

GEOLOGICAL WORK OF THE ITALIAN EXPEDITION  
TO THE KARAKORAM: *A paper read at the Additional Afternoon  
Meeting of the Society on 25 February 1930, by*

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THE geological observations that I carried out during the expedition of H.R.H. the Duke of Spoleto to the Karakoram embraced both slopes of that great chain, with special reference to the basins of Baltoro, Punmah, Sarpo Lago, and Shaksgam.

I shall only be able here to give a summary account of the main results obtained in the field of the stratigraphical geology, tectonics, and geomorphology of the region. As the paleontological material collected has not yet been completely classified by me, and as the lithological collection is still under examination by one of my assistants, this must necessarily be considered as a preliminary report only. The data to which I will refer are really only a summary of my travelling notes.

The information we obtained beforehand about the country that we have explored was very meagre indeed concerning the southern zone (Punmah and Baltoro), and on the northern we found no information whatever. Moreover, what little was known could be traced only to laboratory observations on collections made by casual travellers, not by geologists. One such collection was brought home by Mr. Conway and studied by Bonney and Raisin ; \* another was made by the Expedition of H.R.H. the Duke of Abruzzi and had been illustrated by Novarese. † Up to date no fossil was known to have been traced in Baltistan. More information was available as to the morphology of the zone, specially of the Baltoro, because all the preceding expeditions had furnished reports on this subject.

As to the cartography of the region, I had the opportunity of tracing hurried sketches of the territory along the beaten tracks on my trip across Baltistan, and more accurate maps of the basins of Baltoro and Punmah. Of course they are only as accurate as circumstances would allow in a country of inaccessible mountains and very extensive glaciers. The geological sketches were drafted partly on direct observation of the rocks, partly by the examination of morainic material, and finally by diligent inspection at a distance.

The basin of Baltoro is eroded nearly up to the Concordia amphitheatre, in a powerful series of biotitic gneiss, crossed in all directions by numerous wide dykes of granite and pegmatitic granite. All the north slope of the Masherbrum-Bride chain up to the Chogolisa saddle is composed of such rocks, with the exception of a narrow strip of foliated micaceous gneiss and shales which outcrops on the northern side of the Bride and Mitre.

The side of the Baltoro valley which is formed by the southern slope of the axial range of the Karakoram, is also formed of gneiss and granite up to the

\*“Notes on Mr. W. M. Conway’s collection of rock specimens from the Karakoram Himalayas.” Scientific Reports in W. M. Conway, ‘Climbing and Exploration in the Karakoram Himalayas.’ London, 1894.

†“Appunti geologici intorno alla Spedizione di S.A.R. il Duca degli Abruzzi nel Karakoram.” In De Filippi, F., ‘La Spedizione nel Karakoram.’ Bologna, 1912.

Muztagh Tower, while farther east the foliated gneiss make their appearance in association with shales and crystalline limestone. The outcrop of the former rocks describes a bow with the convexity towards the south-west, and in the inner side the limestone is found, rising up to form the Crystal Group.

Towards the east the limestone spreads out and rises to form the gigantic tops of Broad and Gasherbrum. On the southern and western slopes of these mountains the shales make their appearance and they go on growing in extension northwards, in the basin of the Godwin Austen Glacier. The isolated mountain between the Savoia Glacier and the Crystal Peak is also formed of shales.

The commanding pyramid of  $K_2$  is composed of well-stratified banks of gneiss, occasionally foliated, the same as on the southern slope between the De Filippi and Savoia glaciers. Granite dykes cross-cut the mass of gneiss. Also the snow-clad top of the colossal mountain must be of clear gneiss, a hypothesis that I found upon the appearance of the rocks (in place) and upon the nature of the detritus carried down by the glaciers. More complex is the case of the Broad. On the eastern side we find limestone (non-crystalline) which extends nearly to the top, but in the hills on the northern side the shales are also in evidence, beside gneiss, granite, amphibolic-diorite with serpentine and green rocks of the prasinitic type, which cut into the limestone masses of the Baltoro.

The most northern outcrop of limestone is that which forms the ridge between the Vittorio Sella pass and the Broad, a narrow strip of micro-crystalline limestone of a white and grey colour. South of Broad the limestone series extends over the Gasherbrum group. The enormous group of mountains is almost entirely composed of grey and black limestone, occasionally assuming a schistose character and bearing fossils. Among the debris carried by the glaciers which descend from the southern side, I observed and collected a certain number of fossils, especially lamellibrancs, gasteropods, and corals intensely laminated, in association with foraminifera (*Neoschwagerina*) of the Permo-Carboniferous age.

We have still to make reference to the Golden Throne region, between the ice-stream flowing down from the Chogolisa Saddle and the branch that leads to Conway's "Probable Saddle." In this zone, amid the vast snow cover, outcrop polichromous limestones, yellow, green, and red sand and calcareous schists, brecciated red, white, and grey limestones. Occasionally these rocks present a sub-crystalline facies. According to observations at a certain distance from Conway's "Probable Saddle," the limestone masses extend eastwards, on the other side of the Baltoro watershed.

