ITALIAN EXPEDITIONS TO THE KARAKORUM (K^2) AND HINDU KUSH

Prof. ARDITO DESIO Leader

SCIENTIFIC REPORTS

III - Geology

4th Volume

GEOLOGY OF THE UPPER SHAKSGAM VALLEY, NORTH-EAST KARAKORUM, XINJIANG (SINKIANG)

by

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1980

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SCIENTIFIC REPORTS

I

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ON BEHALF OF THE
ITALIAN NATIONAL COUNCIL OF RESEARCH

E. J. BRILL - LEIDEN (HOLLAND)

PRINTEND IN ITALY

PREFACE

While the previous seven volumes of this series deal with the scientific results of my expeditions in the Karakorum area from 1973 onwards, the present book reports on an area I explored in 1929 in my capacity of geographer and geologist of the Italian Geographical Expedition led by Aimone di Savoia Aosta Duca di Spoleto and organized under the auspices of the Reale Società Geografica Italiana and the Milan City Administration. An official volume about this expedition now seeming so far away in time was published in 1936 under the title « La Spedizione Geografica Italiana nel Karakorum — 1929 — Storia del viaggio e risultati scientifici » (S.A. Arti Grafiche Bertarelli, Milano — Roma).

The story of the journey was related by the Duke of Spoleto, the other parts, except for the Appendixes, by myself and dealt mainly with the geographic results achieved. The geologic results — the only ones that matter here — were concisely reported in the headings of the different chapters on the glacial basins of Panmah, Baltoro, Sarpo Laggo and the Upper Shaksgam valley. At that time a publication of purely scientific works was envisaged giving all the details of the results achieved, but financial and other difficulties made it impossible to carry out this program. Therefore, the scientific results (apart from the above mentioned book referring to geography only) of all other disciplines are briefly mentioned in short descriptive notes on fauna and flora and in some prelimary notes on rock samples and fossils. Only P. COMUCCI*'s report « Le rocce raccolte dalla Spedizione Geografica Italiana al Karakorum — 1929 » (Reale Accademia Nazionale dei Lincei, Roma, 1938) has a certain consistency.*

Starting from 1953 I organized and led several scientific explorations in the Karakorum, precisely in 1953, 1954, 1955, 1961, 1962, 1973, 1975, the last two having merely a geologic purpose.

May I particularly recall here the 1954 expedition aiming at the climb of K² *(8611 m), the second highest peak of the world. Its summit was reached for the first time on July 31 by two members of the expedition I was leading:* ACHILLE COMPAGNONI *and* LINO LACEDELLI.

The 1953 and 1954 expeditions were highly interesting for the subject dealt with in the present book. The area under examination was mainly the basin of the Baltoro glacier sharing the watershed with the Shaksgam Valley along many kilometres.

One of the volumes of the present series (III-2) published in 1970 described the geologic results obtained in this basin.

Owing to more detailed studies of this area I have been able not only to revise the data and the materials collected in the nearby Shaksgam Valley, but also to critically re-examine the previous reports on basins neighbouring the Eastern Karakorum and above all on those of the Siachen and Rimu glaciers. There G. DAINELLI *and* O. MARINELLI, *members of the Italian De Filippi Expedition to the Himalayas, Karakorum and Chinese Turkestan (1913-14) developped their geologic research.*

In the meantime more re-examinations have been carried out: of the fossils I collected in the Shaksgam Valley described for the first time in the volume III-2 of the present series by R. CIRY *and* M. AMIOT *and* N. FANTINI-SESTINI, *while* P. SPADEA RODA *has studied some rock samples I collected in the Shaksgam Valley along with others* DAINELLI *retrieved in the Siachen basin. The latter are dealt with in an Appendix to the present volume.*

I have deemed useful to write the present work availing myself of these data that were partially unknown to me at the time of the publication of the 1936 volume. I was also greatly helped by reports on the western side of the upper Shaksgam basin — partially published, partially still inedited — kindly supplied to me by the geologist of E. SHIPTON'S *1937 expedition* J. B. AUDEN, *to whom I wish to express my warmest thanks.*

My work takes also advantage of the geologic research achieved both in the nearby Baltoro basin with which it shares — as I already mentioned — the southern watershed and in the Siachen basin, although it is much less known from a geologic point of view.

May I also remind the reader that the area under consideration in this volume belongs to the less accessible ones on Central Asia, not only because of its orographic structure, but also for its political situation. Infact it extends along the partially still disputed borders of India, Pakistan and China.

For this reason very few travellers have so far been lucky in penetrating into this valley and only two of them were geologists: AUDEN *in 1937 and myself in 1929. I have had the good fortune of being able to travel almost along the very length of the main valley, i.e. from the junction with Sarpo Laggo at the end of its upper part up to the snout of the Kyagar glacier at only a few kilometres from its origin.*

Moreover, I have visited the tributary valleys of Urdok and Sarpo Laggo and portions of other ones.

I have taken the decision of writing the present volume in spite of the long time elapsed since my exploration in view of somehow filling a gap in the geologic knowledge of a fairly relevant area in Central Asia.

I rely on the indulgence of the reader for imperfections and omissions and for some uncertain conclusions I had to draw. All this is due to the rapidity of my geologic exploration. Among other things it has to be considered that I had to carry out my geologic research at the same time as the topographic survey which I was engaged to perform myself. Difficult mountaineering and logistic problems had also to be solved, among others the crossing of the glaciers bristling with pinnacles that barred the valley.

I recall these facts only in order to explain why I have not been able to collect a broader documentation of the geologic nature of that territory. Anyway, I trust this work will serve its purpose as a base for future geologic inquiries by those who will have the chance of penetrating again into that remote valley separating the chain of the Karakorum from the one of Aghil.

Ardito Desio

CONTENTS

LIST OF THE FIGURES

Figures in text

Plates

I. GEOGRAPHIC OUTLINE

1. General Features.

The Shaksgam river is one of the left tributaries of the Yarkand river and joins it near Toquz Bulaq about 245 km from its source. Nevertheless some authors, such as K. MASON (1929), and S. G. BURRARD & H. H. HAYDEN (1933) consider it the source branch of the Yarkand river.

The headwaters of the Shaksgam outflow from an unnamed glacier belonging to the catchment area of the Yarkand river, into which some of its melt water flow. The Shaksgam and Yarkand basins are connected here by the Shaksgam pass or Shaksgam-la (fig. 1) (1).

It seams that the Balti name *Shaksgam* corresponds to the name *Oprang*, used by Kirghiz people (see F. YOUNGHUSBAND, 1896, p. 157) although these two names may also refer to different parts or branches of the river. According to information I gathered from the Askole (Balti) inhabitants, the name Shaksgam derives from two words: *Shak*, meaning « sandy » and *gam*, meaning « dry ». According to K. MASON (1928), it means « box of gravel » or « dry gravel ».

The drainage basin of the Shaksgam river is located between 35°31′ and 36°50′ Latitude north and 76°08′ and 77°30′ Longitude east (Greenwich).

In order to simplify our description, we shall divide this basin in two sections: one including the area drained by the river between the headwaters and the confluence of the Sarpo Laggo river (near the Tek-ri hillock) to be called Upper Shaksgam, the other between Sarpo Laggo and Toquz Bulaq, an oasis used by the Kirghiz shepherds, which will be called Lower Shaksgam. Only the Upper Shaksgam valley will be described here since it was the only one investigated by some members of the DUKE OF SPOLETO expedition to Karakorum (1929).

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(1) This pass is the " Pass G " of the topographers of the DE FILIPPI expedition, 1913-1914 (see later).

Fig. 1 – *Orographic sketch-map of the Karakorum Mountain Range.*
The grey area marks the Upper Shaksgam drainage basin.

The Shaksgam valley has a length of 127 km from the Shaksgam-la (5465 m) to the confluence of the Sarpo Laggo (3750 m); the average gradient is therefore 13‰.

The valley has a general SE-NW trend, but it is composed of two differently oriented segments: the eastern one going from the headwaters to the Staghar glacier, about 62 km long, is almost rectilinear and trends ESE-WNW; the western one, 65 km long, is sinuous and bears SE-NW.

Near the Tek-ri hillok the Sarpo Laggo valley joins the Shaksgam on its left hand side. Here the valley is much more large than the Shaksgam one and the former looks like the main valley.

15 km upstream from the confluence, the Sarpo Laggo branches out into two valleys occupied by large glaciers bearing the names of Skamri (on the left) and Sarpo Laggo. The latter is the smaller but its valley joins that of Sarpo Laggo nearly at right angle and therefore it appears as a lateral branch of it.

116 km downstream from the confluence the Shaksgam river joins the Yarkand river near Toquz Bulaq.

Without considering the Sarpo Laggo drainage basin, the Shaksgam valley is a longitudinal glacial valley lying between the Karakorum range (towards the south) and the Aghil range toward the north.

The Karakorum range from the Apsarasas group (7249 m) as far as the Indira-la (5776 m) divide the Shaksgam drainage basin from the Siachen glacier basin (tributary of the Nubra river). This 73 km long crest is composed of two very high mountain groups, viz. the Teram Kangri (7468 m) and the Singhié Kangri (7751 m) (1). North-east of the Indira saddle the ridges of the Karakorum rise more and more reaching 8068 m on the Gasherbrum I, 8051 m on the Falchan Kangri, and 8611 m on the top of K^2, the second highest mountain in the world.

The ridges of the Aghil mountains are much more fractioned and also less high than the Karakorum ones. Besides many unnamed peaks, not yet measured, the most elevated of the peaks marked on the maps is one 6767 m high which faces from north the West Chikchi-ri ridge and therefore does not face directly the Shaksgam valley. The western Chikchi-ri crest is 6648 m high. Toward north-west the most elevated Aghil ridges average 6000-6500 m; they do not reach 6700 m a.s.l.

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(1) This altitude (25,430 feet) is marked in the USA map at the scale of 1:250,000 (Sheet NI 43-4, Chulung) but I was not able to find the origin of this value. It does not appear neither in the Mason maps at the scale 1 inch to 4 miles (1:253,440) of the « Shaksgam and Upper Yarkand Valleys », 1928, nor in the list of the principal peaks of Himalaya Mountains by S.Burrard (1933).

Different is the situation of the mountains surrounding the Sarpo Laggo and Skamri drainage basins which represent a kind of western appendix of the main Shaksgam valley. I will deal with them in the section devoted to the geologic description.

The Shaksgam valley floor from its beginning to the Staghar glacier is generally speaking moderately wide, then it narrows and the valley finally becomes a rocky gorge.

The valley is dammed by five glaciers which descend from the high ridges of the Eastern Karakorum. Beginning with the uppermost one, they are: the Kyagar glacier, the Singhié glacier, the Staghar glacier, the Urdok glacier and the Gasherbrum glacier. In 1929 the fronts of three of them touched with the opposite side of the valley but according to some ERTS photographs taken in 1972 the situation of the glacier fronts has sensibly changed (1).

The valley is poorly known due to the limited number of geographic investigations carried out. For this reason it will be briefly described in one of the next paragraphs (2).

2. The Exploration of the Shaksgam Valley.

On his way back from China to India FRANCIS YOUNGHUSBAND discovered the Shaksgam valley in September 1887. He climbed the Aghil pass and saw below a wide longitudinal valley unknown until that time to all western explorers. However it was well known to the local people who frequently travelled through it en route from Yarkand to Baltistan (fig. 2). Previously it was assumed that the rivers draining the northern part of the Karakorum flowed from south to north into the Yarkand.

YOUNGHUSBAND descended southwards from the Aghil pass to a small valley which led him to the Shaksgam valley. He travelled this valley from here down to the Sarpo Laggo confluence and then turned towards Muztagh, a pass across the Karakorum range. Two years later the same traveller went back to the Shaksgam valley in order to explore another pass that the local guide WALI said existed between the Shaksgam and Baltistan. After leaving their heavy baggage and a guide at the mouth of the Aghil valley, on September 12 1889 he and 3 other men with 5 ponies travelled along the Shaksgam valley

(1) I will deal with this question in a separated report.

(2) A more detailed description of the Shaksgam valley is contained in my section of the official report of the DUKE OF SPOLETO expedition (1929).

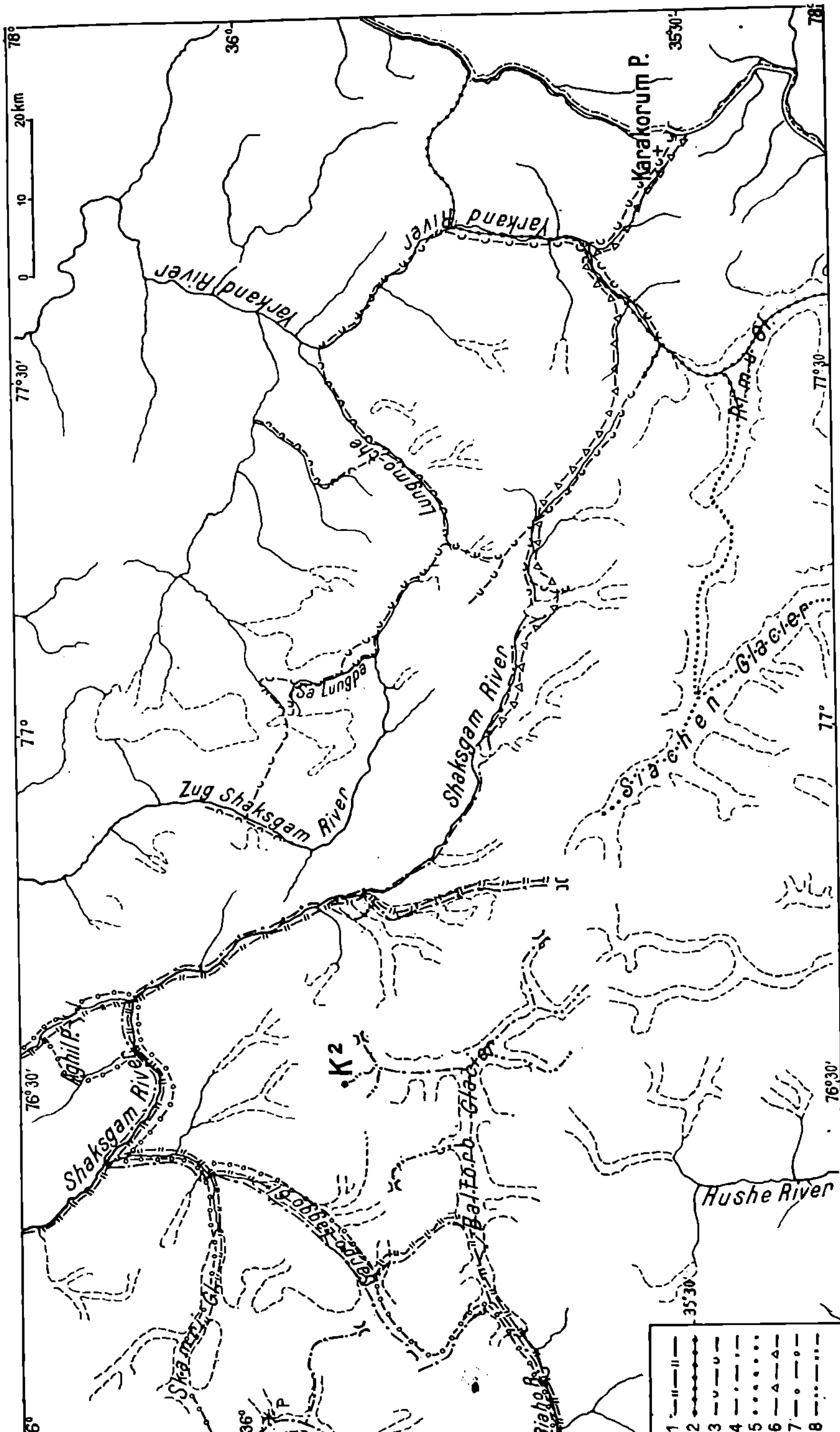

Fig. 2 – *Main routes travelled by the expeditions in the Shaksgam Valley with particular reference to those travelled by the geologists.*

1 YOUNGHUSBAND routes, 1887 and 1889; 2 DAINELLI and MARINELLI routes of the DE FILIPPI expedition, 1913-1914; 3 MASON expedition routes; 4 DESIO routes of the DUKE OF SPOLETO expedition, 1929; 5 DAINELLI expedition routes, 1930; 6 WYSS routes of the VISSER expedition, 1935; 7 AUDEN routes of the SHIPTON expedition, 1937; 8 DESIO expedition routes 1953-1954.

up to Gasherbrum Jilga where they spent the night. The following day they reached a glacier damming the valley and leaving only a narrow passage at its front. This glacier was called *Gasherbrum Glacier*. From here they travelled around the front and met another glacier called *Urdok Glacier*. According to the only available information at that time this glacier descended from a pass called « Saltoro Pass ».

YOUNGHUSBAND and his men ascend the glacier and on the evening of the 13th camped at the foot of a saddle (Gasherbrum-Urdok saddle). On the 14th they went ahead on the same glacier and attempted to climb a branch of it, but were stopped by a range of ice pinnacles. Only on the following day they were able to find a route which brought them to the centre of the glacier whence they could proceed to its upper snow-fields (pl. XVII, fig. 2).

