero to $1\frac{1}{2}$ inches in Baltistan. The monsoons are robbed of their moisture content as they meet the Himalayas. For that reason, the trans-Himalayan region is so much devoid of rain. This great difference in the distribution of rains is shown by the growth of luxuriant vegetation on the southern slopes of the Himalayas, and the barren and waste nature of land on the opposite side.

Due to the rough terrain, population is sparsely distributed in the valleys. Irrigation is carried out with the help of ice-melt water drawn by canals from the upper courses of streamlets and rivers which emanate from the snouts of glaciers.

PHYSIOGRAPHY

Orographic features

The region under consideration contains four roughly parallel and arcuate mountain ranges. From south to north they are :—

1. The Great Himalayas : covers Chilas, Astor, and the tribal territory of Darel.
2. The Kailas Range : consists of Haramosh, Rakaposhi and Masherbrum chain of mountains and runs through Baltistan, Nagir, Punial, and Koh-i-Ghizar.
3. The Karakoram Range : covers northern Baltistan, Hunza, Iskuman, and Yasin.
4. The Hinduraj Range : situated along the northern borders of Gilgit and Baltistan.

The elevation of the mountains generally range from 17,000 to 20,000 feet above sea level. Important peaks in the Kailas Range are Rakaposhi (Mt. Dumani) 25,550 feet, Haramosh (Sassi Sanwar), 24,270 feet, and Kosar Gunge 21,000 feet; in the Karakoram Range, Gamubar, 21,383 feet, Bojihaghur Duansir, 24,044 feet, and Kampire Dior, 23,434 feet; in the Hinduraj Range, Garmosh, 20,454 feet, and Sakar Sar, 20,577 feet. Valley elevation ranges from 4,000 to 8,000 feet above sea level.