The Punmah basin, which lies more towards the east, is mostly cut out in gneisses and granites: such rocks form all the eastern watershed to the head of the Dremang, the chain that divides the branch of the Dumulter from that of Choktoi, and the other chain that separates the latter from the Nobundi Sobundi. The prominent peaks of the Skamri range, which rise at the head of the principal valley and belong to the ridge of the Karakoram watershed, are on the other hand composed of a powerful sequence of white and grey crystalline limestones, with an inter-bedding of shale belts towards the south. This outcrop occupies all the right side of Dremang valley and the left side of the

Nobundi Sobundi valley, but disappears within a few miles of the mouth of the valley. On the hillside the limestone curves towards the north and passes to the other slope of the range. Particular interest is attached to the discovery of *Fenestellae* in the black shales of high Punmah, which I venture to attribute to the Carboniferous formation, also owing to their perfect resemblance to the *Fenestellae* shales of Kashmir.

Let us now pass to the northern slope of the Karakoram. The high valley of Sarpo Laggo is mostly composed of gneisses and granites quite similar to the types already mentioned. In association with them we find shales which reach their greatest development towards the lower and middle section of the glacier. In the former section gneisses and granites alternate with green schists, similar to the Shigar shales, and all the features recall those of the region between Baltoro and Biaho. Towards the end of the Sarpo Laggo glacier, the limestone series is met again, composed of grey limestone, clay limestone with a bluish tinge and fossil-bearing, and red shales and polychromous conglomerates. This series corresponds to that of the Golden Throne, slightly metamorphosed.

The limestone sequence extends in the lower Sarpo Laggo valley, consisting here of grey limestone and black calcareous shales, separated from the preceding sequence by an outcrop of gneiss and granite which descends from the great valley of  $K_2$ . In the region where the valleys of Sarpo Laggo and Shaksgam come together, we find formations answering to the normal facies. They are mostly grey and black limestones, often bearing silex and more or less abundant in fossils, including corals, black, red, and violet calcareous shales, brown sandstones, and polychromous conglomerates. In other places whitish quartzites are met and greenstone dykes.

This formation, which can be followed all along the Shaksgam valley, is frequently rich in fossils. A great many collected by me allowed me to ascertain their age as Permo-Carboniferous revealed by the presence of *Fusulina*, *Poli-pora*, numerous *Productus*, including *Productus punctatus*, and *P. pustulosus*, *Dielasma*, *Reticularia*, including *R. lineata*. The specimens collected were quite numerous, but unfortunately one of the cases containing them went astray during our return trip across Baltistan. The greatest number of specimens were taken in the Sarpo Laggo basin, in the middle Shaksgam valley, and in the Urdok basin. Nevertheless on my return trip I was able to collect a few from this region, which were packed in another case which reached home safely. Above this series lay a dolomitic limestone of light grey colour, in which I noticed the presence of sections of large shells which most probably, on account of their facies and of their stratigraphical position, belong to the Trias.

As to the formation of the region south of Shaksgam, I was able to collect a few data climbing up the Urdok glacier and taking in account the debris from the various glaciers. The northern slope of  $K_2$  must be mainly composed of *augen*-gneiss and of biotitic-granite, because these rocks compose exclusively the moraine coming down from the great valley of  $K_2$ , towards the Sarpo Laggo valley. The shales and a few pebbles of red crystalline limestone which can be found in the moraine, seem to be derived from the northern divide. The northern slope of the high ridge, which extends from Windy Gap to the Indira Col, is composed mostly of limestone entirely similar to that of the Golden Throne. But along the western side of the slope the gneisses and the granites

must necessarily pass also to the northern slope, because these rocks make their appearance in the moraine of the Gasherbrum and Windy Gap glaciers.

To the east of the Indira Col the main ridge of the Karakoram is also formed of sedimentary rocks with normal facies. Of this the moraines of the Stagar, Singye, and Kyagar glaciers bear evidence, carrying slate freely and being entirely lacking in gneiss and granites.