On September 16, they left the ponies behind and proceeded to climb the pass. After having crossed a crevassed zone they were caught by the edge of an avalanche while climbing an ice slope. They continued climbing up to 5200 m, but a large crevasse stopped the attempt definitively. On the following day they turned back and on September 18 they reached base camp. Three days later they started towards the Sarpo Laggo valley.

YOUNGHUSBAND prepared a concise and interesting report on the region he had visited. He could not survey even a simple topographic map of his itinerary, but only some altimetric measurements and latitudinal determinations were carried out.

The section of the Shaksgam valley upstream from the Urdok glacier was shown on his geographic sketch maps as a short valley containing the melt waters of the two above mentioned glaciers. YOUNGHUSBAND, in fact, saw only these glaciers upstream from the Urdok which he thought close to the Karakorum pass.

No other exploration of the Shaksgam valley was carried out from 1889 till the end of the summer of 1913 when the DE FILIPPI expedition left Italy with the purpose. of « exploring the Oprang valley beyond the Karakorum watershed. This valley is marked on the map but its position for most of its course is uncertain » (1).

On July 12, 1913, the topographers of the expedition SPRANGER and WOOD climbed up to the head-waters of the highest left hand tributary of the Yarkand (« River F ») and reached a saddle (« Saddle G »). « Beyond the saddle — they

(1) DE FILIPPI F., " *Storia della Spedizione Scientifica Italiana nell'Himalaya, Karakorum e Turkestan Cinese* (1913-14) ". Zanichelli, Bologna 1924, page 5.

said — there is a valley (1) flanked by very high mountains which short distance hide it from view ». At that time they assumed that this was a tributary valley joining the Yarkand valley a little further downstream; but later they realized that the confluence must be at a much greater distance and they supposed that this valley was the beginning of the « Oprang valley » which joins the Yarkand valley very far away, along the northern slopes of the Karakorum range (De Filippi, 1922). Later on they abandoned the idea of entering the Shaksgam valley through the Aghil range, because it was impossible to ford the Yarkand river.

In 1926 the expedition led by Major Kenneth Mason (1928) left India with the purpose of crossing the mentioned above « Saddle G » and exploring the Shaksgam valley through « Valley H ». They also wanted to map all the unexplored areas encircled by the Baltoro, Siachen and Rimu glaciers. On July 3 the expedition entered the Shaksgam valley through « Saddle G ».

Members of the expedition were, apart from Major Mason, Major H. D. Minchinton, Major R. C. Clifford, Captain F. O. Cave, an Indian topographer, twenty-four porters and some servants with eighteen ponies. The expedition moved down the small « Valley H », which turned out to be the upper part of the Shaksgam valley. After reaching the confluence with another eastern valley, they continued along the river-bank up to a large glacier damming the valley (July 5). This glacier was later named *Kyagar Glacier* (fig. 2 and plate XXXIV).

After a rapid reconnaisance of the hights around the glacier, on July 7 Minchinton and Cave tried to ride across the Kyagar glacier, a few kilometres upstream from its end, but did not succeed. Because of this experience, Minchinton and Clifford turned towards Lungpa Marpo, a right hand tributary of the upper Shaksgam valley. A pass was discovered in the mountains overlooking the Kyagar glacier and they decided to try to re-enter the Shaksgam valley downstream from this glacier. In the second half of August they thought that the Shaksgam could be reached easily, but they soon realized that they were in an unknown parallel valley which was named *Zug Shaksgam* (False Shaksgam).

After Mason's expedition, Montagnier and Captain C. J. Morris carried out a project for exploring the Shaksgam valley. They intended to reach the valley through the Hunza valley and the Shimshal pass (Morris, 1928), but they too failed because they couldn't obtain a permit to cross the frontier.

(1) " Valley H ".

In conclusion, after the YOUNGHUSBAND expedition of 1889, in spite of the fact that three expeditions were mounted, for various reasons many geographic problems of the Shaksgam were still unsolved.

It must be acknowledged, however, that the photogrammetric mapping made by MASON's expedition in addition to the data collected by YOUNGHUSBAND supplied a general outline of the valley.

The DUKE OF SPOLETO expedition, organized during summer 1929, set out to solve, among others, also these problems. On June 9, 1929, a team of six Europeans and forty-two porters left the Urdukas base camp (located on the left side of the Baltoro glacier) and, after climbing the Muztagh glacier and the ice-fall below the Muztagh pass, reached the pass, where a cache of supplies was left. In the following days the expedition proceeded along the Sarpo Laggo glacier down to Moni Bransa from where some surplus porters and two members of the expedition (F. CHIARDOLA and L. DI CAPORIACCO) returned to base camp. The group which actually explored the Shaksgam valley included four Europeans (U. BALESTRERI, A. DESIO, V. PONTI and the guide LEON BRON), twenty porters and one shikari.

On June 12 this group reached the front of the Sarpo Laggo glacier and the next day camped at Sughet Jangal. The following morning DESIO and PONTI climbed the rocky hillock of Tek-ri which rises at the confluence of the Shaksgam and the Sarpo Laggo rivers. From here they observed and took photos for the first time of the towering northern wall of K^2. On the same day the expedition began moving along the Shaksgam valley. Owing to its very steep sides the team had to ford the river repeatedly. In three days the expedition reached the Gasherbrum glacier and crossed it four kilometres upstream from its end because the front was abutting against the steep right hand flank of the Shaksgam valley. On June 19 the expedition reached the Urdok glacier and climbed it the days. On the evening of June 21, they camped near the head of the valley, at the foot of a saddle (Indira-la) (pl. XVII, fig. 2).

The programme was to cross this saddle, to reach the Siachen or the Kondus glacier and from there to try and re-enter the Baltoro through the Conway saddle; this was explored by DESIO and the guide CROUX on May 28. During the night, however, a snow-storm made the access to the saddle impossible. Therefore it was decided that PONTI, BRON and most of the porters would return to Urdukas, while BALESTRERI and DESIO with eight porters and supplies would continue to travel along the Shaksgam valley for twelve days, upstream from the Urdok glacier that had never been visited before.

On the evening of June 25, BALESTRERI and DESIO camped near the front of a large glacier damming the Shaksgam valley; it was called *Staghar Glacier* by the porters. The name means « black and white » glacier. On the following day they continued along a narrow passage between the glacier and the slope of the valley; on June 26 they were very close to another large glacier, broken into ice pinnacles, damming the valley completely. The porters called it *Singhié Glacier* (1). After a vain attempt to pass around its front, the group entered the pinnacle area; it took thirteen hours to cross this glacier tongue that, at this point, is no more than two kilometres wide. (pl. XXVII - XXIX).

From the right side of the Singhié glacier, the group was able to recognize the Kyagar glacier, the « Island Ridge » (Chikchi-ri), and the « Red Wall » (Marpo Rgyang) from the photographs reproduced in the report of the MASON expedition (1926).

On the return route, the K^2 glacier was explored for a short while and the Sarpo Laggo saddle — between the Tramgo and Sarpo Laggo valleys — was climbed for the first time. This saddle (5685 m) was easier to climb than the Muztagh and offered a new route between the Baltoro and the Sarpo Laggo glaciers. Later this way was followed by SHIPTON's expedition (1937), in order to reach the Shaksgam valley from the Baltoro (fig. 2).

Unfortunately, strict orders forced the group to return immediately to base camp and prevented it from further investigation of the northern slopes of the range. After re-crossing the Muztagh pass the group reached the base camp on the evening of July 14.

During the exploration of the Shaksgam valley DESIO, the geologist and geographer of the expedition, collected data, rocks and fossils along the route and carried out a reconnaissance topographic map by means of the « Tavoletta Monticolo » (2) and by measuring the heights with the barometer and the ebullition hypsometer. The topographic field map (1:50,000) provided the basis for the compilation of the map of the Shaksgam valley (at the scale of 1:75,000) enclosed in the official report of the expedition (1936).

It is very strange that in the second edition of the well known and authoritative work by BURRARD and HAYDEN « A sketch of the Geography and Geology of the Himalaya Mountains and Tibet », published in 1933, the geographic results obtained by YOUNGHUSBAND and MASON's expeditions are described extensively while nearly no mention is made of the achievements made by the DUKE OF SPOLETO expedition organized on behalf of the Italian Royal Geographical Society in 1929. This is even stranger if we consider the fact

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(1) I must draw the attention to the fact that in many maps the name *Singhié* is written wrongly (Singhi). The word Singhié means " terribly difficult " and is to be accented on the last vowel.

(2) A reconnaissance topographic instrument.

that the Italian expedition was the first to explore and map the middle Shaksgam valley, and to visit it completely, four years before the publication of the above mentioned work by BURRARD and HAYDEN. Even the new names Staghar and Singhié (not Singhi) glaciers are attributed to MASON.

The above mentioned authors knew what the DUKE OF SPOLETO expedition had achieved because the same authors mention, although only in three and a half lines, the geology of the Shaksgam, Sarpo Laggo and Panmah basins (that of Baltoro basin was ignored). Well, the geological summary presented by these authors was drawn from DESIO's preliminary geological report, published, together with the DUKE OF SPOLETO's report, in the « Geographical Journal » of the Royal Geographical Society (vol. 75, no. 5, 1930), which was and is a very well known journal in geographical circles.

As far as we know, the last expedition to the Shaksgam valley was the SHIPTON expedition (1937) whose members were, besides ERIC SHIPTON and H. W. TILMAN, the topographer MICHAEL SPENDER and the geologist John B. AUDEN with seven sherpas and several Balti porters.

The expedition entered the Sarpo Laggo valley through the Sarpo Laggo saddle on June 3 and proceeded as far as the confluence with the Shaksgam valley. From there they travelled along the latter valley up to the confluence with the Aghil valley and, on June 20, crossed the Aghil pass and camped on the opposite slope, in the upper Surukwat valley (fig. 2).

While AUDEN descended to the Yarkand river, SHIPTON and TILMAN tried to find the Zug Shaksgam explored by MASON's expedition, in order to reach the middle Shaksgam valley. In the meantime SPENDER mapped the surrounding area photogrammetrically. Later on SHIPTON and TILMAN reached the Zug Shaksgam and explored most of it. In the meantime AUDEN travelled along the Surukwat valley and then descended into the Shaksgam valley through the Skam Lungpa. After reaching Durbin Jangal, he descended to the confluence with the Sarpo Laggo valley. On July 8 all the members of the expedition were together at Sughet Jangal.

In the following week the Sughet and K² glacier valleys were explored and mapped.

On July 17 the expedition met at the confluence of the Sarpo Laggo and Skamri valleys and then split up again in order to explore in detail the Skamri glacier (1) and identify its relationship with the neighbouring glaciers, that is the Panmah, the Biafo and the Braldu. Then various members of the expedition

(1) This glacier was explored for the first time by YOUNGHUSBAND during his 1889 expedition. The glacier was called Crevasse glacier and later Wali glacier. Wali was the name of a guide of YOUNGHUSBAND.

left the Skamri glacier through various passes towards the Panmah, Biafo and Braldu glaciers, continuing their investigation outside the region considered here.

In conclusion, apart from SHIPTON's expedition, the middle Shaksgam valley, between the Urdok and the Kyagar glaciers, was visited only by BALESTRERI-DESIO's team in 1929 (1).

3. Physiographic Features.

The Shaksgam-la (a pass 5465 m a.s.l.) at the eastern entrance to the Shaksgam valley links two small valleys, descending in opposit directions: the Yarkand and the Shaksgam valleys. They were called « Valley F » and « Valley H » by Major WOOD, a topographer of DE FILIPPI's expedition, 1913-14 (see p. 6). The wide front of a glacier reaches down to the pass and its melt waters feed two streams flowing in opposite directions, one to the ESE and the other to the WNW. Only the latter is of interest here because it represents the uppermost course of the Shaksgam river.

Immediately downstream from the pass, the Shaksgam valley is wide and has a rolling and gentle topography. An approximately one and a half kilometre long gorge flanked by rocky walls of 10-15 m begins at about 8 km from the pass. Four small strongly crevassed ice-flows, appear on both sides of the gorge. Further downstream, the valley becomes noticeably wider, but a short gorge follows before the confluence of another small valley descending from the west. This latter valley is formed by the junction of two branches at about 1700 m from the previously mentioned confluence; further upstream both branches divide repeatedly.

Six glaciers — two of them of considerable size — are present in this secondary basin, half of which shares the watershed with the upper Yarkand, the other half with that of the Lungmo-che.

Downstream from the above mentioned confluence, the principal valley has an almost east-west orientation and becomes noticeably wider. The right flank of the valley, a little above the river, is terraced. About 6.5 km further downstream, a large tributary, with a general SSE trend, flows into the Shaksgam river. 5 km upstream from the confluence, this tributary is fed by the melt waters of a large, unnamed glacier whose snow field is in contact with

(1) The next SHIPTON expedition (1939) explored the area to the west of the one explored by the 1937 expedition, that is outside the Shaksgam basin. In 1935 one partner of VISSER's expedition (R. WJSS) reached the eastern side of the Singhié glacier from the Karakorum pass (fig. 2).

the one of the northern Rimu glacier. Near this confluence, the valley-floor is wide and covered with alluvial material. A small valley comes down from the right flank of the Shaksgam, between this tributary and the above mentioned confluence. Further upstream, it becomes wider and contains a tongue of the Lungpa Marpo glacier. This glacier entirely fills a saddle at the head of the valley; another tongue of the glacier descends into the Lungmo-che valley.

The lower part of the upper Shaksgam, upstream from the Kyagar glacier, is relatively wide; its floor is covered with extensive alluvial material and is bordered by a series of lacustrine terraces. In 1926 the former lake, dammed by the ice-mass of the Kyagar tongue, was reduced to a pool, called Kyagar Tso (grey-white lake). The front of the glacier abutted against the northern steep flank of the Shaksgam valley. In summer 1926 a number of ice patches resting on the lacustrine terraces gave evidence that during the previous winter the lake had reached that level.

This section of the valley is about 26 km long; the average gradient is 2‰.

The second and longest section of the Shaksgam (54,4 km) has five glacial dams, three of which bar the talweg completely between the Kyagar and the Gasherbrum glaciers. Generally the valley is ESE-WNW directed, except in the final 6 km, where the direction becomes NNW. The gradient is variable and generally there is a considerable decrease just upstream from the glacial dams, and an increase below them. These features are particularly marked upstream and downstream from the Kyagar glacier. The average gradient is about 1,2‰ and the maximum does not exceed 2‰.

From the beginning of this section and for a length of over 3 km, the valley-floor is invaded by the tongue of the Kyagar glacier which is riddled with ice ridges and pinnacles (pl. XXXIV).

Downstream from the Kyagar, the valley is relatively wide and is flanked on the right side by the high calcareous rocky walls of the Chikchi-ri (Island Ridge) and on the opposite side by gentler slopes. The valley-floor is wide and covered with alluvial material and by wide talus belts on the foot of the Chikchi-ri. Here the discarge of the river is more reduced then upstream.

A small stream descends from the right side of a small valley separating the Chikchi-ri from the Marpo Rgyang (Red Wall). A short distance further upstream, on the flank of the Marpo Rgyang, there is a small, but characteristic moraine rampart. Perhaps it marks the arrest of an ice tongue which overflowed a gap of the overhanging ridge (1).

(1) Take account that the description of the valley refers to the 1926 situation.

On the opposite side of the valley there is a series of rocky terraces at an altitude of about 5070 m, that is 170 m above the river course. At about one kilometre from the front of the Singhié glacier — which, like the Kyagar, dams the valley completely — the river-banks are covered with sand which increases gradually and, near the glacier front, covers the valley-floor completely. Occasionally heaped in small dunes are also present (pl. XXXI fig. 1).

The sand undoubtedly represents the deposits of a barrier lake dammed by the Singhié glacier. The existance of an old lake here is also evidenced by small remnants of terraces preserved on both flanks of the valley slightly above the river.

The Singhié glacier coming from a tributary valley, extends its tongue within the Shaksgam valley and abuts its front against the right flank of the valley itself. The surface of the glacier, like that of the Kyagar glacier, is riddled with numerous ice-ridges and pinnacles (pl. XXVI-XXIX). In summer 1929, the melt waters of the glacier formed a shallow lakelet from which gravel-bars emerged. Numerous blocks of ice fallen from the glacier front into the small lake, floated downstream on the outlet. Downstream from the lake the discharge of the Shaksgam was much greater than upstream from the Singhié glacier.

Here also the river-bed is very wide and the Shaksgam river meanders from one side of the valley to the other, flowing through coarse gravel and pebbles. Occasional large rounded blocks of limestone rise above the alluvial material. These blocks were probably carried down the valley by flood waters caused by the sudden bursting of dammed lakes. Rather shallow kettle holes of a few meters diameter were also observed in the river-bed. They were produced by the melting of the ice blocks buried in the gravels. In fact further downstream, I noticed the summit of an ice block outcropping from the alluvial material.