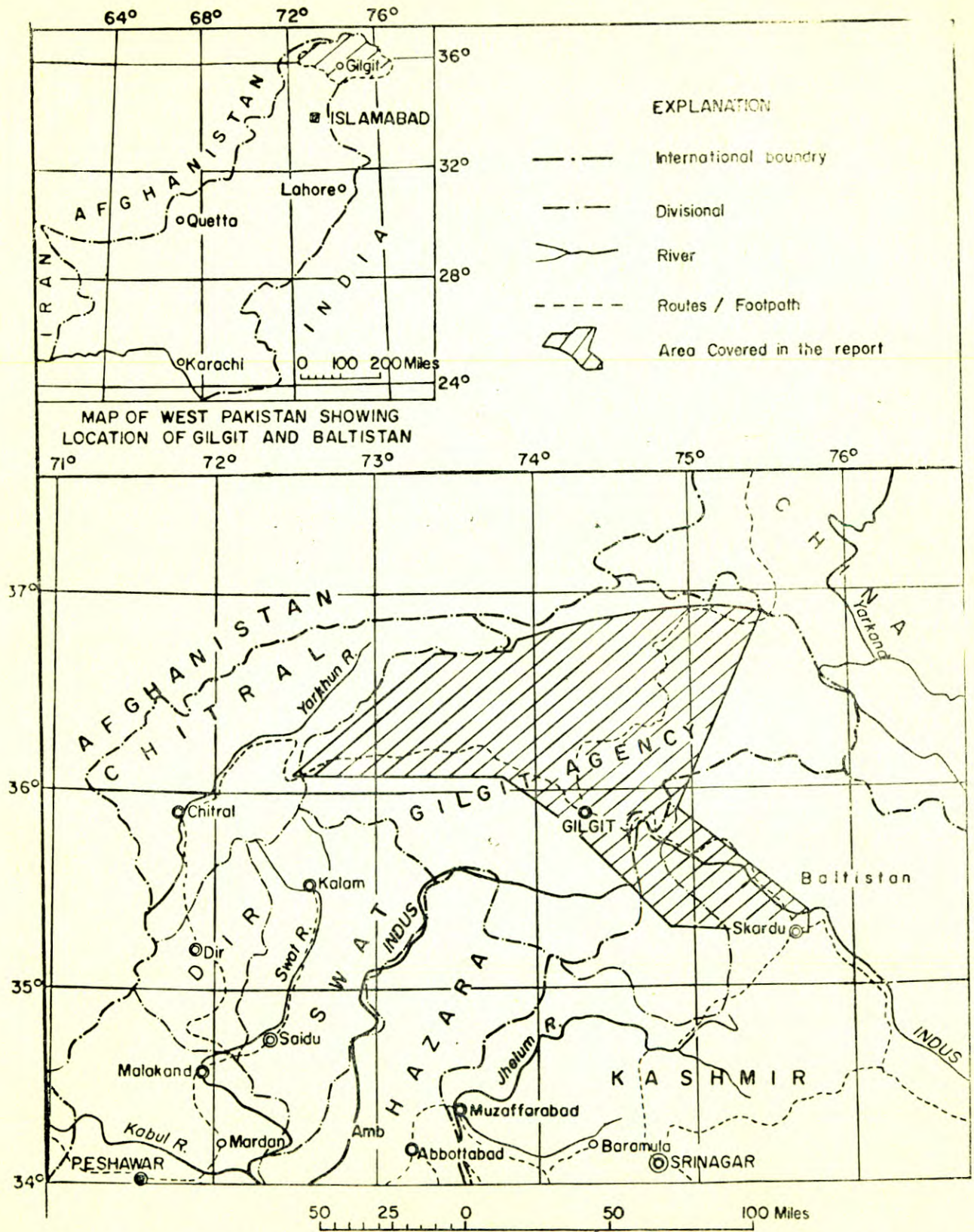


Figure 1:- Index Map of West Pakistan showing the area covered in the report

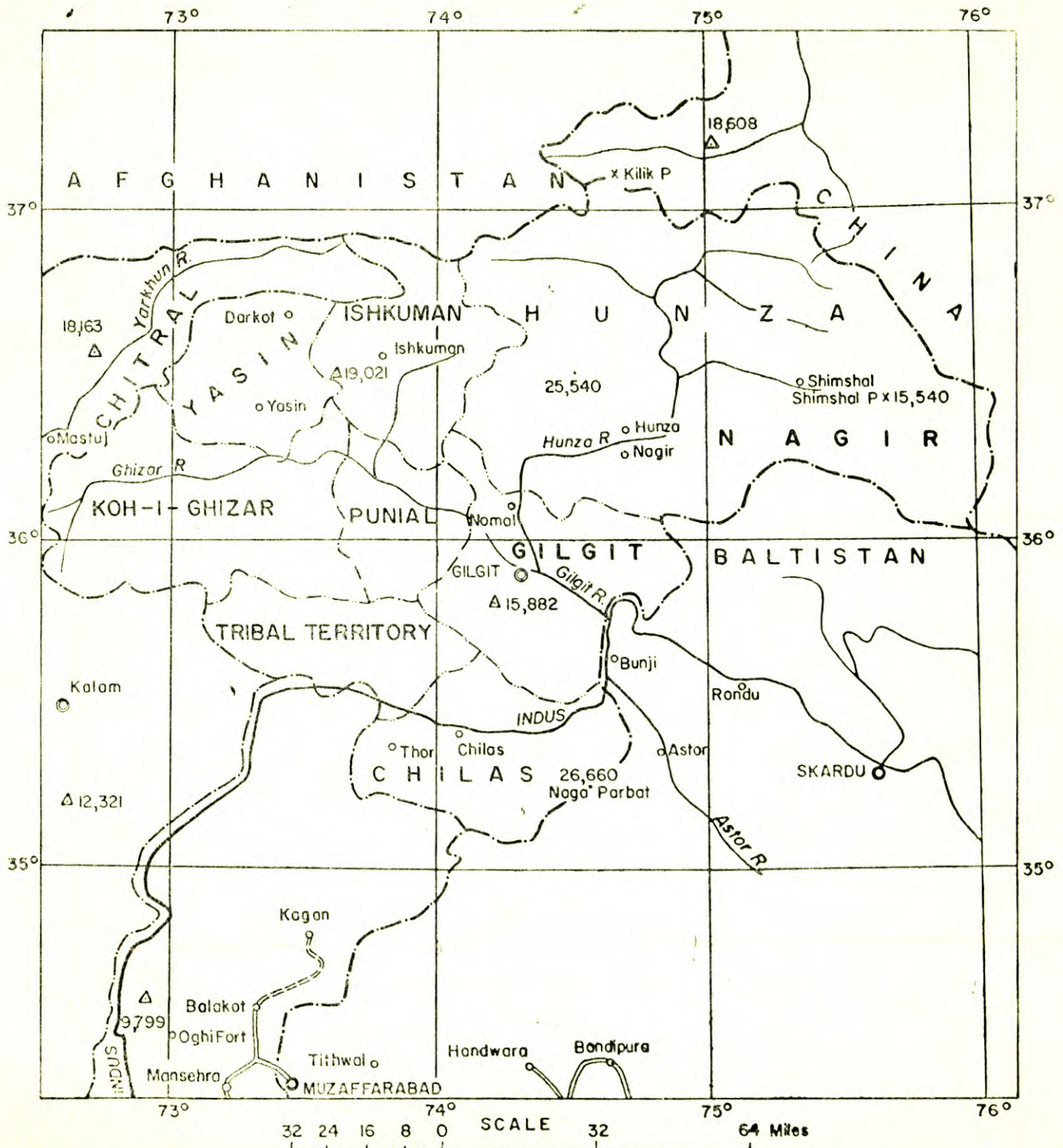


Figure 2:-Map showing the administrative divisions in Gilgit and Baltistan

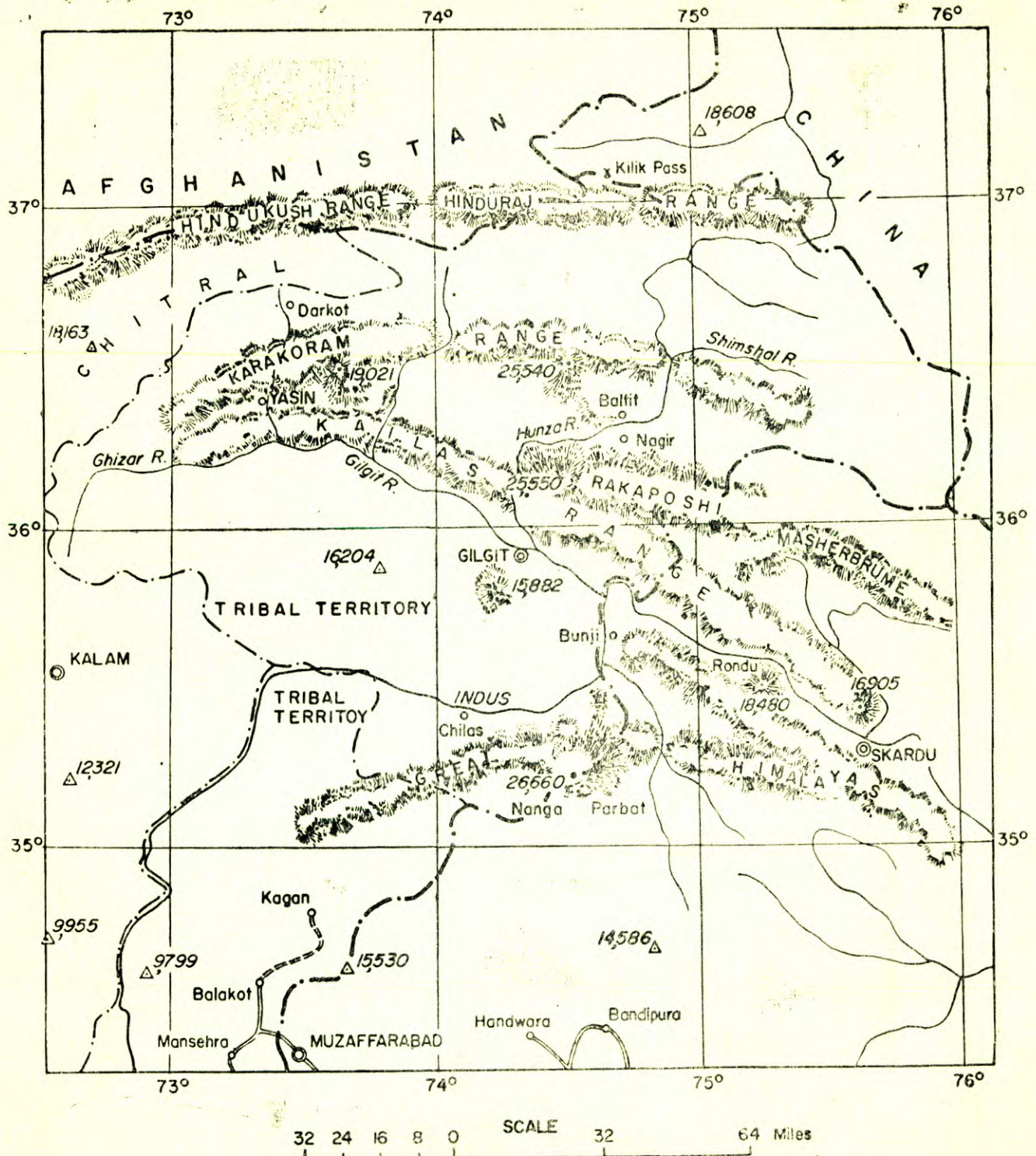


Figure 3--Trend of mountain ranges in Gilgit and Baltistan

The topography reflects to some extent the geology of the area. All the ranges embracing most of the highest peaks are formed of granodiorite. They are remarkable for the rugged nature of topography, high precipices and being the home of glaciers. The intervening regions in between these ranges are formed of metamorphosed sediments and are characterised by semi-rounded peaks and comparatively smooth topography.

The four mountain ranges described above show throughout their length a swinging nature of their strike. The strike in Yasin and Iskuman is E, in Hunza ESE, while in Baltistan SE. The ranges show convexity northward. Their arcuate disposition may be

explained as due to the Himalayan orogeny, the swinging of all the rock masses around the syntaxis of the northwest Himalayas. Thus the outstanding features of orography are (a) the arcuate and parallel mountain ranges with convexity northward and (b) the swinging of the strike of the rocks consequent on that of the ranges.

Drainage system

Roughly the axes of four mountain ranges (the Himalayas, the Kailas, the Karakoram and the Hindu-raj) form the watersheds of this area. The rivers are disposed either longitudinally or transversely with respect to the ranges.