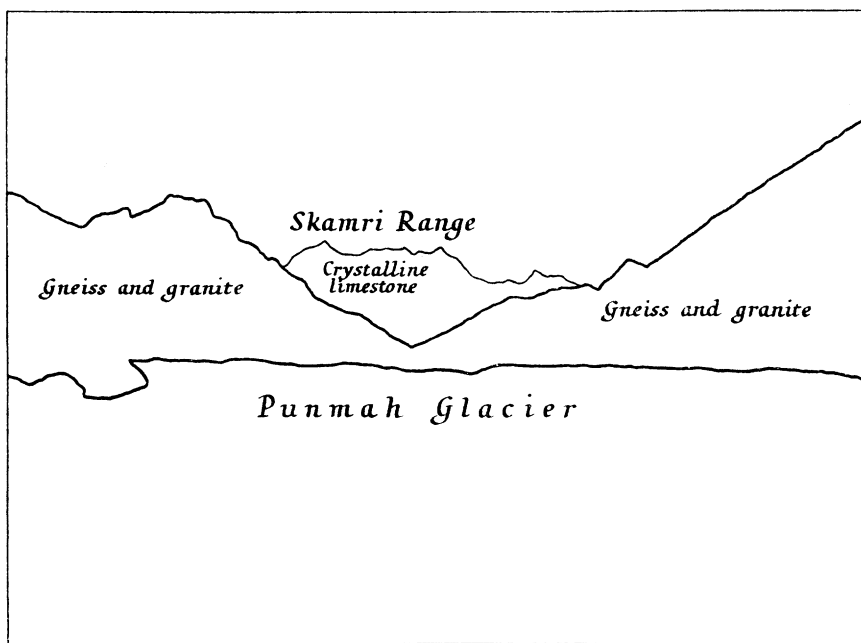
Having thus touched on the main geological regions of the explored country, it may be advisable to refer to the stratigraphical series. The basis of the series is constantly formed of light grey gneiss, nearly always biotitic, occasionally pseudoporphiric, and *augen*-shaped, crossed in all directions by granite dykes which occasionally assume imposing proportions. In the higher levels the black mica content of the gneisses increases, giving them a greater schistosity and a darker tinge. Higher up and next to these occur very thick shales, and farther on crystalline limestones interbedded with shales, amphibolic-serpentine, schists, mica-schists, and *pyllites*. This sequence, on the lower horizon, is crossed by granite veins. Where the action of metamorphism has been less pronounced, we found a few fossils, as for instance in the high Punmah. I see a correspondence between this series, at least in its lower level, and that of normal facies of the Shaksgam valley, of the Golden Throne, and of the Gasherbrum-Broad ridge, of Paleo-Mesozoic age.

I shall be unable to advance accurate information as to the tectonics of the region until the topographical maps are in order, because only with their assistance shall I be in a position to plot down in their place the collected data and thus recognize their relation to one another. On the other hand, a synthesis on the geology of the Karakoram Range would be for the time being somewhat premature. I will, therefore, here report only a few summary data.

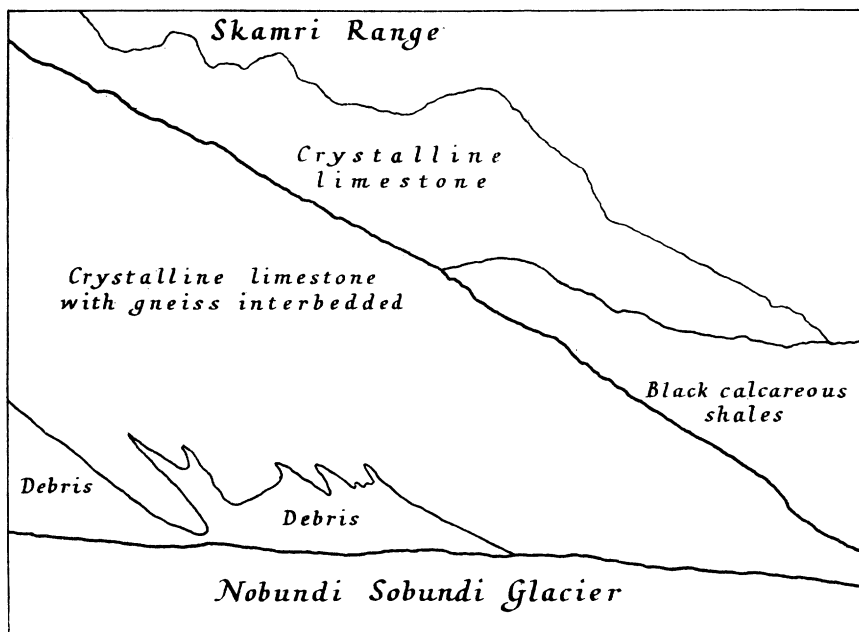
The general trend of the folds of the Karakoram in the region included between  $75^{\circ} 30'$  and  $77^{\circ} 30'$  E. long. is fairly uniform and directed N.W.-S.E. From the Punmah basin, where this direction prevails, the outcrops show a tendency to assume an east-west trend as they approach the high tributaries of the Baltoro glacier: here they describe a slight curve, after which towards the east they once more assume their original direction.