The Shaksgam valley is much wider between the Singhié and Staghar glaciers than upstream. This is due to the presence of black slates, viz. a rock less resistant to erosion. The mountain slopes are not steep and are often covered by talus. The uppermost part of the right hand slope on the contrary consists of walls with two-crested ridges composed of two limestone layers separated by a band of shales.

All lateral valleys are small and in most cases contain ice-tongues in their upper part. The valley mouths generally show alluvial fans which are occasionally very large and their lower margins are partly eroded by the river. Here the valley floor is also overfilled with alluvial material, but less than upstream from the Singhié glacier.

Near the front of the Staghar glacier, which is partly riddled with ice-pinnacles, there are two isolated hillocks rising from the Shaksgam floor. One is on the right side and partly hidden by the lateral moraine; the other, about 40 m long and 7-8 m high, is located between the glacier front and the right side of the valley. In this connection it has to be remembered that unlike the two above-mentioned glaciers, in 1926 the Staghar did not entirely dam the Shaksgam valley, but leaved a passage about 150 m wide, between the ice and the hillocks; the river flowed through it. The hillocks are round and typically « moutonné » showing that they were subject to the erosive action of the ice which isolated and smoothed them.

Between the Staghar and Urdok glaciers the valley, flanked between two high mountain ranges, becomes noticeably narrower except in the last part, just upstream from the Urdok glacier. On the left side the ridges lower gradually becoming a sort of long spur at the confluence of the two valleys. Further upstream, however, the spur is more precipitous with high rocky walls overlooking the river (pl. XXI).

Immediately downstream from the Staghar another glacier tongue, surrounded by a very large moraine rampart, enters the Shaksgam valley but do not damm it. Small valleys cut the right side of the Shaksgam starting below the impending ridges. Alluvial fans, deeply eroded by the river, occur near the valley-mouths. The largest of them is located at about 4,5 km upstream from the Urdok glacier and end like the others, with a narrow gorge.

The Shaksgam floor is quite wide as much as one kilometre upstream from the Urdok glacier. The gravel surface is irregular and strewed with numerous rocky blocks (some of them gigantic) and number of holes produced by the melting of buried ice-blocks (pl. XXIV fig. 1).

The features of the valley resemble the ones produced by waters suddenly flooding from a burst dam. Probably they were produced by the waters of Singhié or Staghar barrier ice-lakes.

It must also be added that the presence of the moraine rampart in the river-bed just downstream from the Staghar glacier, displaced the Shaksgham river towards the right bank where most of the alluvial material was deposited. The opposite side, however, is noticeably lower and even below the water table. Near the left bank there is a small elongated lake covering about one hectare of surface. This lake has an outlet which further downstream enters a swampy area and then continues along the same river-bank. The lake originates not only from the ground waters fed by the glacier, but also from some springs.

About 6 km upstream from the Urdok glacier, the ESE-WNW borne valley turns north, and near the glacier front narrows into a gorge which is also dammed by several isolated rocky hillocks. The right moraine of the Urdok glacier rests on a calcareous hillock protruding towards the centre of the valley and facing an ice-smoothed knob about 10 m high.

Another rocky knob lies about 100 m further downstream, near the right bank, opposite to the mouth of a small lateral valley. It has a flat top on which glacial pebbles rest. Still further downstream there is another isolated knob, partly covered by drift and separated from the glacier by a small valley. The above mentioned gorge was called « Urdok-zgo » (Urdok door) because it resembles the entrance of a gigantic fortress (pl XXIV fig. 2).

Upstream from the latter rocky knob, the waters of the Shaksgam river spread over the valley floor and while one of the streams just touches the Urdok glacier front, another reaches the nearby glacier which dams the valley completely. Then the stream disappears under the glacier, near the right slope of the Shaksgam valley. At the foot of the slope a hole carved in the limestone by the running waters can be seen. In 1926 a passage about 1500 m wide was opened between the Urdok glacier and the valley slope. Although the front of Urdok and Gasherbrum glaciers were in close proximity a small valley opened between them.

The right side of the valley between Urdok and Gasherbrum glaciers shows a high rocky wall coated with talus. A small valley descends towards the end of the Gasherbrum glacier and the river disappearing below the ice reappears further downstream in the narrow gorge between the Gasherbrum glacier and the calcareous slope of the Shaksgam valley. The surface of the glacier is partly cracked into ice-pinnacles and ridges, but less than the Singhié and Staghar glaciers (pl. XV).

As already mentioned, the section of the Shaksgam valley between the Gasherbrum glacier and the Sarpo Laggo confluence (51.5 km) is the most irregular part of the whole valley. Taking account of its orientation the valley can be divided into three different parts: the upper one, 27 km long and SE-NW borne; the middle one, bending towards north ENE-WSW directed and 12 km long; and the lower one, having the same length and ESE-WNW direction.

The average gradient is approximately 1 %, but the one of the section just before Shaksgam Jangal (a place strewed with few dry bushes) is gentler.

The orographic characteristics of this section of the valley are somewhat different from those of the section further upstream.

Below the Gasherbrum glacier the valley narrows and becomes a deep gorge with high calcareous walls. Some of them descend vertically to the talweg while others have large talus deposits at their foot. Near the mouths of the lateral valleys there are some alluvial fans deeply eroded by the Shaksgam river.

Many fans have steep walls, several dozens of metres high, and show strange erosional shapes (pl. X).

A large valley containing the Skyang glacier joins the Shaksgam on the left below the front of the Gasherbrum glacier. The upper part of the Skyang valley borders the basin of the Baltoro glacier.

Downstream two valleys carry the melt waters of two glaciers not visible from the bottom of the Shaksgam valley.

The left slope, up to Gasherbrum Jilga, is much gentler than the opposite one, which has high limestone walls. Three small streams running through deep and narrow gullies, join together in front of Gasherbrum Jilga, on the right side of the valley. Near the confluence there are remnants of alluvial fans with high steep walls. Downstream from Gasherbrum Jilga the left slope suddenly becomes very steep, while the right slope becomes gentler especially in its lower part.

The confluence of one of the largest valleys which enter the Shaksgam from the right, occurs at about 20 km from the Gasherbrum glacier. This valley is called Bya Lungma, and has a WNW direction. At its end the river has produced a large alluvial fan which is still well preserved (pl. XIV fig. 1). The lower narrow part of the valley is mostly covered by water; in the upper part the slopes are quite steep, and very steep rocky walls extend towards the main ridges. At the junction the rocky spurs are completely rounded. The gradient of the river bed upstream from the fan, increases very rapidly.

Downstream from the confluence of Bya Lungma, on the right side of the Shaksgam valley, there is the small oasis of Durbin Jangal (1) the waters of which originate from a group of hot springs situated on the mountain slope.

The oasis lies at an altitude of 4200 m a.s.l. and consists of a large group of shrubs located in a recess on the right hand slope between the confluence of two lateral valleys, one of which has already been mentioned. The other valley is smaller and is situated near to the previous one.

The springs consist of five separate water-outlets on the mountain slope at an altitude of 109 m above the Shaksgam river. They are thermal springs.

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(1) *Durbin* means field-glass: the name was introduced by YOUNGHUSBAND having lost there his field-glass.

On July 5, 1929, the temperature of the water was 24°.4 C., whereas the temperature of the air was 3°.3 C.

The water was clear with neither smell nor taste; it must, however, be rich in Calcium carbonate since below the springs there are some travertine deposits. The streams flowing from the springs join together in the Shaksgam river bed to form a pool which was partly covered with vegetation. This is the last oasis that one meets going up along the Shaksgam valley before reaching the Gasherbrum glacier.

Between the oasis and the first bend, on the left side, the valley is bordered by high rocky walls cut by very deep narrow gorges. The opposite slope is gentler and also the three lateral valleys are wider. On this side the mountain slopes are covered with extensive talus deposits lying on older talus fans near to the confluence of the valleys.

The lateral streams cut these fans deeply and deposited new debris at the end of their furrows.

The Shaksgam valley flor is relatively flat and is covered with gravel. Kettle holes and large blocks are also common in this valley section up to the Gasherbrum glacier and, as will be mentioned later, they also occur further downstream, almost up to its confluence.

Immediately downstream from the first bend on the right an apparently insignificant small valley descends from the Aghil pass (4780 m) (pl. XIII fig. 2). At a short distance further upstream there is another short valley, containing a river carrying the melt waters of a small glacier. Still further upstream there is a large red talus fan, consisting of marly limestone detritus of that colour (Marpo Chholong).

Between the first and the second bend there is no appreciable change in the morphologic characteristics of the Shaksgam valley. On its right side three small valleys meet, the smallest carries the melt waters of a small glacier, the other two are more important and descend from north-west. The one (Skam Lungpa) ends with a very wide thalweg which joins a large talus fan — flanked by the remnants of an older one — which downstream has walls some tens of metres high (pl. XIII fig. 1). Further upstream this valley narrows appreciably and winds slightly. In the background there is a high limestone ridge which falls down abruptly towards the west.

The lower and smaller valley descends from the west. Near the confluence the stream has eroded the old talus fan, leaving only, on the left side, a pier-shaped strip of ground dividing the two river courses. At the time of our expedition a new talus fan was forming within the old one.

The Aghil and Skam valleys are separated by two characteristic crested and spired mountain ranges, called Choto-so and composed of calcareous-dolomitic rocks. At the foot of their slopes there are large amounts of talus thus making them look like the Dolomites of the Italian Eastern Alps (pl. XII fig. 2).

The secondary valleys descending from the left are extraordinarily narrow and deep, true crevasses opened in the slopes, and near their mouths they still show some remnants of intensively eroded old talus fans which are also dissected by high walls.

Downstream from the confluence with the Skam valley, the Shaksgam becomes even narrower. Two high rocky walls enclose a flat gravelly river-bed flanked by the lower walls of the eroded fans which form two almost continuous strips on both sides and look like a system of terraces (pl. XI). On the left side of the valley near our « Dolomite Camp » there is a small limestone terrace, two to three metres above the river-bed, indicating a recent erosion activity by the Shaksgam river.

The Sarpo Laggo confluence is marked by an isolated limestone hillock (Tek-ri) which rises 160 m above the river bed and is in line with a spur of the left side of the valley (pl. IX fig. 2). The summit and flanks of Tek-ri are round and smooth, but they form a cliff falling sheer to the Shaksgam river. Small patches of till are scattered on the spur which is overlooked by a high rocky peak smoothed by the glacial erosion; the summit is strewn with glacial pebbles.

Up to a point near the mouth of the last gorge, the Shaksgam valley floor is relatively flat and gravelly. There are some rounded blocks in the alluvial deposits and kettle holes. The last ones can be found as far as beyond the bend: they have a diameter of two to five metres and are slightly less deep.

Immediately downstream from the Tek-ri hillock, the waters of the Sarpo Laggo and Shaksgam rivers join together and the valley suddenly widens; the right slope remains steep, but the left one becomes gentler and its cirques contain small glaciers below the highest ridges. At the mouths of these valleys large alluvial fans strew down (pl. IX fig. 1).

II. PREVIOUS GEOLOGIC RESEARCH

The first geologic research on the Shaksgam valley dates back to 1930. In that year I published two papers dealing with the preliminary conclusions of the DUKE OF SPOLETO expedition to the Karakorum (1929). These reports describe the various rocks outcropping in the area and the local tectonics, as well as the fossiliferous Permo-Carboniferous and Triassic formations. The existence of ancient glaciations is also mentioned. Later on two preliminary paleontologic accounts were published: one by A. SILVESTRI (1934) on the Carboniferous and Permian fusulinids, the other by G. MERLA (1935) on the Permian fossil shells that I collected.

The official volume of the expedition appeared in 1936. The volume contains a chapter on the geology of the Shaksgam valley (pp. 454-474), with nine geological sections and some lists of the Late Paleozoic fossils.

I would like to point out that the authors who later dealt with the geology of Central Asia were not aware of this publications. The text also contains the first report on the geology of the Gasherbrum and Urdok valleys, which — as we are aware — are tributaries of the Shaksgam valley. I will deal with this subject in more details in the following chapters.

Up to the present time little has been added to our knowledge of that region. However an interesting report by J. B. AUDEN (1938) — a member of the SHIPTON expedition (1937) — should be quoted. This brief report deals with the Shaksgam valley between the Aghil pass and the Skamri valley. AUDEN suggested the following stratigraphic sequence for the Aghil mountains range and the western section of the Shaksgam basin:

Pamirs (Hayden, 1915)	Aghil and Central Shaksgam (Auden, 1938)	Depsang and Yarkand (De Terra, 1932)
Pamir limestone	Aghil Series: Triassic and Jurassic	*Continental* Yarkand Series
	Shaksgam Series: Permo-Carboniferous	Marine Permo-Carboniferous
	.... ? *disconformity*	*Continental* Tisnab Series
Sarikol shales and slates	Sarpo Laggo Series: Lower Palaeozoic and older	Kilian Series with Silurian and Devonian
	? Sarpo Laggo Series: ?	Karakasch Series
	Lamprophyre: post-Triassic and post-granite	
Granite: post Sarikol shales	Granodiorite and gneissose granite: post-Permo-Carboniferous	Granite: post-Kilian ? pre-Devonian
	Dolerite: post-Permo-Carboniferous	

The Permian fusulinids of a sample collected three miles south of Durbin Jangal, were described by C. C. Dunbar (1940).

The 1:250,000 geologic map surveyed by Auden during the expedition, remained unknown because it was not published. At the end of 1972 the author kindly supplied me with the map, which is dated 1938, 1947. Fig. 3 schematically reproduces Auden's geologic map.

I am indebted to Auden also for the geologic information he sent me and for some geologic cross-sections which are reproduced under his name in the present work.

The volume dealing with the geology of the area explored by the 1935 Visser expedition appeared in 1939. It contains no report on the local geology, but only paleontologic and petrographic descriptions and a short commentary by H. Renz, M. Reichel and R. Wyss.

A certain number of the Permian fossils was collected by R. Wyss in the

Shaksgam valley, mainly in its upper part, upstream from the Kyagar glacier. The fossils and two rock-samples come from the slopes between the Kyagar and Singhié glaciers.

The VISSER expedition reports did not mention any previous publication including those of the DUKE OF SPOLETO expedition, with the result that many scientists attributed the discovery of the Permian fossils in the Shaksgam valley to the VISSER expedition.

The numerous fossils collected in that valley by DESIO were later described in the IV-1 volume of the present collection (1965) by R. CIRY & M. AMIOT (Permian foraminifera) and N. FANTINI SESTINI (Permian corals, bryozoans, brachiopods, pelecypods, gastropods and cephalopods). The same volume contains the descriptions of a few specimens of Jurassic corals from Bdongo-la by N. FANTINI SESTINI.

In 1926 MASON's expedition found Late Jurassic ammonites in the southern part of the Aghil range, namely in the Chhe and As valleys, as well as in the « Low Col Stream ». This occurence is worth mentioning even if this area is not included in the Shaksgam valley. MASON did not describe anything, but only gives a list of 34 rock-samples, among them 12 fossiliferous, and some short notes.

In 1947 N. A. BELJAEVSKY published a short account on the geology of the Shaksgam valley (in Russian). The information deals with the stratigraphy and the tectonics, but the author does not specify clearly when he deals with the Karakorum range, when with the Aghil range or with the interposed Shaksgam valley.

The author distinguishes three formations in the stratigraphy of the examined area. They belong to the Late Paleozoic and are: the *Chatyr formation*, the *Nakhavan formation* and the *Barong formation*; they seem to be present also in the Shaksgam area. In connection with the second one, BELJAEVSKY also mentions a « Shansgam Valley » which may correspond to the Shaksgam one, but further in his text, referring to an « Early Cretaceous calcareous formation », the « Shaksgam valley » is explicitly mentioned, with reference to a manuscript on the Karakorum and Kun Lun by V. I. SERPUKHOV (1946).

BELJAEVSKY's report is quoted by many Russian authors, but his data are not included in the « Lexique Stratigraphique International » (1958) which deals with the URSS and is compiled by a Russian geological commission. Therefore I consider it unnecessary to further discuss these data.

The discovery of a fossiliferous Jurassic formation outcropping in the lower reaches of the Shaksgam valley was announced in a preliminary note by

A. DESIO and N. FANTINI in 1960 (1). Later this formation was called the Bdongo-la Formation (1964). The paleontology of this formation was thoroughly illustrated in a subsequent work by FANTINI SESTINI (1965).

The principal formations of the Western Karakorum and Shaksgam valley were briefly described by DESIO in another report (1963).

A geologic map of the Western Karakorum (scale 1 : 500,000) was published by DESIO in 1964; a large part of the Shaksgam valley is represented in it.

The geology of the Gasherbrum and Urdok valleys is expounded in a memoir by T. E. GATTINGER (1961). These informations due to some long distance observations, viz. from the Gasherbrum I ridge, are of no interest, since they were later invalidated (A. DESIO & B. ZANETTIN, 1970).

Publications referring only indirectly to the Shaksgam valley, will not be considered here.

(1) The samples were collected by DESIO during the 1929 expedition.