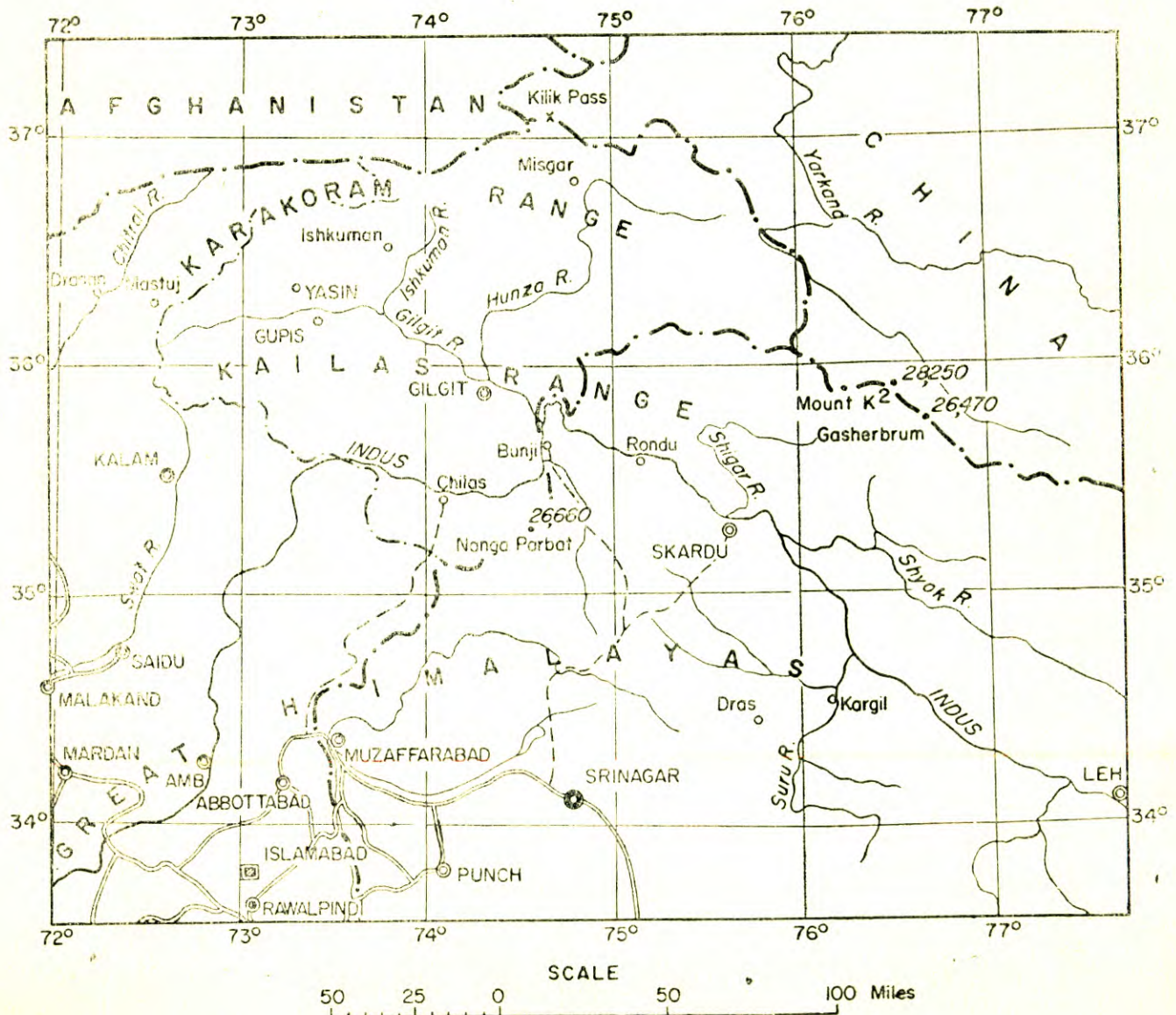


Figure 4.--Trend of rivers in Gilgit and, Baltistan

The rivers in Baltistan, the Indus, the Shigar, and the Shyok, have longitudinal courses. The Indus, throughout its course through Ladakh and Baltistan, has a northwest trend and has given rise to a long defile between the Himalayas and the Kailas Range. The Shyok and Shigar join the Indus near Gol and Skardu respectively.

In Gilgit, the only longitudinal river is the Gilgit River. It originates from east of Shandur Pass, at the border of Chitral and Gilgit, and flows southeast through Gilgit and joins the Indus, north of Bunji. The Indus at Sasli (Haramosh area) changes from its usual northwest course to south, and then flows west through Bunji and Chilas area of Gilgit.

The other three rivers of Gilgit—the Hunza, Iskuman, and Yasin follow transverse courses and flow southward and meet the Gilgit River at Daniyar, Colodus, and Gupis respectively. All these rivers originate from the southern slopes of the Hinduraj Range and cut through the Karakoram and Kailas Ranges about perpendicularly. They are nourished by a great number of glaciers and snowfields of the Hinduraj, Karakoram, and Kailas Ranges.

The deep precipitous gorges and the disposition of old river gravels and silt at different levels on the mountain sides above the present position of rivers probably suggest that the rivers existed before the upheaval of the mountain masses and that the rivers had to keep pace with the slow but gradual rise of the mountains. On the southern slope of the hill which overlooks Gilgit River, just opposite Gilgit town, at least three former levels of the river can be identified.

Lakes

The lakes of Gilgit and Baltistan can be classified into two groups according to their mode of origin—glacial lakes and alluvial basins. Glacial lakes, are results of plucked and eroded hollows on the rocks by the action of glaciers or by morainic material encircling or damming parts of glacial streams. Areas noted for this type of lakes are Darkot and Chhelish in the Yasin Political District. The alluvial basins have been formed by the deserted loops of rivers mostly in the Shigar and Indus valleys. The Baltistani name for lake is Tso.

Glaciers and glaciation

The glaciers of Gilgit and Baltistan are disposed longitudinally or transversely. The longitudinal glaciers are remarkable for their larger length, greater volume and higher snowline while the transverse ones are shorter in length, have lower snowline, and the position of the snout fluctuates more quickly with changes of temperature.

In the Kailas Range, the permanent snowline ranges from 13,000—15,000 feet above sea level; in the Karakoram Range, it is about 15,000 feet; and in the Hinduraj Range, it is generally above 16,000 feet.

The important glaciers in the Kailas Range are the Haramosh group of glaciers; Rakaposhi group of glaciers (Rakaposhi, Pisan, Minapin, Silkiang and others); Bagrot-Phuparash group of glaciers (Sargin, Barpu and others); Kosar Gunge glaciers; and Chongo Lungma group of glaciers. In the Karakoram Range, they include Gulkin, Pasu, Batura, Lapgha, and Hasanabad glaciers; and Gamber and Ganchen group of glaciers. In the Hinduraj Range are the Darkot, Reshitipur and Shimshal group of glaciers.

Most of the valleys in Gilgit and Baltistan show evidences of past glaciation. The Yasin and Iskuman and the smaller valleys joining them are examples of typical glaciated valleys. They are U shaped and have a step-like gradient. Unassorted accumulation of boulders, distribution of erratics, the presence of hanging valleys, cirques and lateral moraines, now dissected by streams, and the old glacial lakes have been noticed all over the area.

PREVIOUS WORK

MacMohan (1900) described some rocks collected in Yasin and Gilgit by him and Roberts. According to them the oldest rock types of the area (slate, quartzite, and limestone) were, either early Carboniferous or Silurian in age. The overlying limestones were correlated by them with the Carboniferous and Triassic rocks of Kashmir.

Hayden (1916) had given an informative account of the general geology of Yasin, Gilgit, and Hunza. He had also described the late Cretaceous rocks of Yasin, outcropping on the right side of Yasin River. The basal tuff bed below the Cretaceous rocks had been correlated by him with the Panjal Trap of Kashmir. He noted the occurrence of thin-bedded Permo-Carboniferous limestone with *fusulina* and *fenestella*, north of Darband in Yasin.

Lydekker (1881) visited Baltistan in the eighties of the last century. He observed the presence of older and newer gneiss of pre-Silurian age, and of Silurian, Carboniferous and Triassic rocks. His basis of division was purely lithological and he tried to correlate these rocks with those in Kashmir. Objection to Lydekker's work had been put forward by all later observers (Desio, 1930; Auden, 1938) because the division of rock-groups into different ages, and their correlation based purely on lithology could not be supported.

Desio (1930) had described the rocks of Sarpo Laggo, Shaksgam and Baltoro which cover the north-east portion of the area described by Lydekker. He divided the rock types into two main divisions.

- | | |
|--|----------------------------|
| (b) Calc. Schistose group of rocks: | } Permo-Carb. |
| Fossiliferous at Sarpo Laggo, Shaksgam and Gasherbrum: | |
| Nomal series | |
| Unfossiliferous metamorphics at Askole and Biafo River | |
| (a) Gneiss and gneissose schist | } Pre-Permo-Carboniferous. |

PRESENT WORK

Auden (1936), while visiting the Baltoro glacier during 1933, traversed through the area mapped by Lydekkar. He disagreed with Lydekkar's division of the Baltoro rocks. Auden suggested that the gneiss with interbedded metamorphosed pelitic and limy rocks belongs to the Precambrian age and that they have been overlain by the Permo-Carboniferous limestone in the Baltoro and neighbouring regions. Auden (op. cit.) wrote "the gneissic series of the Shigar and Braldu valleys, and at the Biafo glacier, together with the associated marbles may be, for the most part, Salkhala and the whole suit may be overlain in the upper reaches of the Baltoro glacier by Permo-Carboniferous limestone. Subsequent metamorphism, involving both the older, possibly Salkhala limestone and the Permo-Carboniferous limestone would considerably converge in aspect. If this interpretation is correct, Lydekkar's Trias of Askole and Biafo would be, in reality, mostly Precambrian and should not be correlated with the proved Permo-Carboniferous of the Sarpo Laggo, Shaksgam and upper Baltoro".

Auden (1938) again visited the area during the Shaksgam expedition of 1937. This time he differed more with Lydekkar and suggested partial modification of his own observations made during the expedition of 1933. He observed (op. cit., p. 41-42) "the older gneiss of the area is probably the youngest rock of the district being what I take to be an intrusive granite of Tertiary age. The marbles which he (Lydekkar) assigns to the Triassic are not synclinally disposed at the Biafo glacier but are interbedded with biotite schist and the structure is anticlinal. Desio considered the metamorphic rocks of the Askole-Korofon area to be altered equivalents of the fossiliferous (Permo-Carboniferous) rocks to the north. When I visited the Biafo glacier in 1933, I was inclined to doubt this correlation and suggested that the metamorphic series was probably equivalent to the Salkhala rocks of Archean age described by Wadia. A wider experience of this area has led me to discard this view".