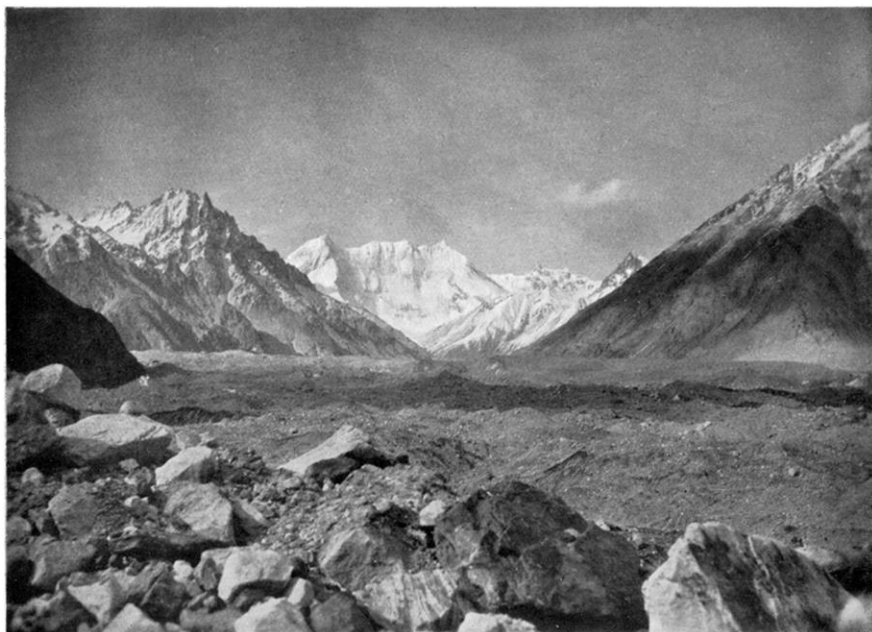
The granite-gneiss principal nucleus, which measures at the surface about 20 km., runs south-east from the watershed ridge between Nobundi Sobundi and Choktoi, with Biaho (going through the principal valley of the Baltoro) in the direction of the Masherbrum-Bride ridge, from which it extends beyond the stretch of country under consideration. The scanty information at our disposal about the south-east country (the basins of Kondus and Siachen) may allow us to think that this nucleus continues in the same direction, towards the Siachen basin and the low Nubra valley.

A secondary nucleus, which has a shorter outcrop, runs to the north-east of the former one and embraces the  $K_2$  group, remaining nearly completely buried under the limestone cover to the west of the Godwin Austen glacier. The calcareous region of Skamri in the Punmah basin lies between these nuclei. Towards the north and south the two nuclei run in between two calcareous-schistose zones, one with normal, the other with metamorphic facies. The latter runs across our region between Askole and the Biaho valley, the former follows the middle and high valley of Shaksgam. Lack of geological records



prevents us from following these zones towards the east and west with any degree of accuracy; but, according to information gathered from the petrographical examination of the specimens collected by various expeditions which have prospected the basins of Biaho, Hispar, and the district of Hunza and





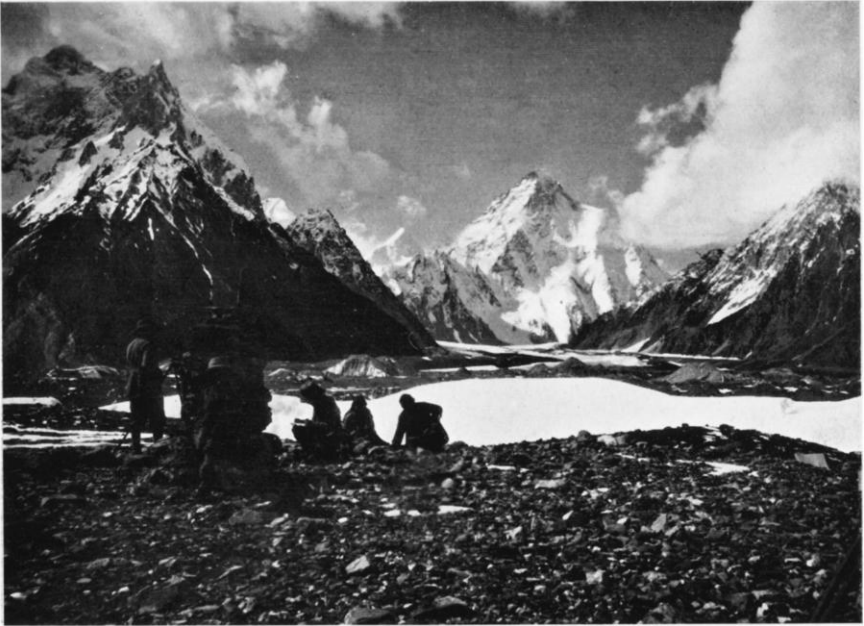
*The Skamri range and Punmah glacier  
Geology indicated on opposite page*