III. GEOLOGIC ITINERARIES

1. Introduction.

It has already been mentioned in the Introduction of this volume that the geologic information reported in this chapter was gathered during an expedition that had to face many logistic difficulties, first of all the limited authonomy. Consequently the author was often unable to carry out detailed field investigations. These were disjointed and incomplete since they were made during a march with a caravan of porters and most of the time I had to travel along a gravelly talweg or on glaciers and moreover I had to carry out the topographic survey. The observations made from a certain distance have not always been corroborated by rock samples for laboratory investigation, both because I lacked the time to collect them, and because I wanted to avoid overloading ourselves and the porters who were already carrying the considerable weight of supplies necessary to survive in such an arid and uninhabited country. Therefore many observations and a number of sight correlations could not be checked.

I want also to mention here that the geologic (stratigraphic and tectonic) sections inserted in these descriptive chapters, are copies of my field book sketches. Therefore they do not claim to be exact, but only indicative. The scale generally was later deduced from the topographic maps and therefore it is approximate.

Another difficulty in carrying out the stratigraphic survey was caused by the fact that most of the Shaksgam valley is almost parallel to the strike of the beds. In order to reconstruct the stratigraphic sequence and the tectonics it would have been necessary to explore the lateral valleys running perpendicular to the Shaksgam, but this was not always possible. The only lateral valley travelled over completely was the Urdok Glacier valley which, unfortunately, crosses the fold axes obliquely. Moreover, because of the presence of crevasses, lateral streams and other similar obstacles, to get near the slopes of a glacerized valley, is much more difficult and takes much more time. For these reasons I prefer dividing my report into itineraries. At the end of it I will try to coordinate all the data to outline the geologic structure of the Shaksgam valley. Nowadays we still do not know much more on the Shaksgam valley than what was in my brief reports published many years ago, particularly in 1936. Since then, however, the paleontologic collections, which previously had been only cursorily studied, were accurately examined, as well as the rock samples; as a result, the present study is not only more extensive than the 1936 one, which was only a short preliminary chapter in a publication of geographic character, but also contains some amendments suggested by the above mentioned determinations.

The geologic map enclosed in this volume was mostly compiled after my return to Italy on the base of my topographic and geologic field survey. Nevertheless the topography was mainly deduced from the MASON and SHIPTON expedition maps.

2. The Valley of the Sarpo Laggo Glacier.

2.1. INTRODUCTION. Downstream from the isolated Tek-ri hillock, which seems to dam the outlet of the Shaksgam gully, the valley becomes so wide that the gully seems to be a secondary branch of the Sarpo Laggo valley.

The larger stretch actually is formed by merging of the two valleys occupied by the Sarpo Laggo and Skamri glaciers in their upper portion upstream from Sughet Jangal.

The stretch in common derived its name from the Sarpo Laggo valley. Though this is the smaller of the two valleys, it was the only one to have a known local name since older times being an usual route for caravans coming from the Chinese Turkestan and directed to India through the two Muztagh passes located at its head. The other valley had no local name when was ascended by YOUNGHUSBAND (1889). This explorer firstly gave to the glacier the name of *Crevasse glacier*, but later he changed it into *Wali glacier*, after the name of his local guide. The 1937 SHIPTON expedition again modified the name into that of *Skamri glacier* from the name of the mountain ridge rising at its head and dividing it from the Panmah glacier.

The Sarpo Laggo valley has a watershed in common with the Baltoro valley toward the south, with the Skamri valley to the north and with the Panmah valley to the west. The last one marks also the division between the drainage basins of the Yarkand and the Indus rivers.

The eastern Muztagh pass is on the first watershed, the western pass on the last one.

According to my Balti porters the name Sarpo Laggo means *Yellow Peak* (sarpo or sarpho=yellow and laggo or lago=peak). The Sarpo Laggo valley trends SW-NE and has a length of about 31 km.

We may thus divide it into two sections: the lower one from the confluence of the Sarpo Laggo and Shaksgam rivers to the glacier end, the upper one from this later point to the valley head.

2.2. PREVIOUS GEOLOGIC KNOWLEDGE. The previous knowledge is based essentially on two sources. The first consists of two DESIO's reports (1930, 1936); one of them is a preliminary report but being written in English it is more widely known. These were the first reports to give information on the geologic constitution of the whole valley and the surrounding ones. A geologic sketch-map of the valley at the scale 1:278,000 enclosed in the last report (fig. 3) showed the surface distribution of the following stratigraphic units:

(a) Permo-Triassic fossiliferous tight limestone,

(b) Conglomerate and arenaceous limestone with *Fusulina*,

(c) Black phyllitic slates,

(d) Foliated plagioclase gneiss,

(e) Granite gneiss and granite.

We are indebted to J. B. AUDEN, member of the 1937 SHIPTON expedition, for other geologic information. These were published in two reports of 1938.

The stratigraphic scheme of the area visited by AUDEN is reproduced at page 20 of this volume. The topographic distribution of the different « series » (that I interpreted mostly as formations) is represented in a geologic sketch-map at the scale of 1:250,000. With the kind permit of the author this map is reproduced at reduced scale in fig. 4.

2.3. THE GEOLOGIC CONSTITUTION. Dealing now with the Sarpo Laggo valley, I like to inform the reader that owing to the loss of the samples I collected in

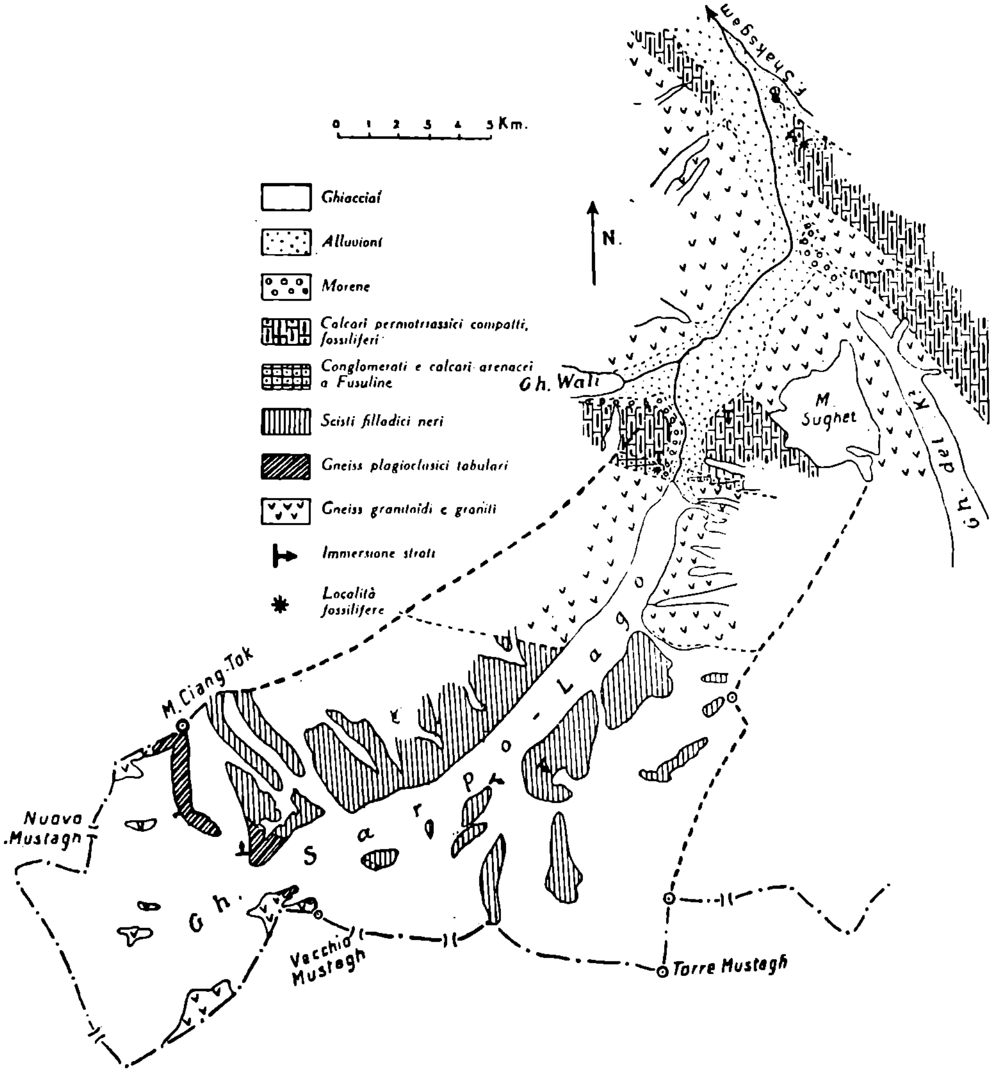

Fig. 3 – *The first geologic map of the Sarpo Laggo Valley* (Desio, 1929-1936).

this valley (1) and to the lack of other samples, I am forced to refer only to my field notes and to the geologic studies of the surrounding areas. Among the better known areas from the geologic and petrographic point of view is the Baltoro valley (Desio & Zanettin 1970) the northern slope of which can supply

(1) All the samples collected in the Shaksgam valley downstream from Durbin Jangal, and in the Sarpo Laggo valley, were lost because a porter emptied the box to put his garments and food inside it. The corals collected on the retour journey were saved since I kept them in my rucksack.

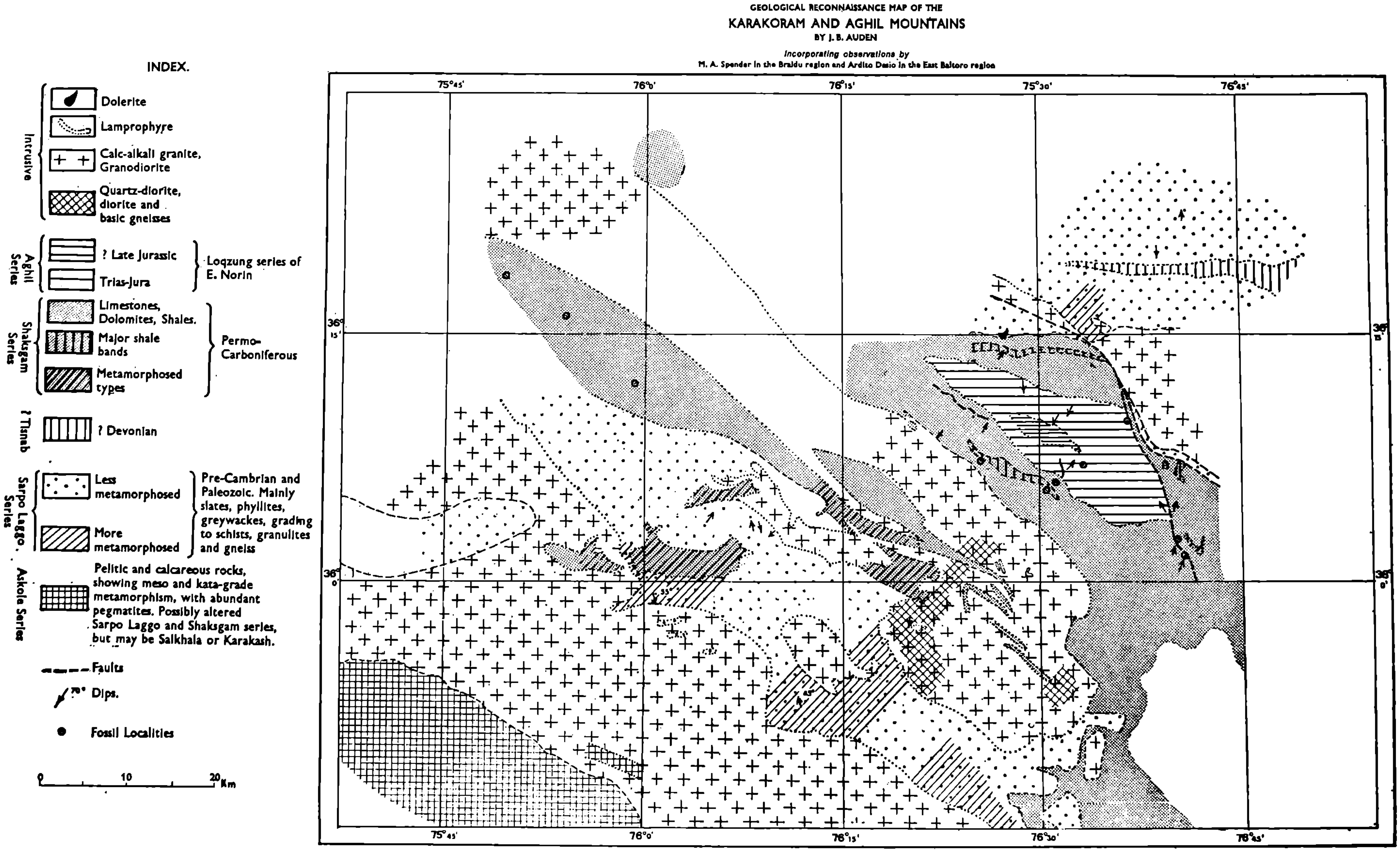

Fig. 4. – *The Geologic Reconnaissance Map of the Karakorum and Anghil Mountains* by J. B. Auden (1938, 1948)

information on the southern slope of the Sarpo Laggo valley. Other data on the western slope can be supplied by my 1936 report on the Panmah valley, together with some still unpublished data. Also AUDEN's information on the geology of that area can complete the present knowledge on the Sarpo Laggo valley.

As I announced in my 1936 report the glacier basin of Sarpo Laggo is almost entirely made up of igneous and metamorphic rocks. Traces of sedimentary rocks I have seen neither in situ nor in the moraines with the exception of the small outcrop along the fault crossing the valley near the glacier front (p. 37).

The geolithologic constitution is rather uniform: shales, gneiss, and granite are the prevailing lithotypes: they form three belts crossing the valley in ESE-WNW direction (fig. 3).

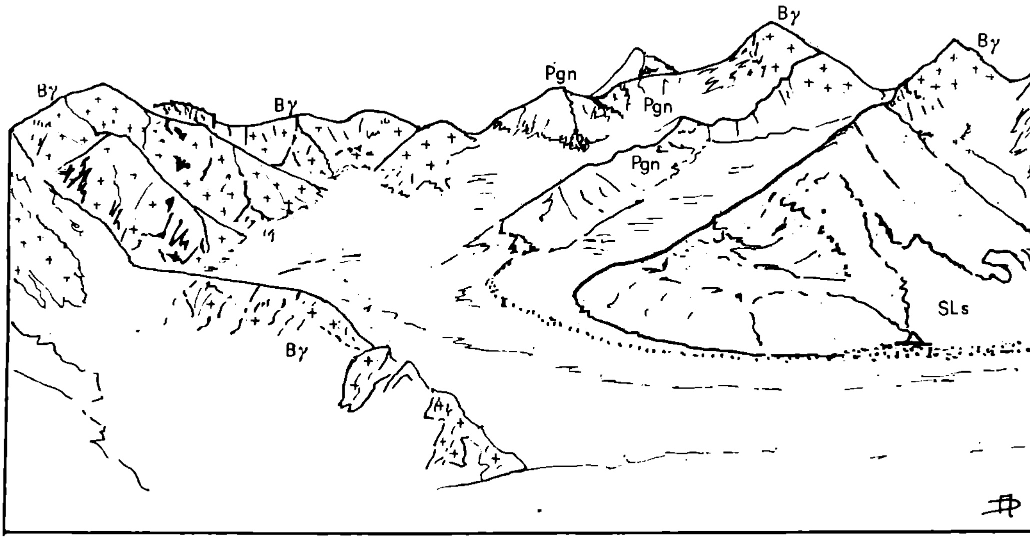

Fig. 5 - *Geologic view of the head of the Sarpo Laggo Valley.*
Bγ Baltoro Granite, Pgn peribatholithic gneiss, SLs Sarpo Laggo Slates (grey).

The upper part of the Sarpo Laggo basin is entirely composed of gneiss and granite (fig. 5, pl. I and pl. II fig. 1). Although no sample was examined petrographically, I assume that most of the rocks belong to the same lithotypes outcropping in the contiguous basins of Baltoro and Panmah. In this connection I remember that the middle and upper Sarpo Laggo valley is represented in the geologic map of the Baltoro basin at the scale of 1:100,000 (DESIO & ZANETTIN 1970) and more ample lithologic data are contained in the memoir of the same authors. On the ground of the above information we can deduce that all the ridges surrounding the catchment basin of the glacier are composed of Baltoro granite. The petrographic facies of this granite is described in the above mentioned memoir (p. 190 and following).

I would like only to point out here what we have written on the granitic rocks cropping out in the common area of the Baltoro, Panmah and Sarpo Laggo basins. In the upper Tramgo and Muztagh valleys bordering the upper Sarpo Laggo valley (p. 197) « the steep sides of the deep Tramgo valley are composed of a homogeneous granite which gives rise to some wonderful spires, such as Ainablak, Tramgo Towers, etc. The relatively uniform nature of the granite is visible on the walls and peaks as far as the head of the valley, and even into the basin of the Panmah glacier ».