A team of three Australian geologists accompanied by the author and M.H.A. Namazie of the Geological Survey of Pakistan mapped the northern part of Gilgit Agency during the summer of 1951 (Ivanac, and others, 1956).

The mapping of the Permo-Carboniferous rocks and their metamorphosed equivalents have been extended by the author into parts of the trans-Himalayan regions of Gilgit and Baltistan. In Gilgit, fossils of Permo-Carboniferous age have been collected by him from the northern slopes of the Karakoram Range in Hunza and Yasin valleys; and also from south of the Karakoram Range in Yasin. These Permo-Carboniferous rocks have been followed toward north close to the Chinese and Afghan borders; to the west upto and well into Mastuj District of Chitral, thus conforming to the mapping done by Tipper in Chitral; to the east conforming to the extension of Permo-Carboniferous rocks of Sarpo Laggo, and Shaksgam valleys in northern Baltistan. To the south, there is progressive increase in metamorphism of the Permo-Carboniferous rocks, and as a result of this, no fossils are found in them.

Mapping of the Karakoram, Kailas, and Hinduraj granodiorite has been carried out and their similarity in lithology and age has been noted. Three unpublished reports on these regions had been submitted by the author (Bakr, 1951, 1952, 1953).

GENERAL GEOLOGY

Sequence of lithological units

Gilgit and Baltistan contain a sequence of sedimentary and metasedimentary rocks, and several types and ages of igneous rocks. The metasedimentary and sedimentary sequence includes slate, quartzite, limestone and gneiss of Permo-Carboniferous age. They are intercalated, overlain and intruded by a group of rocks called Greenstone complex which consists of epidiorite, dolerite, basalt, andesite and hornblende gneiss. All the above mentioned rocks are intruded by granodiorite. The igneous rocks are post Permo-Carboniferous in age. Late Cretaceous sediments overlie the Greenstone complex in the Yasin valley. Quaternary lake deposits, moraine, stream-gravel and alluvium cover the bed rock in the valleys. The sequence of rock-types, arranged with the oldest at the bottom, is given in Table 1. Correlation of the rocks of Gilgit and Baltistan with those of Pamir, Aghil, Central Shaksgam, Despang, and Yarkand are shown in Table 2.

TABLE 1.—Sequence of rocks in Gilgit and Baltistan.

System	Group	Thickness (feet)	Character
Quaternary	..	0—100	Lake deposits, moraine, stream gravel and alluvium
Tertiary (?)	.. Granodiorite	not known	Biotite granodiorite, biotite granite, and pegmatite.
	.. Hornblende granite.	not known	Hornblende granite, hornblende gneiss, and hornblende.
Cretaceous	.. Yasin Group	2000 +	Limestone, tuff, and quartzitic limestone.
Mesozoic (?)	.. Greenstone complex	probably several thousand feet.	Epidiorite, dolerite, basalt, andesite, and hornblende gneiss.
Permian Carboniferous	.. Darkot	14,100+	Slate, quartzite, limestone, and gneiss.
	.. Group		

TABLE 2.—Correlation of the rocks of Pamir, Aghil, Central Shaksgam, Despang, Yarkand, Chitral, and Gilgit

Age	Column I	Column II	Column III	Column IV	Column V
	Pamir (Hayden)	Aghil and Central Shaks- gam (Auden)	Despang and Yarkand (De Terra).	Chitral (Tipper)	Gilgit and Baltistan (author)
Tertiary	..			Eocene	
Mesozoic	.. Pamir limestone	Aghil series: Triassic and Jurassic.	Continental Yarkand series.	Dark limestone: late Cretaceous and Mesozoic, undifferentiated.	Yasin Group: late Cretaceous.
Permo-Carboniferous.		Shaksgam series	Marine Permo-Carb.	Marine Permo-Carb.	Darkot Group: Marine Permo-Carb.
Early Paleozoic	Sarikol shales and slates	Sarpo Laggo series: Early Paleozoic and older.	Kilian series with Si- lurian and Devonian beds, Karakash series.	Fossiliferous limestone with quartzite and slate: Devonian and late Paleozoic.	
	<i>Intrusives:</i>	<i>Intrusives:</i>	<i>Intrusives:</i>	<i>Intrusives:</i>	<i>Intrusives and lava flows:</i>
	Granite: Post Sarikol slates	Lamprophyre: Post- Triassic and granodiorite	Granite: Post-Kilian series. Pre-Devo- nian (?)	Granite and gneiss: Post-Permo-Carb.	Basic dykes: Post Granodiorite: Granodiorite Post- Permo-Carb. and Post- greenstone Greenstone complex: Post-Permo-Carb.
		Granodiorite: Post- Permo-Carb. Dolerite: Post-Permo- Carb.		In Drosch, cuts through late Cretaceous lime- stone.	

Note.—Columns I, II and III from Auden's report 'Resume of geological results, Shaksgam expedition, 1937'. The Himalayan Journal, vol. 10, 1938.

Permo-Carboniferous

Darkot Group

Named first by Ivanac, and others (1956), the Darkot Group of rocks are in three east-west running zones separated by intrusive granodiorite bodies. The northern zone is between the Hinduraj and Karakoram Ranges; the central one between the Karakoram and Kailas Ranges; and the southern one between the Kailas and the Himalayas.

The southern zone is usually discontinuous and their sedimentary characters in places have been totally obliterated due to intense gneissification. Innumerable pegmatites, and granite tongues cut through them.

The Permo-Carboniferous sediments are mostly devoid of fossils due to intense contact metamorphism they have suffered. Only in locations sufficiently away from contact with granodiorite, some poorly preserved invertebrate fossils, ranging mainly in age from late Carboniferous to early Permian, have been found.

The fossiliferous localities are:

A. North of the Karakoram watershed:

(a) Hunza State:

- (1) Khaibar area .. from slaty limestone and dark limestone of Khaibar nala

- (2) East of Morkhun .. from the slate, slaty limestone overlooking Morkhun village, on the right side of the Hunza River

- (3) South of Gircha .. from the slate, slaty limestone and dark limestone on the right side of the Hunza River

(b) Yasin valley (Yasin Political District):

- North of Muduri .. from thin-bedded limestone and slate

B. South of the Karakoram watershed:

Yasin valley (Yasin Political District):

- Tokemali area .. from thin-bedded limestone and shale, south of Darkot village

Between the Himalayas and the Kailas Range.—They have been studied in the following areas: Haramosh, Henzal Umain, neighbourhood of Gilgit town, Silpi-Gakuch (Punial State), Astor valley, and Katzarah—Shigarthang—Alam Pir area (Baltistan).

The rocks consist mainly of quartzite, biotite schist, phyllite, quartz schist and crystalline limestone. In the Haramosh area, all around the contacts of the

metasediments and intrusive granodiorite, the phyllites and slates have been enriched with felspar thus forming gneiss indistinguishable from the plutonic gneiss. In the Silpi—Gakuch area (Punial State), the slate, phyllite and schist are interbedded with greenstone schist, the later being metamorphosed extrusive basic rocks. In the Astor valley, injections of sills of basic rocks, metamorphosed in most places to garnetiferous mica schist are found. Xenoliths of slate and quartzite are widely distributed through the intrusive granodiorite bodies.

Between the Kailas and the Karakoram Ranges.—They are present from Bar to Hini in the lower Hunza valley, in the Yasin valley and in the Shigar valley (Baltistan). The rocks are mainly quartzite, biotite schist, slate, phyllite, quartz schist, marble, biotite-sericite schist, chlorite schist, gneiss, quartzite, and limestone.

A layer of garnet-mica schist has been mapped from Khanabad to east of Hini. In the same rocks, in places, staurolite is quite important and appears as crosses. North and east of Baltit, Hunza State, marble occurs interbedded with paragneiss and biotite schist. The marble is saccharoidal and contains phlogopite, garnet and graphite as accessories. A large number of pegmatite, aplite and granite dykes are intrusive into these rocks.

The sequence of rock types in the Permo-Carboniferous formation is as follows, starting with oldest at the bottom:—

TABLE 3.—Sequence of Permo-Carboniferous rocks in Yasin valley.

Rock types	Thickness (approx) (in feet)
Limestone, thin-bedded, and slate; fossiliferous, containing <i>fenetella</i> , <i>fusulina</i> , and <i>crinoids</i> .	4,500
Limestone, massive	6,600
Limestone and slate, interbedded ..	2,400
Slate and quartzite, interbedded ..	600
Total ..	14,100

The above Permo-Carboniferous rocks have been folded into an anticline. Intrusion of Karakoram granodiorite has taken place along the axis of this anticline.