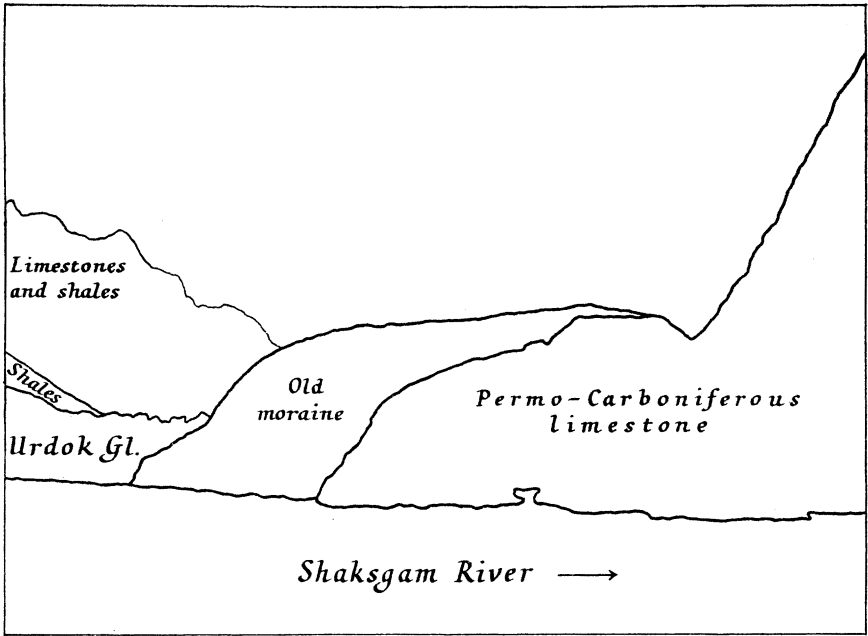
*The Skamri range and Nobundi Sobundi glacier*



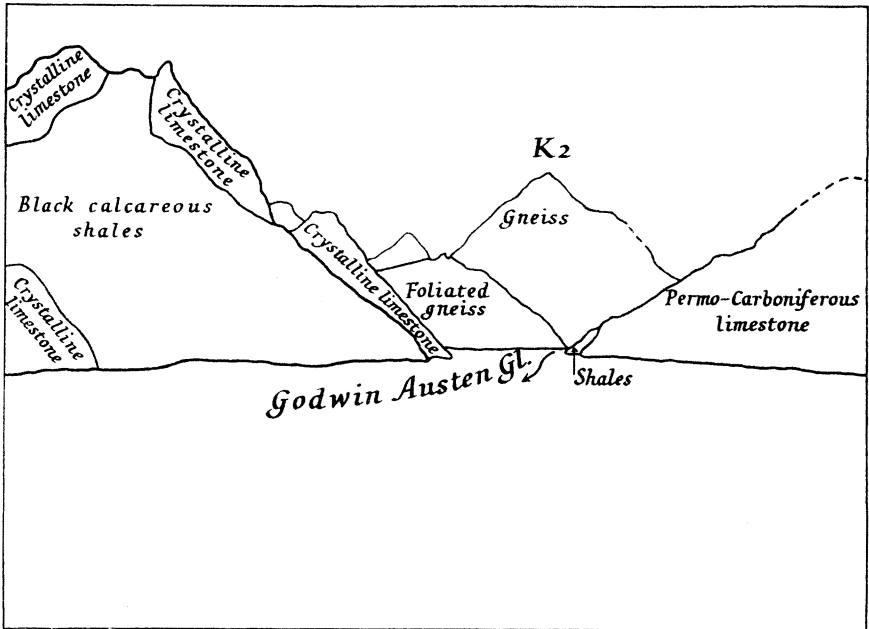
*Isolated rock in front of snout of Urdok glacier, Shaksgam valley*



*K2 and Godwin Austen glacier from Concordia (Baltoro)*



Nagar, the extension towards the north-west of the very same formation that we have studied in our region may be considered as likely. The principal granite-gneiss zone extends towards the high Biaho, the Hispar, and the Hunza; more to the north a calcareous-schist zone makes its appearance, following in a general





way the Shingshal valley and the Batura glacier. An indication of the crystalline nucleus of  $K_2$  may be represented by the granite-dioritic outcrops of the Gujirab valley, while more to the north limestones and shales appear. Farther on again we find the granites in the high valley of Barakhum. Certain evidence of the continuity of the zones in this strike is also forthcoming from the observation of the general direction of the strata, a direction which varies from N.W.–S.E. to W.–E., and which coincides with that found by me more to the east.\*

Following our zones eastward we see that the crystalline nucleus extends to the south-east in the direction of the Siachen basin. It seems that the calcareous zone of Gasherbrum, with a more schistose texture, crosses the same basin with a slight curve in the outcrop from south-east to east. I cannot advance any statement as to the continuity of the crystalline nucleus of  $K_2$ , while it appears that the paleozoic-mesozoic zone points towards the Karakoram Pass. From the old geological map of Lydeker,† it would appear that the synclinal zone of Gasherbrum ought to join with the syncline of the Chang Chenmo valley in Ladakh, but recent observations on the east Karakoram Range do not agree with the data furnished by this map. Therefore the position to-day is that the meagre geological observations at our disposal hinder us in an accurate interpretation of the present morphology of the country.

Considering only the region that we have examined, we cannot trace a genetic connection between its tectonics and its morphology, because in connection with sinclinals we do not find depressions, nor high ground corresponding to anticlines. Let us recall as an evident proof to this effect that the groups of Broad and the Gasherbrums and the Skamri range are found in a synclinal zone.