The structure of the granite changes in a north-east direction within the upper basin of the Muztagh glacier (fig. 6). On the northrn wall of the Karphogang the granite is striped with numerous lenses of banded gneiss, giving the appearance of an arterite (pl. III).

The granite outcrops disappear north of the Karphogang and West Muzthagh pass where it is replaced by peribatholithic plagioclase gneiss. This rock constitutes the divide between the Sarpo Laggo and Chiring glaciers and spreads toward east over the north-east slope of the upper Chiring valley, towards north on the Karpo-go group and towards east up to the western slope of the Lekhar Glacier valley. The granite is crossed by pegmatite dykes, fragments of which are frequent in morainic debris.

In that area the ice blanket is extraordinarily wide so that the bedrock outcrops are sporadic, and only on the steepest walls.

The only outcrops of the bedrock I was able to examine were those exposed on the slopes of the East Muztagh and in the Sarpo Laggo saddle. At the East Muztagh the outcrops consist of peribatholithic gneiss, while at the Sarpo Laggo saddle they show Baltoro granite. The gneiss layers dip 30°-40° toward north.

From Chang Tok one can see the contact of the plagioclase gneiss with an epimetamorphic complex composing the central belt of the valley and running over the highest ridge which flanks the Karphogang glacier across a small saddle leading to the Moni glacier. This complex, which in the 1936 geologic skechmap was called « black phyllitic schist », is essentially made of black slates grading into phyllites and dark foliated gneiss. In my 1963 report I attributed the role of formation to this complex with the name « Sarpo Laggo Slates »; it mostly corresponds to the « Sarpo Laggo Series » in AUDEN's geologic map (fig. 4). According to this author it is composed by « mainly slates, phyllites, greywackes, grading to schists, granulites and gneiss » and is referred to Pre-Cambrian and Paleozoic.

As regards nomenclature, the name « Sarpo Laggo Slates » for this formation can be considered as a valid name. Nevertheless, a similar formation outcropping in the Baltoro basin was called « Baltoro black slates » and it represents the Singhié Shales (DESIO & ZANETTIN 1970) (1).

The lack of samples of the Sarpo Laggo slates is a hinderance for establishing the real identity of the two formations. Anyhow, generally at the base of the Sarpo Laggo sequence there is a grey foliated micaceous gneiss which upwards alternate with dark phyllite. Further upwards black slates, sometime associated with chloritic and amphibolic schists, become the prevailing rocks.

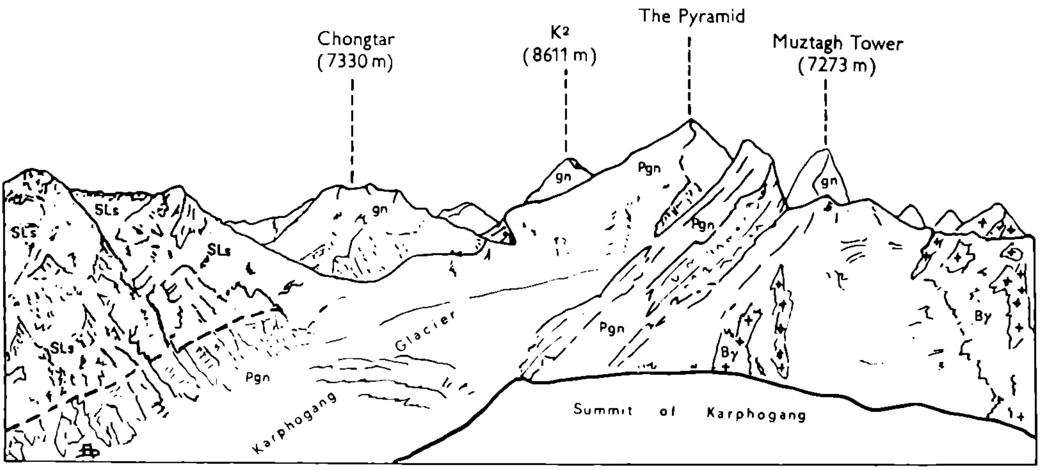

Fig. 6 – *Geologic view from the summit of the Karphogang toward east.*
Bγ Baltoro Granite, Pgn peribatholithic gneiss, gn gneiss in general, SLs Sarpo Laggo Slates

On the right hand moraine of the Karphogang glacier I have seen only fragments of plagioclase gneiss and Baltoro granite. Near Chang Tok the left hand moraine of Sarpo Laggo glacier, which collects the materials coming down from left hand tributary glaciers, is mostly composed by black slates, secondarily by grey foliated micaceous gneiss, whitish granite and pegmatite.

The slates and the dark foliated gneiss constitute all the slopes overlooking Chang Tok and spread several kilometres downstream on both sides of the Sarpo Laggo valley. The geologic constitution of the surrounding mountains is revealed also in the distance not only by the colour of the rocks, but also by the rounded profiles of the hills (pl. II fig. 2).

(1) In the geologic map accompanying the same work the name « Sarpo Laggo gneiss » is applied to a different formation outcropping downstream. I will deal with it later on.

The Sarpo Laggo slates must extend toward the north as far as the watershed of the small glaciers ending near Chang Tok.

The floating moraine of the glaciers meeting Sarpo Laggo downstream from that locality contains only black slates, grey micaceous gneiss and few pieces of pegmatite which possibly represent detrital fragment of dykes crossing the older formations.

In the area between Chang Tok and Moni Bransa AUDEN noticed the following rock types: black slates, banded phyllites mainly dark in colour, chiastolite (?) phyllites, dull grey quartzites.

The same author noticed lamprophyre dykes intruded into dark mica-schists about 1 km north-east from Moni Bransa.

Near Moni Bransa light grey gneiss is intercalated in the black slates. The same rocks, dipping 25° to 45° south-east, outcrop on the opposite side of the valley. It seems that the gneiss is much more frequent in proximity of the north-west watershed of the valley, for the lateral glaciers sloping down near Moni Bransa (pl. IV fig. 1) bear numerous fragments of that rock. Downstream from Moni Bransa granite dykes, too, are frequent.

The black slates are widespread toward the west in the lower Moni valley and they seem to continue in the upper South Chongtar glacier valley. The lack of knowledge on this area is also due to the presence of the wide ice cover. The Summa-ri ridge rising at the head of the same valley is composed of Baltoro black slates (DESIO & ZANETTIN 1970) and the distance between the two black slate outcrops is only 9 km. This situation substantiates the hypothesis of the existence of a continuity between the two black slate outcrops and consequently of a possible correlation of these beds.

Further downstream from Moni Bransa, the Sarpo Laggo slates grade into a gneiss complex (pl. IV fig. 2) of different petrographic composition, called « Sarpo Laggo Gneiss » in the Baltoro geologic map. Porphyroblastic gneiss, biotite and amphibole gneiss with intercalations of green schists (chlorite schists, amphibolite etc.) form this metamorphic complex. Evidently the above quoted name is to be changed for the homonymy with the Sarpo Laggo Slates, which have the priority.

In the memoir on Baltoro geology (DESIO & ZANETTIN 1970) this metamorphic complex is compared with the gneiss complex outcropping in the western slope of the Muztagh Tower. I will recall in this connection that « we have called the metamorphic formation, composed of biotite-amphibole gneiss and amphibolite, associated with tonalitic gneiss of the Muztagh Tower, the *Muztagh Tower Gneiss* since it represents a distinct lithostratigraphical unit ».

Furthermore in my field book I mention the frequent presence of K^2 Gneiss in this complex, and this assertion can be explained by the fact that in the Muztagh Tower area the porphyroblastic gneiss, lying close to the fine-grained paragneiss, is similar, both in texture and mineralogy, to some facies of the K^2 augen gneiss, from which it can be distinguished by the absence, or very low content, of potash feldspar.

I think it may be useful to report here what ZANETTIN and I have written in the above mentioned « Geology of the Baltoro Basin » on the Muztagh Tower Gneiss (page 179).

« Most of the Muztagh Tower is composed of an association of prevalently biotite-amphibole and tonalitic gneiss. Due to the large ice cover very little research was done in this region. Nevertheless, it was enough to ascertain that the above-mentioned rock association represents a lithostratigraphic unit, perhaps of formation rank. We called this unit *Muztagh Tower Gneiss.* Other outcrops of this rock association within the Baltoro basin are unknown to us. Having so little petrographic data at our disposal, it is a difficult task to compare the Muztagh Tower Gneiss with other metamorphic formations of the Western Karakorum.

A somewhat similar complex crops out next to the Muztagh Tower, in the valley of the Sarpo Laggo glacier.

A gneiss complex has been recorded from the lower valley, which was geologically explored by DESIO in 1929, and AUDEN in 1937. The lithotypes of this stratigraphic sequence are not exactly known because the samples collected within the valley were lost by the porters. However, we do have the field descriptions. According to these notes the "Sarpo Laggo Series,, should be composed of porphyroblastic biotite and amphibole gneiss with intercalations of amphibolite and metadiorites. The similarity between the two "formations,, is thus very high, since we cannot make direct petrographical comparisons, we provisionally maintain the two names. Data are lacking for the determination of the geological age of both "formations,, ».

Even though the identity and the continuity between the outcrops of the Muztagh Tower and the lower Sarpo Laggo outcrops was not ascertained, nevertheless the Muztagh Tower formation is known to compose the Steste ridge which is located more northwards and precisely on the watershed of the South Chongtar glacier (a tributary of the Sarpo Laggo), that is not far toward the north from the gneiss complex of the lower Sarpo Laggo. The intermediate area is nearly completely buried below the ice and it was never explored. For these reasons in the volume on the Baltoro geology we maintained separated the two formations which should perhaps be unified under the name of *Muztagh Tower Gneiss.*

In front of the North Chongtar glacier junction, on the left side of the Sarpo Laggo valley, some outcrops appear to consist of grey and greenish amphibolic augen gneiss while on the opposite side black slate intercalations are still to be found.

A few kilometres downstream, gneiss layers dip 70°-80° WSW, and they keep the same attitude further northward. Occasionally the rock is crossed by dykes of a green rock not well identified (perhaps dacite).

The gneiss complex disappears suddenly on the left hand side of the valley, a few hundreds metres from the glacier front. A fault (*Sarpo Laggo Fault*) separates them from the sedimentary formations. Near the contact the gneiss shows a porphyritic facies with yellow-orange weathered surfaces.

In AUDEN's geologic map (fig. 4) this gneissic complex is represented under the name of « Quartz-diorite, diorite and basic gneisses ». I suppose that together with the above mentioned gneiss also diorite may outcrop even though it is not mentioned in my field notes.

The limits of the different rock units are not the same in AUDEN's and in my sketch-maps and I do not know which of them is the more exact. It is easy to understand these differences on account of the short time devoted by both travellers to the investigations, the great extent of the ice cover and the logistic difficulties in visiting that area.

3. The Valley of the Skamri Glacier.

3.1. INTRODUCTION. As I have briefly mentioned in the preceding paragraph, the Skamri valley is mostly occupied by the glacier whose meltwaters feed the stream wich joins the Sarpo Laggo river near Sughet Jangal.

The valley has an east-west trend and a length of about 39 km (41 km along the Wesm pass branch) of which 32 km are filled by the glacier tongue. To the west the valley borders on the Braldu Glacier valley, to the south-west on the Panmah Glacier valley, to the south-east on the Sarpo Laggo valley.

3.2. GEOLOGIC CONSTITUTION. The only available geologic data that we have on this valley so far are those recorded by J. B. AUDEN during the 1937 SHIPTON expedition. I will try to report them here utilizing the summary data published by AUDEN, and informations I had from him directly. Among the last ones I will especially quote his unpublished geologic map at the scale 1:250,000 (fig. 4) and the geologic section across the Skamri valley at the scale of 1:100,000 (fig. 7) (1).

As a premise to this geologic summary I wish to emphasize the general trend (WNW-ESE) of the layers so that being those of the Skamri valley on the strike line of the of Sarpo Laggo ones, most of the stratigraphic units of one valley are to be present also in the other.

In the lower Skamri glacial valley the rocks of the Shaksgam Formation, locally with metamorphic facies, alternate with « Calk-alkali granite, Granodiorite ». Particular interesting is the Crown, a peak towering on the northern side of the lower Skamri valley.

I call here what AUDEN (1938) has written about this site: « By the K² glacier and toward the west the dark limestones [of the Shaksgam Formation] lose their colour and turn more into white marmors. This is well seen up the Crown glacier, west of the peak 23,829 feet from the moraines of which fossiliferous (unindentifiable) ferrugineous limestones were collected as partially transformed marbles ».

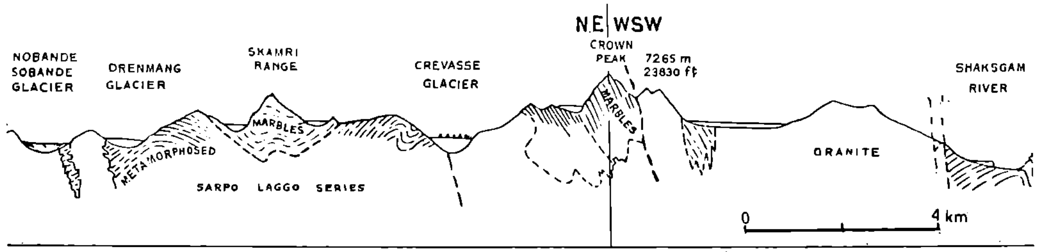

Fig. 7 - *Facsimile of a geologic section across the Skamri Valley by* J. B. AUDEN (1938).

The upper Skamri valley is mostly composed of the socalled « Sarpo Laggo series » (= Sarpo Laggo Slates) more or less metamorphic, referred by AUDEN to Pre-Cambrian and Paleozoic. As we have seen (p. 30) I suppose that the Sarpo Laggo Slates are correlatable with the Baltoro Slates which were referred to Carboniferous (DESIO & ZANETTIN 1970).

The ridges overlooking the valley to the north are mostly composed of rocks of the Shaksgam Formation showing metamorphic facies toward north-

(1) This is the western part of the section. The entire section continues to the east as far as the Yarkand river. For the eastern part see the section fig. 40.

Pag. 34 fig. 7 – This figure is incomplete: the sketch below may integrate it.

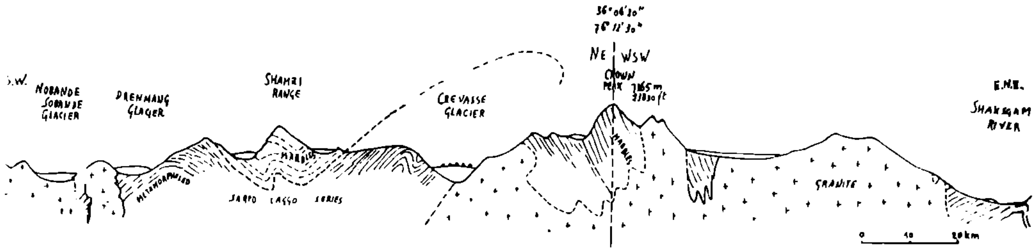

Fig. 7. – *Facsimile of a geologic section across the Skamri Valley by* J. B. AUDEN (1938.)

Pag. 78 fig. 36′ – In this page one figure was omitted. Please insert the following one.

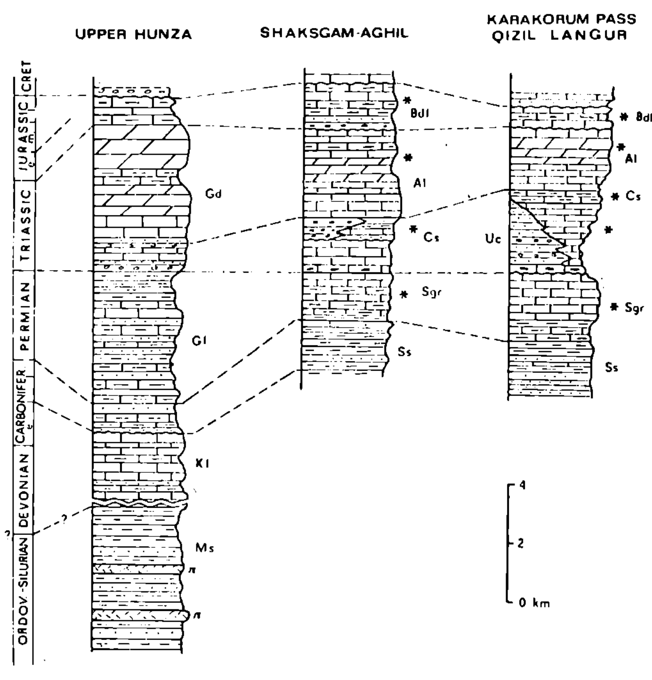

Fig. 36′ – *Correlation of the stratigraphy of Upper Hunza, Aghil, Karakorum Pass and Qizil Lungur series.*
Gd = Gujal Dolomite, Gf = Gircha Formation, Kf = Kilik Formation, Ms = Misgar Slates, Bdf = Bdongo formation, Al = Aghil Limestone, Cs = Chikchi-ri Shales, Uc = Urdok Conglomerate, Sgr = Shaksgam Formation, Ss = Singhié Shales, π = porphyritic dacite, * fossils.