In the Shigar valley these rocks are mainly slate, quartzite, phyllite, schist, and gneiss. In the Kosergunge area they are less metamorphosed and are folded into a syncline.

Between the Karakoram and Hinduraj Ranges.—These have been studied in the area extending from Sarat to Murkhusi in the upper Hunza valley and in

the Darkot area of Yasin valley. The Permo-Carboniferous rocks, north of the Karakoram granodiorite are less metamorphosed compared to the rocks of the same age south of the granodiorite. Thus, fossil preservation at some suitable points have been possible. The rock types are interbedded slate, limestone, and quartzite. Their southern contact with the Karakoram granodiorite is sharp, while the northern contact with the Hinduraj granodiorite is gradual, that is, the pelitic rocks merge into gneiss which, in turn, into granodiorite. The Darkot area is covered by the Permo-Carboniferous rocks which form the northern limb of the anticline described above. In this area the uppermost band of thin-bedded limestone and slate is thinner compared to that in the southern limb of the anticline. The thin-bedded limestone and slate of Tokemali village contain some poorly preserved fossils (*fenestella*, *fusulina*, crinoid stems, and broken bivalves).

Discussions on the age of the Darkot Group.—Fossils of Permo-Carboniferous age are present in rocks north of the Karakoram watershed in Hunza, Yasin and Baltistan. In the Yasin valley, as described before, the fossiliferous Permo-Carboniferous rocks are folded into an anticline along whose axis intrusion of Karakoram granodiorite has taken place. Thus, we also get fossils of Permo-Carboniferous age south of the Karakoram watershed in Yasin valley.

Further south, these proved Permo-Carboniferous rocks can be followed into their more metamorphosed equivalents. Close to the intrusions of granodiorite, widespread contact metamorphism has resulted in the total obliteration of fossil remains in these areas.

The above observation about the Permo-Carboniferous age of these rocks, and the effects of metamorphism on them, specially in the south, are in conformity with those made by Desio (1930) and Auden (1938) in the Baltoro area of northern Baltistan.

Post Permo-Carboniferous Greenstone complex

It is present on both flanks of the Kailas Range mainly in the lower parts of Hunza and Yasin valleys, the upper course of the Ghizar River, and in the Shigar valley. It is generally light to dark green, and consists of epidiorite, dolerite, basalt, andesite, hornblende gneiss and hornblendite. Hornblende gneiss and hornblendite represent metamorphosed basic igneous rocks.

In the lower part of the Hunza River, the Greenstone complex extend from Chalt to Gwach. It has intrusive vertical contact with quartzite of Permo-Carboniferous age. In places it is serpentinous and occurs as talc-serpentine rock. Northwest of Chalt, magnetite crystals are seen disseminated in the Greenstone complex.

From Naltar northeastward, a complex admixture of epidiorite, dolerite, quartzite, hornblende schist and hornblende gneiss is present. The hornblende schist and epidiorite represent metamorphosed dolerites. The Greenstone complex has been intruded by granodiorite, a few miles south of Chalt near Chaichar.

The Greenstone complex of Yasin valley is generally massive but schistose when interbedded with limestone and slate. It shows both discordant and concordant intrusive contact with the Permo-Carboniferous beds, but there is little or no contact effect. The occurrence of hornblende gneiss at the contact of granodiorite and Greenstone complex is due to the addition of feldspar into the latter.

In the Ghizar River area, the Greenstone complex has been observed from west of Gupis to Shandur Pass. Tongues of granite, which are intrusive into Greenstone complex are common specially in Pingal and Langar areas. The Greenstone complex is represented by massive epidiorite and hornblende gneiss in the Dishupagan-Chumik areas; by hornblende gneiss, hornblendite and epidiorite in Matulu and Nielle areas; and as intrusive basic sills and dykes, north of Shigar. It is intrusive into marble and quartzite of Permo-Carboniferous age. The Greenstone complex, in turn, has been intruded by granodiorite, the contact zones having been altered to hornblende gneiss and hornblendite.

✓ Late Cretaceous

Yasin Group

North of Yasin, on both sides of the Yasin River, late Cretaceous rocks have been mapped. They have been named by Ivanac, and others (1956) as Yasin Group. The sequence of rock units is as follows, starting with the oldest at the bottom :—

TABLE 4.—Sequence of late Cretaceous rocks (*Yasin Group*) in the Yasin valley.

Yasin Group : Limestone, grayish-black, highly fossiliferous containing <i>hippurites</i> , <i>orbitolina</i> , corals, etc.	} 2000 feet +
Limestone, quartzitic, thick-bedded	
Limestone, quartzitic, slaty	
Limestone, slaty, thin-bedded	
Tuff (Panjal trap ?)	
Unconformity	
Greenstone complex (? Mesozoic)	

The northern boundary of the Cretaceous rocks in Yasin is a fault contact between the Permo-Carboniferous and Cretaceous rocks.

Tertiary (?)

Hornblende granite and hornblendite

They are present in the lower Hunza valley, in the Gilgit-Hanuchal area, and in the Shigar valley. In the lower Hunza valley, the Kailas granodiorite has an

outer rim of hornblende granite at its contact with metasediments and Greenstone complex. Within the hornblende granite are segregated patches of hornblendite. Southeast of Garesh, the granodiorite gradually merges into hornblende granite.

From Gilgit to Hanuchal, specially north of the Gilgit River, the rock types are hornblende granite, hornblende gneiss and hornblendite—all profusely injected by biotite granite, aplite, and pegmatite. Garnet occurs both in the pegmatite and hornblendite, but is restricted only within a few inches from the contact.

In the Shigar valley, the Greenstone complex have been intruded by granodiorite and pegmatite and also have been enriched in feldspar leading to the development of hornblende gneiss and hornblendite.

Hornblende granite and hornblendite may represent an early basic phase of the main intrusion of granodiorite, or a complex of granodiorite and metasediments or greenstones.

Granodiorite

This rock forms the core of the Kailas, Karakoram and Hinduraj Ranges. It has intrusive relation with Greenstone complex, and Permo-Carboniferous rocks. The rock is grayish white to green, coarse grained, and consists mainly of plagioclase feldspar, hornblende, biotite, and quartz.

Karakoram granodiorite.—From the point of view of its great extension it can be called a batholith. The batholith shows varying contact relations with respect to the invaded rocks. Along its southern contact in Hunza State, there is a gradation from the granodiorite through gneiss to schistose rocks (metamorphosed Permo-Carboniferous rocks), but the same contact, when followed westward into Yasin valley, is sharp and no gradation is observed.

Around Pasu, the northern contact of the granodiorite with the Permo-Carboniferous rocks is sharp. Tongues of pegmatite extend from granodiorite into slate. In the upper reaches of the Batura and Pasu glaciers, the occurrence of xenoliths of slate and quartzite in granodiorite can be seen. The western continuation of above contact in the Yasin valley is represented by a complex gneiss.

Kailas granodiorite.—In the Yasin valley, the Kailas granodiorite shows two phases of intrusion—the older or the basic phase, and the younger or acid phase. The later is intrusive into the former. In the lower Hunza valley, the Kailas granodiorite runs along the axis of a west-plunging anticline at Nomal. Its northern contact with the greenstone is shown by a band of hornblende gneiss and hornblendite. Basic dykes traverse through the granodiorite. In the Hanuchal-Iskere area of the Haramosh Range, the predominant rock type is biotite granite. The pegmatites cut through biotite granite and are seen to contain quartz, beryl, tourmaline, and a little muscovite mica.

In the Shigar valley of Baltistan, granodiorite is present in the upper reaches of this valley, and around and north of the confluence of the Basha-Braldu Rivers. The granodiorite, in places, is gneissose, its strike of foliation being northwest. Intrusion of quartz veins and pegmatites have mostly taken place along this line of foliation. In the past, mining for aquamarine had been carried out on those pegmatites which are close to Dasu village.

On the western part of the Shigar River, granodiorite extends from Chauchupa to Kaiyu. Its northern contact with the Greenstone complex is gradual. Addition of feldspar in Greenstone complex has been profuse with the result that the contact rocks have altered to hornblende gneiss. Along the southern contact, the granodiorite gradually merges into biotite gneiss.