On the other hand, it is fairly easy to recognize a remarkable coincidence between the morphology and the lithological composition of the ground. Thus we find in correspondence to soft schists the occurrence of erosion features, such as valleys, saddles, etc., while in connection with hard rocks we find high ground. I may quote as examples the Shaksgam valley just above the Agbil Dawan gulch, cut mostly in the shales interbedded between limestone; the valleys of the Urdok, Stagar, and Singye rather similar; the high Baltoro valley corresponding to a schistose belt, close in between the Gasherbrum limestones and the granite-gneiss of Bride; and the valleys of the Nobundi Sobundi and Drenmang in a similar position. Referring to the high ground, we notice that all the tops of the ridges are composed of crystalline rocks or of very compact limestones.

But numerous valleys, including some of the principal ones, do not show such a correspondence, inasmuch as some of them assume the very same direction as the folds, while other transverse valleys show a completely independent character. Among the last I note the Dumordo–Punmah valley, and part of the Sarpo Laggo valley; among the former the valley of the Baltoro, Choktoi, and Dumulter, and the Shaksgam Valley above the Sarpo Laggo junction.

In these instances the origin of the valleys appears to be quite obscure, if we

\*Kuenen, Ph. H., "Petrographic description of rock from the Hunza valley in the Karakoram," *Leidsche Geologische Mededeelingen*, III, 1, 1929. Leiden.

†Lydekker, "The Geology of the Kashmir and Chamba territories and the British District of Khagan," *Mem. Geol. Survey of India*, vol. xxii. Calcutta, 1883.

wish to consider the geolithological constitution without taking into due account the initial topographical surface, on which the primitive drainage system was developed, and of which the present feature of the ground is only a consequence. At the present stage of our knowledge the reconstruction of the original surface of the country is quite out of the question. Nevertheless a rough idea of it may be obtained by supposing all the valleys to be filled up with the debris carried by the agents of erosion, and the tops of the hills that the meteorological agents have in recent times broken and sharpened, rounded. We would then obtain an undulating country with summits corresponding to the central range of the Karakoram and sloping down with a certain irregularity north and southward: a sort of undulating highland in which we would find inlaid, as in mosaic work, the upper plateau of Tibet and Kashmir, and minor tracks of uplands that can actually be found on the Aghil Range. On this imaginary surface the trend of the valleys under discussion only seems to fit indifferently. Therefore, if in a few cases it may be considered as the last remnant of the consequent drainage system, in general we miss a sure and evident connection. This suggests the conclusion that the original topographical surface of the country has not only been deeply cut by erosion, but also remarkably distorted by endogenous forces. But if it may be allowed tentatively to suggest some possible solution to the geomorphologic problem of the region, we cannot, at the present stage, proceed any further without stepping into fancy speculations.

From the far-off ages in which we suppose that the drainage system originated, many facts have evolved and new morphogenetic agents have made their appearance. The present morphology manifests a great prevalence of young forms which lead us to the conclusion that the uplift and folding of the region have not ceased. These are young forms which, though worn by the glaciers, still show a fluvial origin, at least considering the enormous depth of the present valleys, lying thousands of metres below the remnants of the oldest topographical surface of the region, which could not be accounted for only by the theory of the active erosive effect of the glaciers. Also in the Karakoram the glaciers have limited their action in correcting and adapting to their particular requirements the fundamental lines of the features that other agents before them have established.

The glaciers we see at the present time, of the Alpine type, though some of them are amongst the largest in the world, are only the remnants of more powerful ice-streams filling all the valleys of the country during the Ice Age. In the Shigar and Braldo valleys we see two evident systems of old lateral moraines; the highest runs 300-400 m. above the present bottom of the valley and continues towards the Skardu basin. Higher up the valley the moraines go gradually up and connect with the old moraines of the Baltoro basin, between Urdokas and the front of the glacier. The morainic band bordering the great ice-streams during the Pleistocene Age suggests that during the Ice Age the Punmah as well as the Biafo glacier were right-bank tributaries of the great Baltoro glacier, numerous other smaller glaciers flowing down the sides of the valley.

We observe also in the Shaksgam valley old moraines lying 300 m. above the bottom, near the junction of the Sarpo Laggo with the Shaksgam rivers.

The morainic material extends upward in the Sarpo Laggo, Gasherbrum, Urdok, Stagar, Singye, and Kyagar valleys. We can consequently conclude that during the Ice Age large glaciers flowed together in the Shaksgam valley and formed a direct ice-stream towards Yarkand.

Among other signs of the Ice Age we must not forget the *roches moutonnées* and the scratched rocks, everywhere scattered about on the slopes up to conspicuous heights. We also find remnants of more recent ice stages, such as morainic amphitheatres that side glaciers constructed mostly at the bottom of the main valleys, as, for instance, near the Shimtsa Jangal in the Dumordo valley, not far from the front of the Punmah glacier.

All these facts concern rather old movements of the fronts of the glaciers, but we also have proofs of quite recent movements, small though they may be. Before the prominent side of the Baltoro front, Prof. Dainelli,\* during the winter 1913, observed a huge morainic block about 80 m. from the end of the ice. In May 1929 I found the same block in contact with the ice. During the last fifteen years the front of the Baltoro glacier has advanced about 80 m., and at the present time it appears so much swollen as to suggest that it may be increasing.