Pag. 61 line 9 – *Hemiphtichina* corrige *Hemiptichina*

Pag. 94 line 27 – *Productus puntatus* corrige *Productus punctatus* east. They supplied also some fossils from beyond the northern watershed, on the Braldu glacier side.

In the area around the junction of the first glacier branch coming from the south, AUDEN « found a series of quartzo-pelitic rocks, clearly bedded, but in some respect resembling paragneiss. In hand specimen some of the rocks looked igneous in origin, but megascopically in the field the series have a bedded sedimentary appearance ». In my opinion these rocks belong to the Sarpo Laggo Slates formation.

As to the south-west slope, AUDEN (1938) wrote: « Turning southwards from the Crevasse glacier [= Skamri glacier] across the Karakorum watershed into the Panmah region, a syncline of marbles and pelitic rocks is crossed, with an east-west axis running along the Skamri range. The south limb of this syncline, which is seen above the Nobande Sobande glacier, contains rocks of the following types: coarse marbles, fine-grained biotite-schists, quartz-biotite-granulites and banded green calc-silicate hornfels, types which are common in the Askole area. The same pelitic rocks, which along the Crevasse glacier were in form of slates, are to the south altered to biotite granulites and schists ».

To the above mentioned data I can add some other information that I got from the southern side of the Skamri range (Desio 1936).

Between the Drenmang saddle and the Margedi saddle (5475 m) the range is constituted of a sequence of mostly calcareous beds, about 2000 m thick. The prevailing lithotypes are white and yellowish locally banded waxy limestone grading to marble and interlayered with black slates. The interlayers increase in thickness downwards until they become predominant.

White marbles alternating with biotite-plagioclase quartziferous gneiss, crossed by andesite (29KD-101) dykes outcrop below the black slates. The lowers beds are in contact with the granite and the gneiss granite of the Bobisghir peak.

The Skamri calcareous beds are folded in a wide but short syncline followed to the south by an anticline with black slates in the core, running along the foot of the range.

Among the clasts of black rocks composing the floating moraine coming from the foot of the Skamri range, near the junction of the Drenmang glacier, I collected a specimen of *Fenestella* (pl. XXXIII fig. 2). The fossil is preserved into a grey-blackish amphibolic arenaceous and carbonaceous shale described in the paragraph VIII-3. I thoroughly investigated the morainic debris and the outcrop of similar rocks at the foot of the mountain from which came the moraine in the hope to find other fossils, but without success.

Nevertheless the fossile probably comes from an outcrop composed of a sequence of beds 30 m thick dipping 70° S 10° E. Some layers are more metamorphosed, like phyllites, other less. Further upwards follows a thick bed of white saccharoidal and waxy limestone with cinder-grey veins like cipollino and yellowish weathered surfaces, 1,50 m thick. Upward micaceous calc-schists alternating with thick beds of saccharoidal limestone follow until they grade into the main white-grey beds, some hundreds of metres thick, with a black band near the bottom.

Among the debris spread at the foot of the wall there were also some pieces of plagioclase gneiss coming perhaps from the foot of the wall.

The source-bed of the *Fenestella* is not known: probably it is the above mentioned black band.

The knowledge on the southern slope of the Skamri range can be extended to the opposite side of the range, that is to the Skamri glacier valley. One problem to be faced now is to know the stratigraphic position of the upper Panmah *Fenestella* beds. The more suitable unit seems to be the Sarpo Laggo Slates which were correlated with the Singhié Shales (p. 30) belonging to Carboniferous. Probably the *Fenestella* beds represent the top of the Sarpo Laggo Slates grading upwards into a limestone sequence like the Singhié Slates grade upwards into the Shaksgam Formation.

Another possible interpretation is that the Skamri limestone unit belongs to the Aghil Limestone.

Nevertheless in the Shaksgam valley the Aghil Limestone is generally underlain by a conglomerate (Urdok Conglomerate) or a shaly horizon (Chikchi-ri Shales) and no traces of them are present in the upper Panmah valley.

Besides the presence of *Fenestella* there is another noteworthy element in favour of the first interpretation; in my field-book the same fossil is mentioned near the cairn of Gasherbrum Jilga, where the oldest Permian (Karachatyrian) fossils of the Shaksgam valley were collected. These reasons postulate the fact that the Skamri range limestones belong to the Permian series, but here they have a greater abundance of limestone than towards the east. For this reason I prefer to maintain the name still used in my 1:500,000 geologic map of the Western Karakorum (1964), that is *Skamri Limestone.*

Before concluding this section I want to refer to the presence of a conglomerate with purple and green-brown matrix mentioned by AUDEN in one of his letters. According to my opinion (page 37) this rock is in connection with a similar conglomerate outcropping along the fault crossing the Sarpo Laggo valley near the front of the glacier.

4. The Shaksgam Valley from the Lower Sarpo Laggo to the Skyang Glacier.

4.1. Lower Sarpo Laggo Valley. An important tectonic line runs near the front of the Sarpo Laggo glacier and marks the contact between the metamorphic formations of the Sarpo Laggo valley and the mainly sedimentary formations of the Shaksgam valley (1).

A sequence of light grey and dark grey limestones and black-blue arenaceous limestones with fusulinids is in contact with a gneiss complex (page 33); it outcrops a few hundreds of metres upstream from the front of the Sarpo Laggo glacier. In the limestones there are layers of bright red shales and also a multicoloured conglomerate. Only angular fragments of the latter rock were collected at the foot of a cliff composed of the previously mentioned rocks; therefore it is assumed that they came from the upper part of the sequence.

Near the contact, the limestones strike east-west and, where they are not vertical, dip southwards; but the contorsions of the beds immediately from the end of the glacier produce frequent variations in the local dip. Further downstream first we meet grey limestones, probably Permian, then black shales.

Below the confluence of the Skamri valley, green schists, micaceous and amphibole gneiss and granitoid gneiss outcrop. On the whole they are similar to the rocks occurring further upstream, near the end of the Sarpo Laggo glacier, and dipping southwards. Further downstream greenish granitoid gneiss with yellowish weathering like those which outcrop near the front of the Sarpo Laggo glacier, take the place of the green schists and gneiss.

The gneissic belt continue along the right hand side of the valley and probably also on the opposite side, as far as about half way between the mouth of the K^2 glacier valley and the lower end of the gorge of the Shaksgam river. Here the gneiss is in direct contact with grey and black reticulate limestones.

These strongly deformed and fractured limestones directly overlie, with a clear (tectonic) unconformity, the crystalline rocks. They form the crests of the two ranges separating the deep valleys of the K^2 and Sughet glaciers and also the gorge of the Shaksgam river. About 2 km from the lower end of the gorge, the limestone beds plunge 35^0 to ESE.

Fossils collected on the isolated hillock (Tek-ri) at the outlet of the Shaksgam river gorge might have given information about the age of the limestones; unfortunately the fossils were lost. Nevertheless, other fossils were collected

(1) See the geologic map enclosed at the end of this volume.

in the saddle on the north-west end of the ridge between the Shaksgam and the Sarpo Laggo valleys which was called « Bdongo-la » (1). These fossils will be mentioned below. A sample of *Megalodon* was collected by AUDEN « on south-west side of the 4350 m saddle between the Shaksgam and Sarpo Laggo » (2), that is on the Bdongo-la. That means that the limestone composing the ridge between the K^2 glacier and the Shaksgam valley belong to the Aghil Limestone.

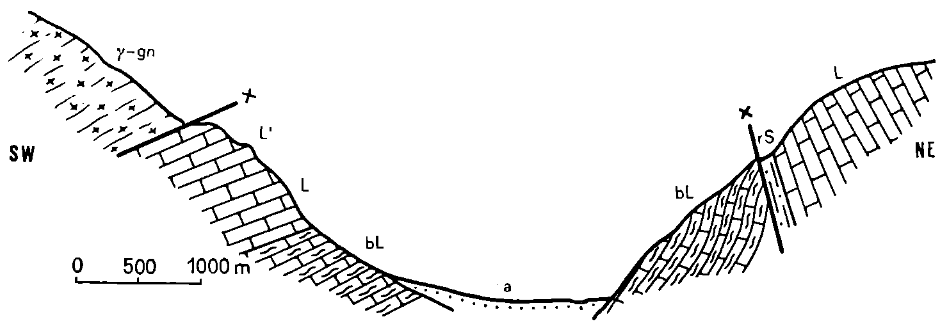

Fig. 8 – *Geologic section across the lower Shaksgam Valley about one mile downstream from the Sarpo Laggo river confluence.*
bL thin-bedded black limestone; L grey and light grey limestone and dolomite; L' idem but black; rS red shales; γ-gn gneiss granite; a alluvial deposits; x fault.

From the summit of Tek-ri hillock it is possible to observe the flanks of the Shaksgam valley (fig. 8 and pl. IX fig. 1). The right flank forming the southwestern side of the Khorkun Range, consists of black and grey limestones. Towards the foot of the slope, the limestones dip steeply. They are in contact by a fault with red schistose rocks outcropping in the lower beds of a thick, alternation of black, grey and white limestones, with few intercalations of black shales in the upper part. The latter ones become thinner and disappear northwards.

The fault dividing the two limestone blocks seems to continue downstream for a long while and to be an important element of the local tectonics. Probably also the Shaksgam valley downstream from Tek-ri was hollowed along this fault, which I called *Khorkun Fault.* The left hand side of the valley is composed of black, grey and white limestones, similar to the ones of the opposite side. The beds dip gently towards south-west, that is in a opposite direction

(1) The suffix *-la* means *saddle.*
(2) AUDEN's private information.

to the one of the eastern side. It may be an anticline, but the presence of the above mentioned fault doesn't support this interpretation completely. From the observations I made in the lower Sarpo Laggo and lower Skamri valleys (see page 37) I am induced to think that the gneissic belt outcropping near Sughet Jangal extends to the upper left flank of the Shaksgam valley downstream from Sughet Jangal.

4.2. K^2 GLACIER VALLEY. Now we will deal with the geology of the *K^2 Glacier valley*. Before expounding the data I collected, I think it is advisable to report AUDEN's published and unpublished information and others deducible from his geologic map (1:250,000) (fig. 4) which includes also the basins of the Sughet and K^2 glaciers. According to this map, the valleys are built up almost completely of « Calc-alcali granite, Granodiorite », except the K^2 peak and a band along the eastern slope of the Sarpo Laggo valley, which are marked as « Quartz-diorite, diorite and basic gneisses ». The Sughet crest up to the Skyang Kangri is composed of « Limestones, Dolomites, Shales » of the « Shaksgam Series » belonging to the Permo-Carboniferous. Within the granite outcrop « 5 wedges of marble interbedded with purple shale are prominent on the west side of the valley », but — AUDEN wrote (1) — « evidently I did not notice them on the east side ». « Lamprophyre dykes are common on both sides of the valley as far south as Latitude 36°01′, intruded within fine-grained granite ».

The old moraines of the K^2 glacier, downstream from the present end contain K^2 Gneiss, Falchan Gneiss, whitish granite gneiss, black slates and scarce pebbles of white marble. On the moraine above Sughet Jangal there are also grey limestones, red shales and conglomerate similar to those of the Sarpo Laggo glacier snout.

I was not able to locate the outcrop of these rocks precisely; however, part of the K^2 gneisses certainly comes from the north wall of that peak and from the catchment area of the underlying glacier (2). The slates probably derive from the south-western tributary glacier which gathers the debris from the northern side of the Savoia-Skyang Kangri-K^2 crest. The white marble pebbles come from the wedges indicated by AUDEN in the upper basin of the K^2 glacier. The outcrops of grey limestone, red shales, and conglomerate should be small at least in the K^2 glacier valley. This limestone partly composes the crest dividing the gorge of the Sughet glacier (Sughet Crest) from the Shaksgam valley; in fact they were observed in the lower part of the gorge, where they overlie

(1) From AUDEN's letter.

(2) The geology of the K^2 peak is described in the memoir by DESIO and ZANETTIN on the "Geology of the Baltoro basin" (1970).

the granitoid gneiss directly. Moreover I believe that they also compose the eastern flank of the K² glacier valley. Probably this limestone grades into marble because on the Bdongo-la some fragments of dark limestone and conglomerate, derived from the southern slope above the saddle, were collected together with fragments of marble and multicoloured conglomerate showing a metamorphic facies.

It seems that these rocks are similar to those outcropping near the front of the Sarpo Laggo glacier, but they show a more metamorphic facies.

The presence of conglomerate fragments in the old moraine of the K² glacier suggests at an outcrop of that rock in the K² glacier basin.

This occurrence is confirmed in a personal letter by AUDEN, who wrote: « numerous boulders of limestone conglomerate some of them limestone-breccia, were found on the east side of the K² glacier but none was seen *in situ.* »

The above-mentioned occurrences of red shales and conglomerate from the Sarpo Laggo glacier and the K² valley as far as Skyang Kangri induce me to presume the existence of a thin, more or less continuous outcrop, of the two lithotypes along the fault crossing the Sarpo Laggo valley near the end of the glacier and the western side of the Skyang Kangri.

I want to add some words on the difference in the nomenclature of the gneiss (DESIO) and granite (AUDEN) outcropping in the northern side of the K² massif.

The lack of samples of such rocks leave the question open. My interpretation is based on the results of the geopetrographic investigation carried out on the other three slopes of the K² massif (DESIO & ZANETTIN 1970). Nowhere was real granite found on these slopes, but only different gneissic lithotypes. The commonest being a greenish porphyroblastic gneiss, among which augen gneiss prevails; the most granite-like gneiss commonly occurs on the walls west of the De Filippi glacier. Together with these rocks there are also granite gneiss, granodiorite gneiss and other metamorphic rocks (1). Cataclastic structures and mylonitic rocks are also present. Marble and black slate slivers are contained in the gneissic bulk of the K² massif, as in the K² glacier valley, and some are in

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(1) DEE MOLENAAR, one of the geologists who partecipated to the 1953 K² expedition under the leadership of C. HOUSTON, informed me about the rocks he found along the Abruzzi ridge. He summarized in a letter his observations as follows: « K² is very complex geologically, with many small faults and folds. While climbing to the Shoulder camp we encountered much steep slabs of blackish argilliteshale, like the shingles of a roof. The House Chimney was cut through a band of highly fractured limestone or dolomite, very reddish and rusty in places. I didn't see any granite on the Abruzzi Ridge, but much schistose material ».

contact with faults. Pegmatite, lamprophyre and minette dykes are also scattered here.

The above summarized petrographic elements substantiate my view that the northern side of the K² massif should have a petrographic composition similar to the other slopes.

4.3. THE SHAKSGAM VALLEY FROM THE TEK-RI HILLOCK TO THE SKYANG GLACIER VALLEY. The isolated Tek-ri hillock, which bars the Shaksgam gorge near its lower end, is 148 m above the river and is largely coated by glacial drift (pl. IX fig. 2). The rocks outcropping here and there show traces of intensive glacial erosion. They consists mainly of grey limestone alternating with well bedded, black, fossiliferous limestone (1). In this sequence, dipping 80° to the south-west, thick beds of brown shales are intercalated, and dykes of a dark volcanic rock occur. The attitude of the beds and their nature show that they are part of the above-mentioned wedge of black limestones which lower down rests against the above mentioned fault.

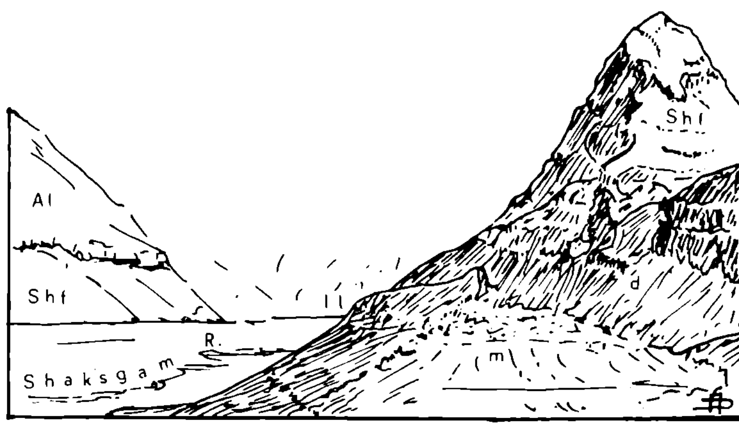

Fig. 9 – *The Bdongo Peak from downstream.*
Shf limestone of the Shaksgam Formation, Al Aghil limestone, m moraine.

The spur dividing the Sarpo Laggo valley from the Shaksgam valley in front of Tek-ri is built up of black cherty reticulate limestone. The beds are so deformed, that it is impossible to identify their attitude and this confirms the proximity of a dislocation.