Hinduraj granodiorite.—The southern contact of this granodiorite with Permo-Carboniferous rocks is gradual. The ferromagnesian minerals in this rock are, in places, unimportant and the rock tends to aplite.

Basic dykes

These dykes are seen intrusive only into the Kailas granodiorite around Nomal in the lower Hunza valley where they are seen cutting through granodiorite, and in the Barche—Iskere area, Haramosh range, where they traverse through biotite granite.

Discussion on the age of the intrusive rocks

The greenstones are either intrusive into or intercalated with the Permo-Carboniferous rocks. In the south, these rocks can be followed into the basic dykes of Astor which have been referred to by Wadia (1937) as the northern continuation of the Punjal volcanics.

The three granodiorites—the Kailas granodiorite, the Karakoram granodiorite, and the Hinduraj granodiorite are similar in composition, lithology and mode of occurrence. They are intrusive into the Permo-Carboniferous rocks and also into the Greenstone complex. The Cretaceous rocks in Yasin have not been intruded by them. But as these Cretaceous rocks are folded with the Permo-Carboniferous rocks which have been intruded by the granodiorite, the age of intrusion of the granodiorite is at least post-Cretaceous. The granodiorites probably originated from a common magma. They are probably exposures, at different localities, of a great batholithic mass at depth.

Quaternary

Lake deposits consisting of siltstone, sandstone and thin carbonaceous beds are horizontally disposed in the Indus valley near Skardu and in some parts of the Shigar valley. The lakes were formed probably due to the damming of parts of these rivers either by glaciers or by rockfall. Moraines and stream gravels cover extensive areas.

STRUCTURE

The salient structural features of the Gilgit-Baltistan region are :

1. Parallel and arcuate mountain ranges with convexity northward.
2. Swinging of the strike of the rocks consequent on that of the ranges.
3. Isoclinal folding of the Permo-Carboniferous rocks, in places, tending to recumbent folds.

The strike of the ranges and also that of the rocks in Baltistan is northwest ; in Hunza State, it is west-northwest ; in Iskuman and Yasin, west. This swinging nature can be explained as due to the bending of all rock components around the syntaxis of the north western Himalayas.

The Permo-Carboniferous rocks, north of the Karakoram watershed in Hunza State are isoclinally folded and are also affected by closely spaced faults. The important faults are seen south of Pasu, north of Yasin, and at Shimshal valley.

Two plunging anticlines have been mapped. One of them is at Boladas River area, near Chalt, Nagir State. This is a north plunging anticline in the metasediments consisting of quartzite, biotite schist, quartz schist, and quartz-sericite schist. There is an intrusion of granodiorite at the nose of this structure. The other plunging anticline is at Nomal, 18 miles north of Gilgit town. Kailas granodiorite is intrusive along the axis of this anticline.

The courses of some rivers, it seems, are controlled by structures. The Hunza, in its upper course, flows south ; from Sarat to Chalt, it flows west ; and from Chalt to Gilgit again south. From Chalt to near Sarat the river runs along the axis of an anticline formed of metasediments. The upper and lower southerly courses may be explained as due to the existence of fractures normal to the axis of the anticline.

The Boladas River, all through its course, runs along the axis of a north-plunging anticline, and the Naltar Gah River at Nomal follows the axis of the west-plunging Nomal anticline.

METAMORPHISM

Metamorphism is primarily due to contact phenomena—the intrusive granodiorite rendering thermal metamorphism of the Greenstone complex and Permo-Carboniferous rocks. Also the Himalayan orogeny has brought out intensive and widespread regional metamorphism. Metasomatism, to a great extent has taken place due to the effects of gneissification by the addition of feldspar to phyllite and schistose rocks.

The Permo-Carboniferous rocks, north of the Karakoram watershed are less metamorphosed compared to their occurrences elsewhere in Gilgit and Baltistan. Their southern contact with the Karakoram granodiorite in Hunza State is sharp. But the western continuation of the same contact in Yasin is gradual.

This moderate and localised effect of metamorphism on the Permo-Carboniferous rocks, north of the Karakoram granodiorite has favoured the preservation of fossils in Yasin, Hunza and Shaksgam-Aghil region.

Permo-Carboniferous rocks south of the Karakoram watershed are highly metamorphosed. The profuse addition of feldspar to phyllite and schist in many places has obliterated the sedimentary nature of these rocks. The Permo-Carboniferous rocks, south of Kailas granodiorite are also highly metamorphosed. Tongues and dykes of granodiorite, granite, aplite, and pegmatite are common.

The greenstones at the contact of granodiorite have changed to hornblende gneiss and, in places, to hornblendite. Gradual transition from greenstone to hornblende gneiss is noticeable on the right side of the Shigar River in Baltistan, and north of Gilgit River.

GEOLOGICAL HISTORY

The Tethys which spread over parts of northern West Pakistan and Turkistan in central Asia during the beginning of late Carboniferous time gradually began to recede westward at the end of the Palaeozoic time. The Permo-Carboniferous beds of Gilgit and Baltistan were deposited during this period in the sea, which extended from the Urals to China on one side, and Chitral and Gilgit on the other.

The Permo-Carboniferous beds seen in northern Baltistan, Hunza, and Yasin were thus formed under marine conditions. The same conditions prevailed during the formation of Permo-Carboniferous and Mesozoic rocks of Aghil Range and Shaksgam valley (Auden, 1938; and Desio, 1930). But the Permo-Carboniferous rocks of Despang and Yarkand (De Terra, 1932) include continental as well as marine rocks. This shows the presence of changing land and marine conditions in that area.

Reed (1925) after examining the fossil fauna of Permo-Carboniferous age from Chitral, Gilgit and Kashmir valley has remarked that the fauna of the first two places are same but that of third totally different. Hence, he has concluded that the sea of Gilgit-Chitral area must have been disconnected from that of Kashmir area.

A great transgression of sea took place during late Cretaceous times. The uplift of the Himalayas and also of the trans-Himalayan ranges rendered great increase in the erosive power of the rivers. The soft Cretaceous limestone, deposited on the Permo-Carboniferous rocks were thus eroded away leaving a few isolated exposures.

The sequence of events in the trans-Himalayan regions of Gilgit Agency and Baltistan, starting with oldest at the bottom, are :

6. Occasional damming of rivers (the Indus, Shyok, and Gilgit) and formation of lake deposits during Pleistocene to sub-Recent
5. Himalayan Orogeny : Bending of rock-components around the syntaxis of the N. W. Himalayas ; folding and metamorphism
4. Wide spread transgression of the sea during the Cretaceous
3. Intrusion of Karakoram-, Kailas-, and Hinduraj granodiorite : probably exposed parts of a great batholith at depth
2. Intrusion and extrusion of the basic igneous rocks. Formation of Greenstone complex
1. The late Carboniferous disturbances (the Hercynian Revolution) : great extension of the Tethys, deposition of Permo-Carboniferous rocks (now metamorphosed to slate, quartzite, and limestone) on the floor of Tethys.

ECONOMIC GEOLOGY

None of the mineral deposits examined in Gilgit and Baltistan is suitable for commercial exploitation.

Quartz crystal

Quartz crystals have been reported from Khaibar and Morkhun in Hunza State ; from Iskere, Hanuchal, Jutial-Bunji in the Haramosh Range ; and from Dasu, Niesolo, and Shigarthang areas in Baltistan. These crystals occur in quartz veins that are intrusive into slate and quartzite. These deposits were studied with a view to collect suitable crystals for piezo-electric tests. Laboratory tests have proved them unsuitable for this purpose.

Khaibar area

Although quartz veins are widespread around Khaibar, but clear quartz crystals are only seen one and a half mile west of Khaibar village, on the north side of Khaibar nala. The veins occur at elevations ranging from 11,000 to 12,000 feet above sea level, south-east of Shaujerab snowfield on a dip slope of slate and quartzite.

The veins strike north, dip 85 degrees east, and ramify at most places. Thickness ranges from one half of an inch to 2 feet; length of the veins cannot be measured accurately because they ramify only after short distances, but generally they range from a few feet to 20 feet.

The injections of quartz-bearing solution are along fissures and cracks in slate and quartzite. Crystallisation of most of clear quartz has taken place only on both walls of the fissures and cracks for thicknesses ranging from one half of an inch to one inch. The crystals generally point out transversely with respect to the walls of the cracks.