Quite different are the conditions of the front of the Biafo glacier where, 80-100 m. from the ice, there are short morainic heaps. If we compare Dainelli's observations made in the winter of 1913, when the minimum of the distance between the front and the left side of the Biafo valley was about 40 m., with the conditions found by me in May 1929, when the distance was about 180 m., we may conclude that during the last fifteen years the front of the Biafo glacier has retired more than 100 m. But it seems that the retreating movement has not been continuous, because Featherstone in 1922† observed that the glacier was advancing. The information about the Punmah glacier is more meagre and uncertain. Godwin-Austen‡ in 1861 found the glacier retreating, observing that the camping-ground of Punmah was at that time buried by the ice. At the present time it is uncovered again, but the glacier end is very swollen, and other symptoms seem to indicate that the glacier is rising.

I have scanty information about the glaciers of the north side of the Karakoram Range. The most interesting fact is that Sir Francis Younghusband,§ in the year 1889, travelled round the front of the Gasherbrum glacier along a gorge open between the ice and the cliff of the valley side, while in the June of 1929 the glacier pushed its front, bristling with ice-pinnacles, against this cliff, and the Shaksgam river was obliged to flow below the ice. But we possess no information about the movement during the last forty years of the front of the Gasherbrum glacier, now extending farther in the valley, as in 1889. We have lost, also, previous data on the glaciers crossing the Shaksgam valley higher up. The two highest, the Singye and Kyagar glaciers, push their fronts up to the cliff on the right side of the valley; whilst in front of the Urdok and the Stagar

\*Dainelli, G., "Le condizioni fisiche attuali," Vol. iv, Ser. ii, of 'Relazione scientifiche della Spedizione Italiana De Filippi nell' Himalàia, Caracorum e Turchestan cinese, 1913-1914.' Bologna, 1928.

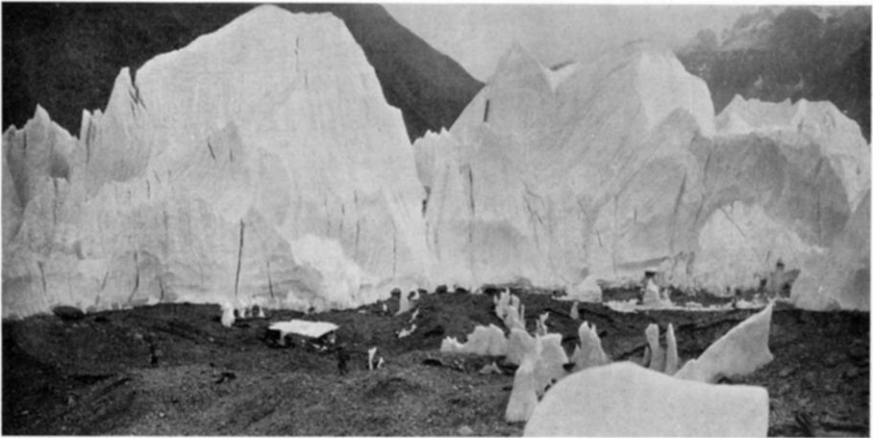
†Featherstone, B. K., "The Biafo Glacier," *Geogr. Journ.*, LXII. London, 1926.

‡Godwin-Austen, H. H., "On the glacier of the Mustagh Range," *Journ. Roy. Geogr. Soc.*, London, 1864.

§Younghusband, F. E., "The heart of a continent.' London, 1896.