Upstream a large glacial drift, consisting mainly of pebbles of gneiss, black slate, cherty limestone and white limestone is deposited on the above mentioned spur. A rocky pyramid polished by the ice (*Bdongo Peak*, fig. 9) overhangs this spur. To the south this pyramid overlooks a deep saddle in the

(1) The fossils collected here have been lost by the porters.

the spur once frequented by caravans and which we called *Bdongo-la.* This site is mentioned because it is of stratigraphic interest (fig. 10). Black limestone, with quadrate joint patterns and a few chert nodules, outcrops at the foot of the path leading from the bottom of the Shaksgam to the saddle; this limestone is the same as the one outcropping on the northern side of the spur. Above the limestone there are yellow or brown, calcareous-marly sandstones with *Ostrea* (?) shells similar to those of Tek-ri; the sandstones are cut across by dark green dykes of rhyolite (29KD-70) (1). Higher up there is a black slightly arenaceous limestone with yellowish wathered surfaces containing numerous isolated corals which are also abundantly spread in the detritus (see list below). An unclassifiable ammonite was collected together with the corals.

The arenaceous limestone is overlain by multicoloured conglomerate, consisting of pebbles of black, white, and red limestones, fragments of red shales and nodules and pebbles of chert. The clasts of the conglomerate are partly angular and partly rounded. The matrix is a yellow or reddish marly-sandy-calcareous material which occasionally forms beds rich in corals, small *Ostrea* (?), and crinoid ossicles.

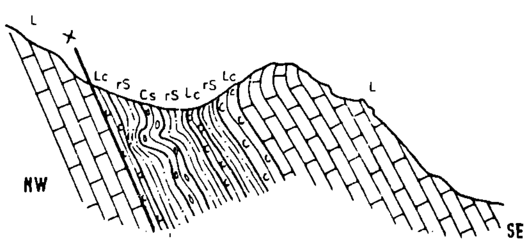

Fig. 10 – *Geologic section across the Jurassic beds of Bdongo-la*

L white and grey limestones; Lc brown and yellowish arenaceous limestone with corals; rS red and purple shales; Cs multicoloured conglomerate; x fault.

Red and yellowish fossiliferous arenaceous shales cut across by dykes of green-grey propylitized dacite (29KD-V40)* (2) seem to underlie the conglomerate. Beyond the saddle, cut through the arenaceous rocks on the flank of the Sarpo Laggo valley there are dark grey and black limestones which lower down, at the foot of the mountains, are in direct contact with the granite gneiss. Provisorily I shall call the fossiliferous sequence outcroping on this saddle *Bdongo formation.*

The beds dip steeply south-west.

(1) The numbers into the brackets marck the specimens.

(2) See at the end of this volume the description ot the rock samples by P. SPADEA RODA. The samples studied by this scholar are marked with an asterisk *.

The species identified by N. Fantini Sestini (1965) are the following:

Macgeopsis cf. *subcylindrata* All.
Isastraea explanata (Gold.)
Thecosmilia costata From.
Thecosmilia magna Th. & Et.
Thecosmilia dichotoma Koby
Thamnoseris froteana Th. & Et.
Dermosmilia sp.
Ceriopora? sp.

The age of this fauna ranges from the Middle to the Late Jurassic or, more precisely, from Callovian to Tithonian.

Bdongo-la is strewn with blocks of white marble and multicoloured metamorphosed conglomerate fallen down from the southern slope of the saddle.

The detailed stratigraphic position of the Jurassic outcrops of Bdongo-la is not clear because all the fossils collected from the underlying limestones were lost. Probably the beds are part of a faulted syncline, formed by Early Permian black cherty reticulate limestones outcropping at Gasherbrum Jilga.

Upstream from Bdongo-la, the Shaksgam valley is built up of the same type of limestone with grey and black bands which occurs downstream from Tek-ri. In some blocks made of light grey and whitish, massive limestone fallen from the right flank of the valley, there were fairly well preserved remains of big bivalves referable to the genus *Megalodon*. The rock is similar to the Norian Hauptdolomit of the Southern Alps.

From the bottom of the valley it is difficult to reconstruct the sequence of the more or less dolomitic limestone beds composing the steep flanks of the Shaksgam valley between Tek-ri and the mouth of the Skam Lungpa (pl. XI and pl. XIII fig. 1). The sequence might be from top to bottom the following:

4. White and light grey limestones with *Megalodon* (fig. 12);
3. Very thick alternating black and white limestones;
2. Red, dark brown or black shales, a few tens of metres thick;
1. Grey and black reticulate limestones a few hundreds of metres thick.

It is not clear whether the red shales represent an intercalation, or mask a fault plane, as seen downstream from Tek-ri (fig. 8).

The black thinly bedded fossiliferous limestones probably occurring at the base of the sequence belong to the Permian.

The Skam valley cuts through the calcareous horizons 3 and 4. The beds which in the lower part of the Shaksgam valley dip 70° north, upstream, in the same valley, have a low dip and mark a wide syncline with a north-westerly axis. This syncline includes a series of impressive indented crests resembling the Italian Dolomites rising on the right flank of the Shaksgam valley between the mouths of the Skam and Aghil valleys. Our porters called these ridges Choto-so (fig. 11, 13, and pl. XII fig. 2). On the left side of the Shaksgam

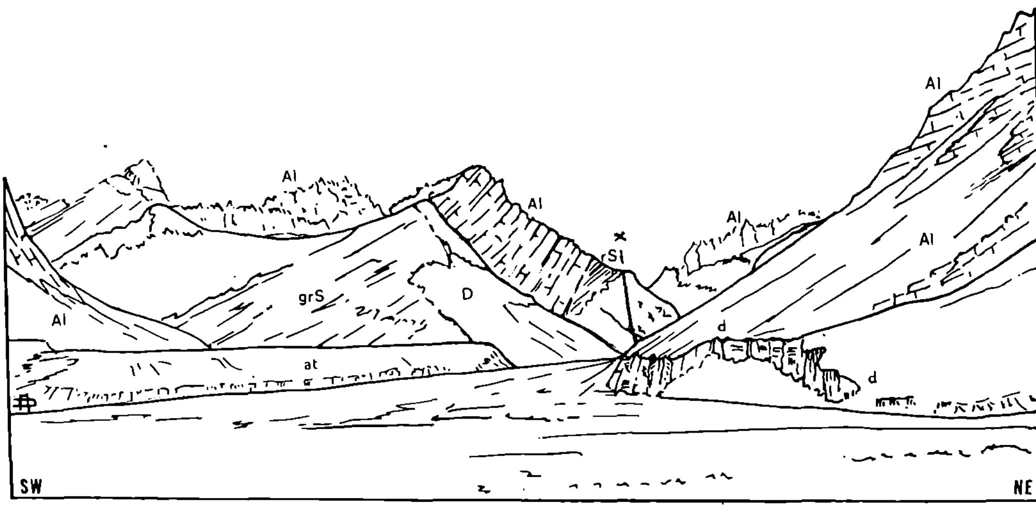

Fig. 11 - *Geologic view of the Skam Lungpa outlet.*
Al *Megalodon* limestone; rSl red shales; grS green schists; D limestone or volcanic rock; at alluvial terraces; d debris; x fault.

valley opposite Skam valley confluence, AUDEN notice a fossiliferous limestone with numerous *Megalodon* sections (fig. 12).

The constitution of the Skam valley is represented in AUDEN's geologic map. In this map (fig. 4) we can see a large syncline, with a NW-SE trend made up of the « Aghil Series » with an inferred « Late Jurassic » core (fig. 40). Probably the core is composed of the Bdongo formation, but we have no valid proof thereof.

In his report AUDEN writes that « Jurassic fossils have been found for the first time » in the visited area, but he did not specify exactly where the fossils were found. Nevertheless in his map a fossiliferous locality is marked downstream from the Aghil pass, on the west side of the valley (fig. 36).

In one of his letter he supplied me with the following information: « Aghil Valley near 36°09': 76° 37° 1/2' west side. Callovian. *Mytilus* (*Modiolus*) allied to *M. imbricatus*, *Ptyctothyris.* »

We can accept the above mentioned age as a clue, but the fossils are inadequate for establishing a geologic age.

The upper portion of the valley is visible through the mouth of the Skam valley cut into the sequence of 30-40 cm thick limestone beds with large *Megalodon*. This part of the valley is composed mainly of green shales associated

Fig. 12 – *Megalodon limestone : Shaksgam Valley, opposit Skam Lungpa confluence.* (Photo by J. B. AUDEN).

with limestones and brown massive (igneous ?) rocks. Near the head of the left tributary valley of the Skam composed of marls, a band of red rocks underlie the limestone sequence. This marly horizon seems to surround the calcareous ridges of Choto-so to the north, since it reappears in the upper valley descending from the Aghil pass (1).

This observation not only seems to confirm that the *Megalodon* limestone overlies a marly formation, but also that it probably represents the shaly and

(1) In the first reports by DESIO (1936) the Skam valley was mistaken for the Aghil valley.

conglomeratic red band underlying the limestone sequence like downstream, in the Shaksgam valley. Nevertheless I cannot exclude that the marly horizon belongs to the Shaksgam Formation.

Immediately downstream from a red fan (Marpo Chholong) deposited by a right side stream, upstream from the Aghil river, the calcareous-dolomitic beds are folded in a syncline in which the Shaksgam river has deeply hollowed its valley. In the northern limb below the calcareous-dolomitic formation a few hundred of metres thick is well exposed, as can be seen in fig. 14, a red shale bed, underlain by green arenaceous marl and greysh limestone like in the Skam valley.

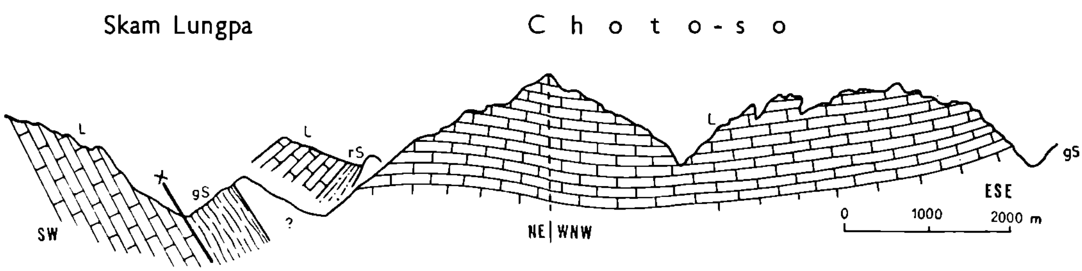

Fig. 13 – *Geologic section along the right hand side ridge (Choto-so) of the Shaksgam Valley.* L grey limestone and dolomite with *Megalodon*; gS green shales and green rocks; rS red shales; x fault.

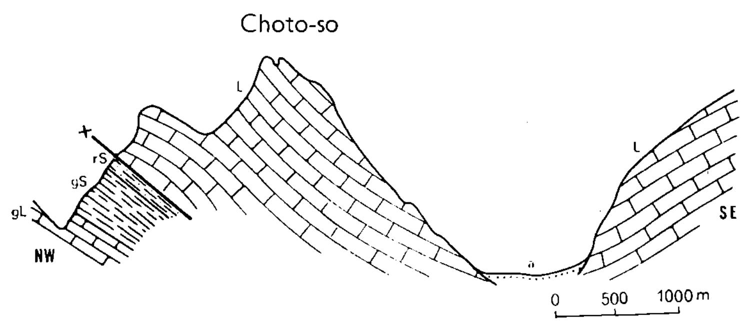

Fig. 14 – *Geologic section across the Shaksgam Valley upstream from the junction of the Aghil Valley.* L grey and light grey limestone and dolomite (Aghil Limestone); rS red shales; gS green shales; gL grey limestone (probable Shaksgam Formation); x fault.

The red beds outcrop again in the core of a recumbent syncline above Marpo Chholong (fig. 17) which abundantly contains boulders of red shales and conglomerates with a red matrix similar to those of Bdongo-la.

Above Marpo Chholong the following short section was surveyed (fig. 15):

4. Grey, brown and black reticulate limestones, with fusulinids, in beds 30-40 cm thick, occasionally massive and marly;
3. Green arenaceous shale;
2. Blackish shales;
1. Black limestone with gastropod and brachiopod remains, in beds 10-20 cm thick, with some black fossiliferous interlayers.

Because of a series of folds visible from below these beds are repeated higher up on the slope of the mountain (figs. 16, 17). The limestones of member 4 continue on the right flank as far as the mouth of the Bya Lungma (valley), then they are replaced by blackish and yellow arenaceous limestone, thinly bedded, alternating with fossiliferous marly beds. The latter member resembles the one — also arenaceous — outcropping near the front of the Sarpo Laggo glacier,

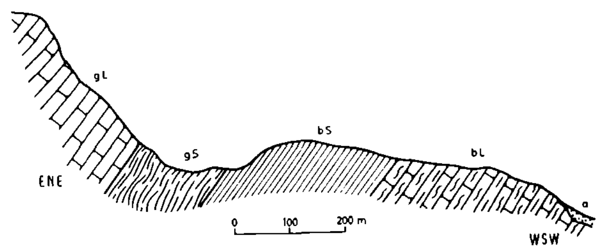

Fig. 15 - *The stratigraphic sequence near Marpo Chholong.*
gL grey limestone with Permian Fusulinids; gS green shales; bs black shales; bL black limestone with marly intercalations and fossils of the Late Paleozoic (mostly gastropods and brachiopods; a debris and alluvional gravels.

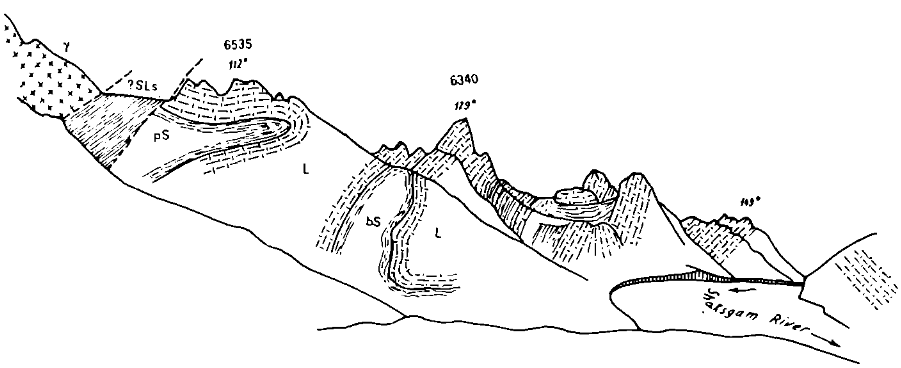

Fig. 16 - *View ESE from camp 4066 m at the foot of Aghil Pass by* J. B. AUDEN (1937)
SLs Sarpo Laggo black slates; bS black slates; pS purple shales; L Limestone; γ granite.

and like it contains fusulinids. Among them A. SILVESTRI (1933) identified: *Fusulina wanneri* Shub., *F. granum-avenae* Roem., as well as a new variety (*crassisaeptata*) of *F. uralica* Krot. (sample 29KD-257). According to R. CIRY and M. AMIOT (1965), the last fossil form should be *Paraschwagerina* sp. Anyhow — according to both authors — these fossils belong to the lowest strata of the Late Permian.

The beds, which dip 25° north, overlie the black shales about 50 m thick and are interbedded by brown marls containing oval nodules of black chert. The shales overlie a fossiliferous calcareous conglomerate (containing particularly crinoids and brachiopods), which in its turn overlies a layer of black shales 7-8 m thick; at the base of it there are brown marly limestones. Near Durbin Jangal on the left hand side of the valley the beds dip almost vertically south-southwest and maintain the same attitude further upstream, on the right side. Below the Durbin Jangal springs a glacial drift outcrops from the talus.

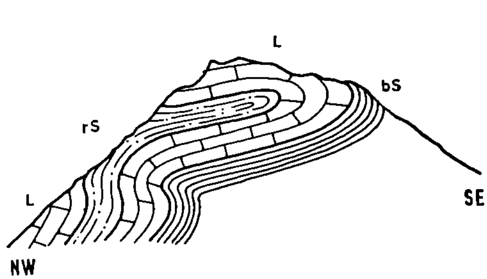

Fig. 17 A – *Recumbent fold in the Marpo Chholong Valley on the right hand side of the Shaksgam Valley.*
L limestone; rS red shales; bS black shales.

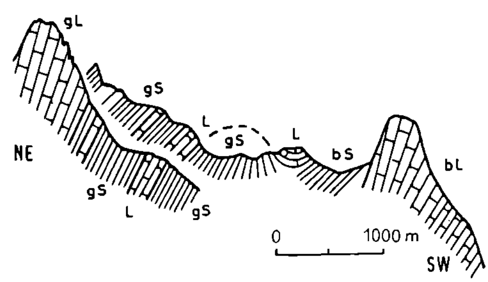

Fig. 17 B – *Geologic section across the western slope of the Aghil Range from the outlet of Bya Lungma.*
bS black shales; bL black limestone with Permian fossils; L limestone; gS green shales and "green rocks"; gL grey limestone and dolomite.