Excavations were carried out at suitable points to see whether better quality crystals were available at depth. Following are the results :

1. Crystallisation of pure and clear quartz crystals has taken place in quartz veins along the walls of fissures and cracks in slate and quartzite.
2. Clear quartz crystals range in sizes from one to $1\frac{1}{4}$ inch, but they are mostly cracked and twinned with poorly developed faces toward the base.
3. Most of the clear quartz crystals are clustered on the country rock, or on lumpy quartz, creating difficulty in taking them out.
4. The quantity of quartz crystals available is small. The veins have not given rise to clear quartz crystals at depths generally for more than one inch into the veins, excepting one and half inch at some rare points.
5. Thus, the quality and quantity of the quartz crystals available do not warrant any economic proposition.

Morkhun area.

The quartz veins occur a mile upstream from Morkhun village on the left side of Morkhun nala. They course along the bedding planes and cracks in quartzite and slate, at an elevation of nearly 10,000 feet above sea level, and can be approached after a climb of 1000 feet from Morkhun-Shimshal foot path, which runs beside the Morkhun nala.

Only those veins which traverse through quartzite contains clear quartz crystals. The veins generally strike west-northwest and dip at moderate angles. Ramification of the veins is a common feature.

In thickness, the quartz veins range from one half of an inch to one and a half feet ; length ranges from a few feet to 25 feet. Crystallisation of clear quartz is restricted to the walls of the country rock along whose bedding planes and cracks the veins generally run. Size of the crystals range from one-fourth to one half of an inch with poorly developed lower parts.

Thus, the quantity of quartz crystals available in Morkhun is small and their sizes are also too small for industrial uses.

Haramosh Range

Quartz crystals are in pegmatites which are intrusive into biotite gneiss, hornblende gneiss and granodiorite in Bunji, Hanuchal-Jutial area, and south of Iskere. The crystals of quartz are neither well-developed nor clear.

Baltistan

In Dasu and vicinity, quartz crystals are in pegmatites that are intrusive into biotite gneiss. The pegmatites are segregated into layers of felspar and quartz. The larger quartz crystals are not clear while the clear ones are small. The quartz crystal occurrences of Niesolo and of Shigarthang areas are of no economic importance.

Beryl and aquamarine

Beryl and aquamarine have been found in Dasu and vicinity in Baltistan, and at Iskere area, Haramosh Range, Gilgit.

Dasu and vicinity

The above minerals occur in segregated felspar bands in pegmatites which are intrusive into biotite gneiss. The pegmatites generally strike northwest. Their length ranges from 15 to 200 feet, and thickness from 15 to 30 feet. Middlemiss and Joti Parshad (1918) did some mining for aquamarine and beryl on the segregated felspar bands of three pegmatites for 12 days which yielded a fair production of those minerals. This confirmed the presence of beryl and aquamarine in this area. Afterwards the contractors without any technical assistance, and small funds failed to achieve much success. It is recommended that future mining on the pegmatites, if carried out on the following lines, may yield some production of the minerals :—

1. Mining should be concentrated within the felspar layers of pegmatites ; and at the contact of felspar and quartz layers in the pegmatites.
2. Mining should be carried out along the dip and strike of the pegmatites where the old workings are situated.
3. Mining should be carried out on the three parallel northeast striking pegmatites just east of Dasu nala. The pegmatites dip 70 degrees southeast. Their length ranges from 200 to 300 feet and width from 2 to 4 feet. Also investigation should be carried out on the two felspar veins just north-northwest of upper Dasu village near the footpath connecting upper and lower Dasu village.

Iskere area

Beryl occurs in pegmatites which traverse through biotite granite south of Iskere. The pegmatites are few inches in width. Associated minerals are quartz, tourmaline, and galena. The quantity and quality, of beryl do not warrant any economic proposition.

Muscovite

Muscovite mica had been reported from Haiderabad in Hunza State, from Dasu and Niesolo in Baltistan. None of these occurrences were found

to be of any economic significance. In Haiderabad, muscovite occurs in pegmatite which cuts through gneiss and marble. Some books of mica of appreciable sizes and good quality are seen on the scree slope. The lower part of the pegmatite contains a little quantity of muscovite. The upper part of the pegmatite occurs on a cliff face, and it is difficult to approach. It is probable that good books of mica may be found in the upper part of the pegmatite. In Dasu and vicinity, and in Niesolo, muscovite occurs in pegmatites traversing biotite schist and biotite gneiss.

Gold washing

In Gilgit, gold washing is carried out mainly in the Shimshal area (Hunza State), and in Astor and Bunji areas on the Astor and Indus valleys respectively. Formerly, Hindus from the plains of the Punjab used to come to carry out gold washing in these places. After independence they have stopped coming and very few local people have put themselves to this work.

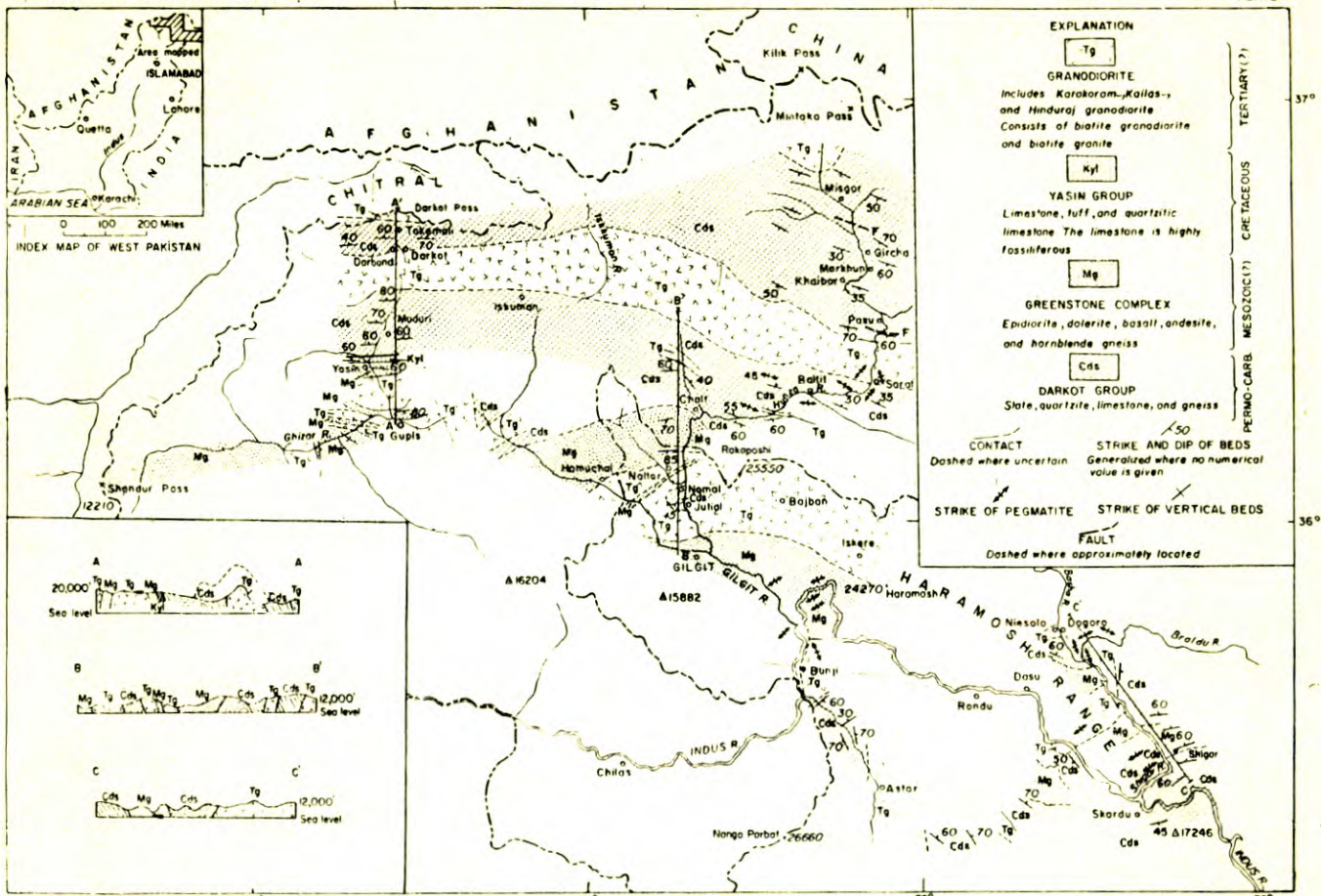
In Baltistan gold washing is carried out from September to December at Basha valley, from Niesolo upward upto Arandu, the main centres being Sesko, Bisil and Arandu; at Braldu valley, from Dasu upward along the river to Askole; at Shigar valley, from Shigar to Yano; at Rondou area which includes Rondou and vicinity; and at Parkulti area which includes Maimusthang and vicinity.