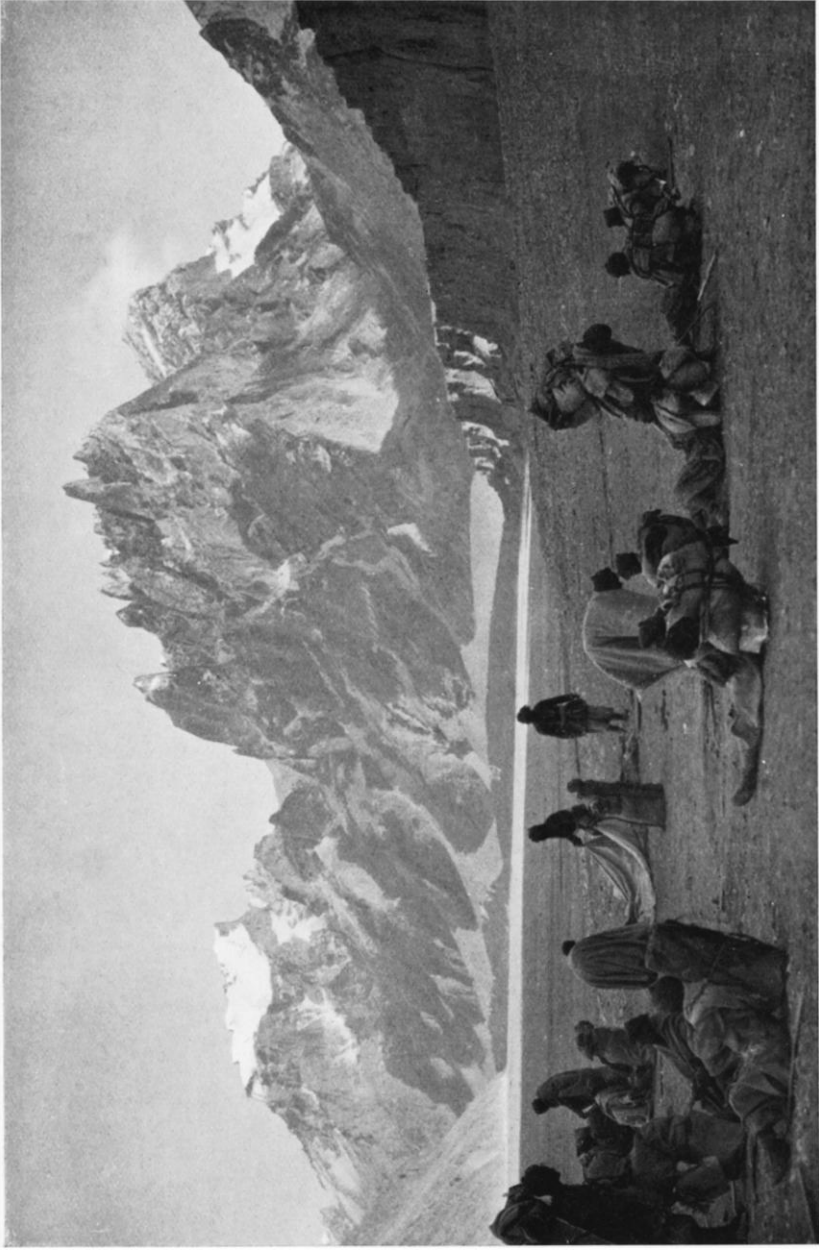
*Jangal in the Sarpo Lago valley*



*Highly inclined ice strata in isolated pinnacles of the Gasherbrum glacier*



*The front of the Gasherbrum glacier*



*Dolomite peaks along the Shatksgam valley*

glaciers there is a fairly broad gorge. Judging by appearances, it seems that the former are rising and the latter retreating. The conditions of the Kyagar glacier were just the same in 1929 as they were when observed in 1926.\*

The last variations affecting the fronts of the Kyagar and Singye glaciers were apparently not very remarkable. The lacustrine terraces above the Kyagar testify that the damming of the Kyagar lake by the glacier may not be of recent date. We observe the same facts above the Singye glacier, where there are sandbeds and remains of terraces testifying the existence of an old lake dammed by the glacier. About the Urdok and Stagar, we observed that beyond the fronts of the glaciers isolated rocks covered by morainic gravels and moraines up to the right bank of the Shaksgam river testify that these glaciers also barred the valley. It seems, however, that at the same time two glaciers—one flowing down the Windy Gap near the Gasherbrum glacier, the other lying between the Urdok and the Stagar glaciers—heaped up two characteristic morainic amphitheatres, some 100 metres from the present front, and that other front moraines observed by me not far from the end of some slope-glaciers, were accumulated at the same time.

I examined some problems connected with the morphology of the glacier surface during the expedition, and one of the most interesting is that of the origin of the ice-needles with which the surface of some glaciers, especially those in the Shaksgam Valley, are filled. If the phenomenon had already been noticed on certain glaciers of the southern portion of the chain, it was certainly not to be compared with the forest of ice-needles of the Singye and Kyagar glaciers (the ice-needles on the latter have already been described by Mason), in which the pinnacles of ice rise to 60–70 m. and almost entirely cover the main ice streams. I will not now refer to the various explanations of this strange phenomenon, but I will only touch on the results of my personal study.

In examining carefully the structure of the ice-needles it is noticed that in every case they are formed from white stratified ice, and the strata are more or less upright. Of these strata, some appear to be made of thick crystalline ice, and others of ice less thick and granular. I think that the development of the ice-needles might be attributed to the minor fusibility of the thicker strata and the intense rays of the sun. It is unnecessary for me to enlarge too fully upon the reasons (considering always composed glaciers) for the strata being upright below a certain height. But if this fact will help to explain the longitudinal decomposition of the glacier surface, some explanation is needed on the transverse decomposition, which is also due to the same causes. It is noticed that in the terminal part of the glacier the strata form a table-spoon curve, or rather that the tops of the ice-strata rise up towards the sky in all directions and therefore transversally also to the glacier. Where the fronts of the glaciers encounter an obstacle this vertical tilting of the strata is stronger, and so we should find a greater development of needles. In fact, in the Kyagar and Singye glaciers, and on a minor scale in the Gasherbrum glacier, whose fronts abut on a rocky wall, the phenomenon of the needles is much more developed than elsewhere.

At the same time higher up, yet always in the melting zone, we find some needles, but always lower and more aligned in the longitudinal sense the nearer they are to the upper limit of the melting zone.

\*Mason, K., 'Exploration of the Shaksgam Valley and Aghil Ranges, 1926.' 1928.