Other mineral occurrences

Northwest of Chalt, magnetite crystals are disseminated in talc-serpentine rock. Malachite staining is widespread in greenstone schist and dolerite from Chalt to north of Gilgit, and also from south of Tisar to Chumik. Near the contact of the greenstone schist and quartzite, the staining in greenstone is more common. Malachite staining is also noticed in the pegmatites and biotite schist of Niesolo area. Northwest of Chhelish, graphite occurs in pegmatites traversing granite gneiss. It is exposed on a scarp overlooking the village Chhelish. The graphite is pure but the quantity available is small.

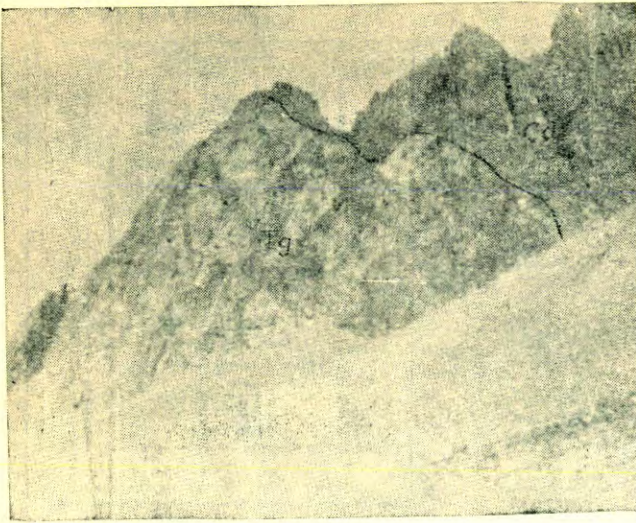
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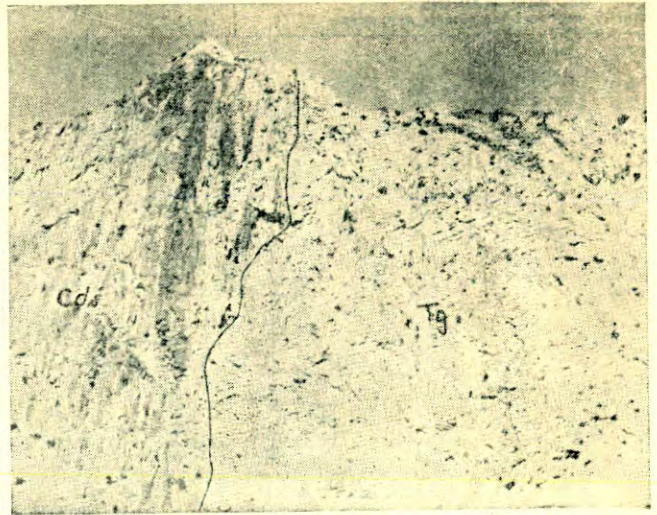


Base from Survey of Pakistan 1:1 million map of Kashmir. Drawn by A. Hamid and B. H. Zaidi.

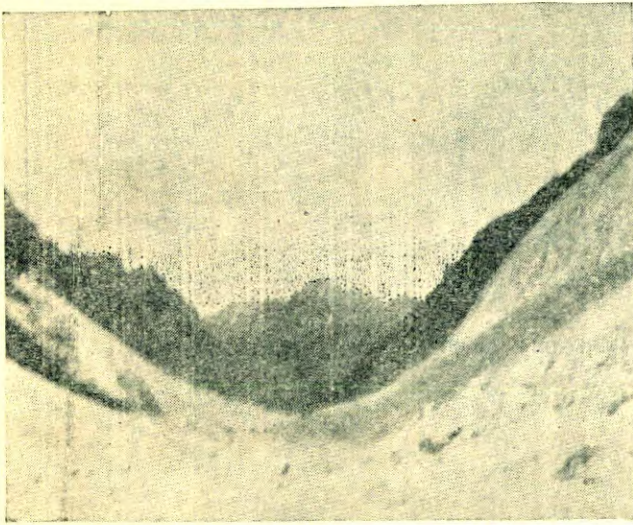
GEOLOGICAL MAP AND SECTIONS OF PART OF TRANS-HIMALAYAN REGION IN GILGIT AND BALTISTAN, WEST PAKISTAN



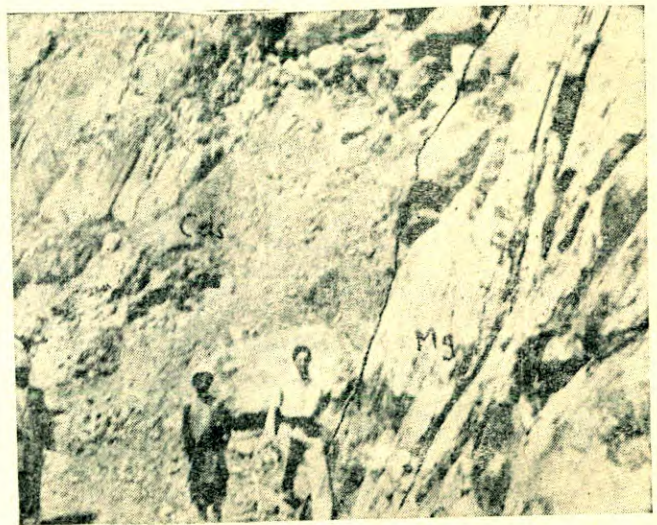
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B

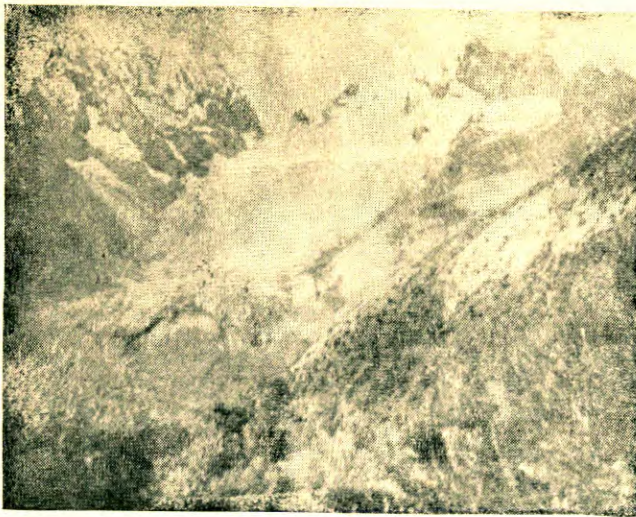


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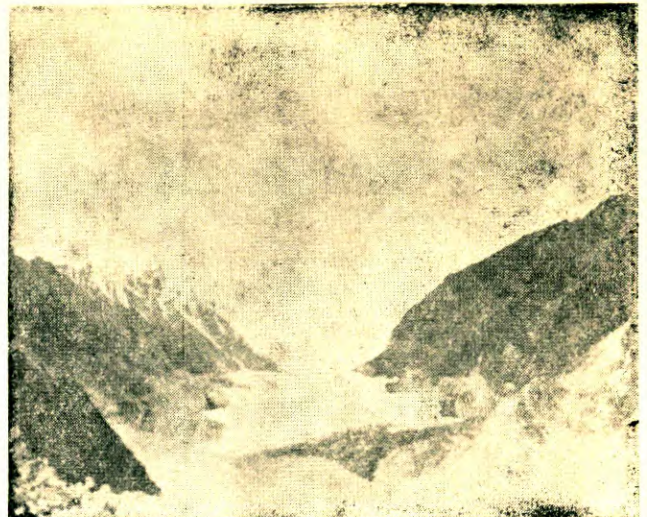


D

- A. Contact of Karakoram granodiorite and Permo-Carboniferous slates of Yasin valley.
 B. Contact of Hinduraj granodiorite and Permo-Carboniferous rocks (slate and quartzite), north of Kalamdarchi.
 C. Glaciated valley of Upper Shigar, Baltistan.
 D. Contact of Greenstone complex and quartzite, Gwach, Hunza State.



A



B



C



D

- A. View of Chhelish glacier, Chhelish village, Yasin.
 B. View of Pasu glacier from Pasu village, Hunza State.
 C. View of West Gamubar glacier, Gainter Aghost, Yasin.
 D. U-shaped glaciated valley. View looking east from Darkot village, Yasin.