Slightly downstream from the mouth of the Bya Lungma there is a good Late Paleozoic fossiliferous locality. Brown-grey limestone alternating with marls of the same colour, rich in fossils, mainly brachiopods, overlies a layer of black shales occurring at the base of the sequence. The limestone is overlain by yellow-brownish sandstones with plant remains and Permian fusulinids overlain, in their turn, by dark grey limestones, also with fusulinids. Still higher up there is a small calcareous breccia rich in crinoid ossicles. Most of the Bya Lungma is also hollowed in the calcareous sequence; its alluvial fan is composed mainly by gravels of grey and blackish limestone, greenish sandstones similar to the one of the Skam valley, and finally of massive white limestone (pl. XIV fig. 1).

Dark grey, brownish and black limestones, occasionally slightly arenaceous, with marly intercalations occur just upstream from the mouth of the Bya Lungma. According to R. Ciry and M. Amiot (1964) the marly intercalations contain *Parafusulina shiptoni* Dunbar, certainly belonging to the Permian, and probably to the Middle Permian or to the lower part of the Late Permian (29KD-257).

The tectonics of the Bya Lungma valley are characterized by an anticline, the core of which consists of green, red and black marly-calcareous beds. The axis is almost parallel to the Shaksgam valley. The anticline is followed by a shallow syncline, the southern part of which is faulted against black and brown shales followed by black fossiliferous Permian limestone (fig. 17 B).

Further upstream a fault suddendly cut off this sequence of black fossiliferous Permian limestones, where they are in contact with the thick sequence of mainly grey limestone forming the mountains of the right flank of the Shaksgam valley, near Gasherbrum Jilga. These grey limestones, folded in a shallow syncline cross the valley (fig. 18).

At the base of this sequence, near the river bed, a thin lens of black and red shales was just visible.

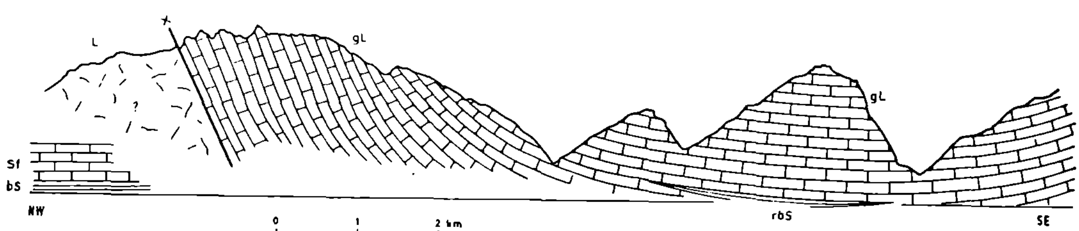

Fig. 18 – *Geologic section along the right hand slope of the Shaksgam Valley upstream from the confluence of Bya Lungma.*
gL grey limestone and dolomite of the Aghil Limestone; L limestone; Sf fossiliferous limestone of the Shaksgam Formation; rbS red and black shales; bS black shales; x fault.

Proceding along the Shaksgam valley, from the Bya Lungma to the cairn (1) of Gasherbrum Jilga, on the left bank, one can see grey and white limestones with numerous calcitic veins. Near the rocky spur of the cairn the beds become very thin (a few centimetres) and puckered. They are alternate with brownish-grey marls with rare sections of fossils. Further on, blackish limestone alternates with brown marls containing some chert nodules. The marls and the limestone, occasionally pink, contain numerous brachiopods, crinoids, corals, gastropods and bryozoans. The beds dip 80° east.

(1) This is a stone pillar used as a local reference, and lies on the left hand side of the valley above a rocky ledge below which we camped in 1929.

Near the 1929 Cairn Camp, the marls alternating with the limestones (microsparite) (29KD-V35/498), in the lower beds contain foraminifera (*Archaeodiscidae*, *Ammonodiscidae*, *Globovalvulinae*, *Tuberitinae*), numerous crinoids and brachiopods, a few lamellibranchs and bryozoans (*Fenestella*); in the upper levels, mainly corals (isolated).

The species identified by N. FANTINI SESTINI (1964) are the following:

Amplexocarinia sp.
Marginifera ? *altimontana* ((Merla)
» *gratiodentalis* (Grabau)
» *gratiosa* (Waagen)
» ? *rimuensis* (Merla)
» *septentrionalis* (Tschern.)
Waagenoconcha pseudoirginae (Huang)
Cancrinella cancriniformis (Tschern.)
Chonetinella ? *latesinuata* (Schellwien)
» sp.
Neochonetes sp.
Spirifer ? *psittacus* (Merla)
Crurithyris tschernyschewi (Likharew)
Brachithyrina cf. *sokolowi* (Tschern.)
Spirigerella derbyi kweichowensis Grabau
Martinia orbicularis Gemm.
» *subtriquetra* (Merla)
» cf. *uralica* (Tschern.)
» sp.
Notothyris exilis (Gemm.)
Straparollus (*Euomphalus*) cf. *oldhami* (Reed)
» » cf. *parvus* (Waagen).

According to this fossil fauna, the Gasherbrum Jilga outcrop may probably be attributed to the base of the Permian.

The fossiliferous limestones and marls overlie red shales which, in turn, overlie green and black shales (fig. 19).

Between Marpo Chholong and Gasherbrum Jilga Quaternary fans occur along the river, but only on the right hand side: on the opposite side high limestone cliffs overhang the gravelly bed of the river. From the alluvial fans glacial till occasionally outcrops: it is rich in striated pebbles and glacial silt and occurs as high as 150 m above the river. Black shales outcrop on both sides and on the left hand side they compose the hills below the calcareous ridges.

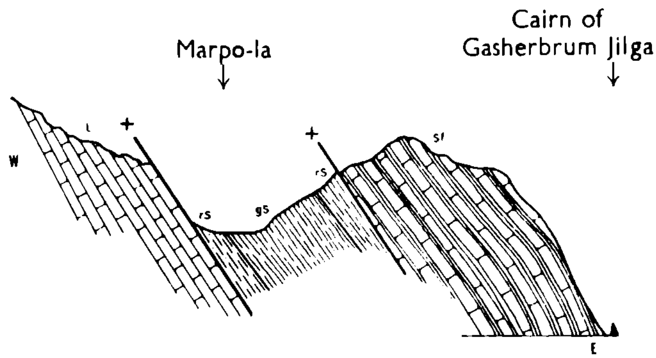

Fig. 19 – *Section across the cairn spur of Gasherbrum Jilga.*
L Limestone; Sf limestone interbedded with fossiliferous marls (Permian); rS red shales; gS green shales; x fault.

It seems that the black shales or, better, some peach-coloured brown and reddish arenaceous argillites outcropping only at the base of the black shales on the left hand side of the Shaksgam valley, form the core of an anticline striking approximately north-northwest.

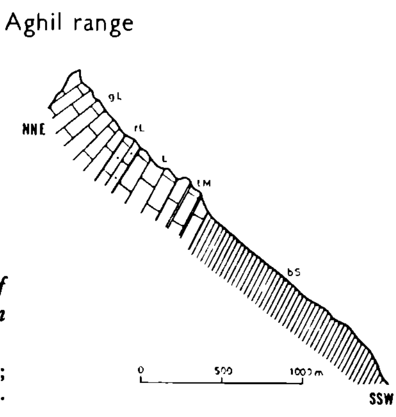

Fig. 20 – *Stratigraphic sequence on the right hand side of the Shaksgam Valley above the snout of the Gasherbrum Glacier.*
gL light grey limestone; rL reddish limestone; L limestone; LM dark limestone interbedded with marls; bS black shales.

This fold continues as far as the lower end of the Gasherbrum glacier. The right hand side of the valley is made of limestones and the tongue of the glacier is leaned against it. Light coloured limestones overlie here the red layer (fig. 20).

5. The Valley of the Skyang Glacier.

On the left hand side of the Shaksgam river, less than one kilometre downstream from the front of the Gasherbrum glacier, there is a valley, from the head of which the pyramid of the K[2] is visible. This is the valley of the Skyang glacier descending from the Skyang-la (Windy Gap); its tongue ends before reaching the bottom of the Shaksgam (pl. XIV fig. 2).

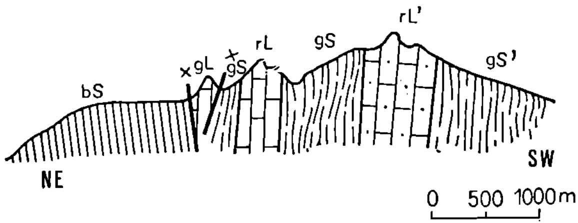

Fig. 21 – *Geologic section along the ridge between the lower Skyang and the Gasherbrum valleys.*

gL grey limestone; rL brown and reddish limestone; rL' black and reddish limestone; gS grey and greenish shales; gS' brown shales; bS black shales; x fault.

The upper part of the valley was observed from the Skyang-la, from where it appears to be mostly built of black shales and slates (DESIO & ZANETTIN, 1970). The rocky ridge between point 6526 m and 6740 m of the map, over-

The lower part of the Skyang valley was hollowed in black shales overlain by a thick bed of grey cherty limestone. The contact between the limestone and the shales is marked by a detached fault (fig. 21 and 22). Further upstream outcrop brown and grey-green shales, intercalated in subvertical beds by brown, black and reddish limestones.

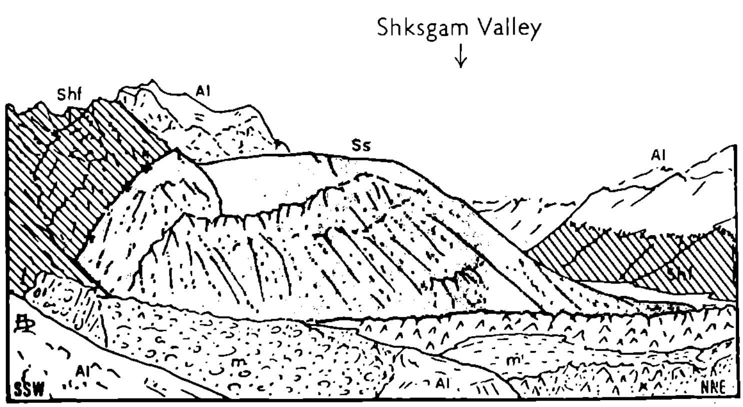

Fig. 22 – *Geologic view from the Gasherbrum-Urdok Saddle toward north-west.* In the foreground the Gasherbrum Glacier with ice pinnacles.

Al Aghil limestone; Shf Shaksgam Formation; Ss Singhié Shales; m moraine; m' floating moraine; x fault or slide surface.

hanging the northern catchment area of the glacier to the north-east, is composed of the same rocks. The contact between the black shales and a presumably calcareous formation can be seen east of the last mentioned points. This contact did not appear to be normal; probably it represents a slip plane between the two formations endowed with a different deformation capacity.

6. The Valley of the Gasherbrum Glacier.

Little is known about the geology of the Gasherbrum glacier valley. Only the lower part of it was crossed by few members of our expedition; however the small amount of data collected is recorded here because they are the only ones known.

The flanks of the valley — near its mouth — consist of a sequence of almost vertical beds, dipping south; the lithology is illustrated in fig. 22 (drawn from my field notes).

The black shales and slates outcropping on the left bank are cut across by dykes of a green volcanic breccia (dacite ?), and contain some thin beds of greyish-white limestone.

On the opposite side of the valley there is a thin low rocky spur dividing the lower part of the Gasherbrum glacier from the neighbouring Urdok glacier. This spur which I crossed through a saddle is made of black shales overlain by beds of grey limestone with stripes and nodules of dark chert (gL in fig. 24). I believe that the beds marked gL on the section fig. 21 have the same composition.

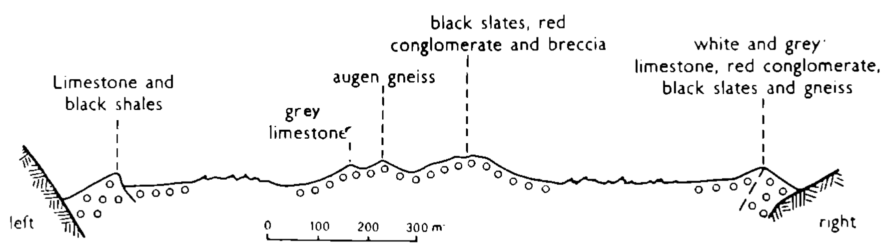

Fig. 23 - *Distribution of the rocks in the moraines of the lower Gasherbrum Glacier.*

The geologic constitution of the upper glacier basin can be inferred by the composition of the rocks of the moraines (fig. 23). The left lateral moraine is composed of fragments of limestone and black shales and slates with rare blocks of an altered basic dacite (29KD-195). The left ridge of the median moraine is rich in grey limestone; another moraine parallel to the first is composed of green « augen gneiss » similar to the K^2 Gneiss (DESIO & ZANETTIN, 1970).

The median moraine comprises mostly fragments of black slate which — towards the right hand side of the glacier — are mixed with blocks of conglomerate and breccia with red matrix. These two lithotypes become more and more frequent till they become prevailing on the eastern margin of the median moraine.

The right hand moraine of the Gasherbrum glacier is composed of an association of prevailingly white and grey limestones and fragments of red conglomerate, black slates (probably also gneiss) and « augen gneiss ».

If we take into account the distribution of the till rocks and the only partially known provenance of the moraines, we can try to locate the outcrops of the rocks mentioned (1).

The limestones of the lateral left moraine are probably derived from the ridge flanking the lower tongue of the glacier on the left hand side, as shown in fig. 23. The black shales and slates (also Falchan Gneiss) may derive in part from the same ridge, but mainly from the left first feeding ice-flow of the glacier, which is located below the Sella saddle. This is confirmed by photographs taken from the highest 1954 camps on K^2, and from the summit of Gasherbrum IV (pl. XXII) (2). The limestone of the left median moraine probably originate from the northern slopes of the Gasherbrums III and IV.

It is much more difficult to discover the origin of the K^2 Gneiss pebbles composing the left ridge of the median moraine. The extensive ice cover and the few observations made prevented us from locating this material exactly, especially as the very topographic distribution of the ridges in the upper glacier basin was little known. The outcrop, however, should be in the valleys of the right hand tributaries of the Gasherbrum glacier flowing down to the west of the East Nakpo glacier, that is the West Nakpo glacier and another glacier more to the west.

The abundant black slate fragments of the right ridge of the median moraine derive from the right bank of the Gasherbrum glacier, and from the catchment area of the East Nakpo glacier.

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(1) On the geologic map at the scale 1 : 100,000 of the Baltoro basin (DESIO & ZANETTIN, 1970) the topography of this area probably is not exact. Here I have adopted another topographic representation which appears to be more correct than the preceding one, having been improved with the ERTS imageries. Se the geologic map at the end of this volume.

(2) I thank FOSCO MARAINI who kindly sent me some of his photographs taken during the Gasherbrum IV expedition of 1958. Some of them are reproduced in the plates XXII and XXIII.

The conglomerate and breccia with red matrix should outcrop in the eastern part of the Gasherbrum glacier basin, that is in the catchment area of the East Nakpo glacier. The head of this valley seems to reach the ridge of the Gasherbrums peaks. Possibly the red conglomerate debris derives from that area, since some fragments have been collected on the opposite side, that is on the moraines of the South Gasherbrum glacier (Baltoro basin).

From the lower part of the North Gasherbrum glacier I observed that the northern side of the Gasherbrum ridge consists of well-bedded and gently dipping limestones, underlain by very dark coloured rock (probably black slates or gneisses). These rocks, together with the conglomerates, form the right ridge of the median and lateral moraines of the Gasherbrum glacier.

The data regarding the outcrop of the rocks composing the till were used in drowing the geologic map enclosed at the end of this volume.

7. The Valley of the Urdok Glacier.

The introducing remarks made on the preceding valley are also valid here, although in this case I was able to climb the whole glacier, up to the catchment area below Indira-la. I could not, however, visit the lateral slopes, except the ones of the spur dividing the Gasherbrum from the Urdok glacier.

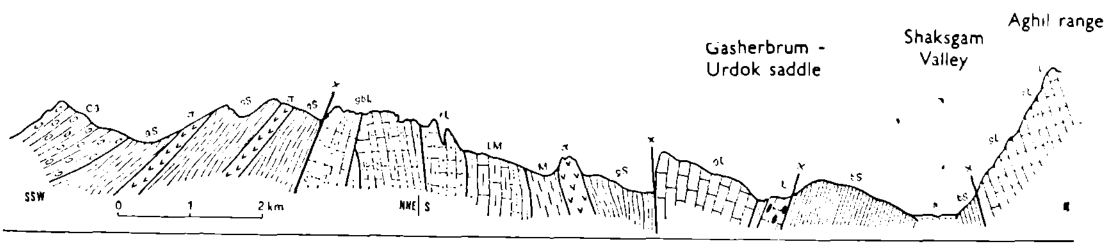

Fig. 24 – *Geologic section along the crest dividing the Urdok from the Sgan and the Nakpo (Gasherbrum) glaciers.*

bS black shales; gS green and black shales; M marles; LM limestone with marl intercalations; L limestone; L′ cherty limestone; gL grey limestone; rL grey and reddish limestone; gbL grey and black limestone; Cg conglomerate; π green (volcanic ?) rocks; a alluvial deposits; x fault.

From below I attemped to survey the stratigraphic sequence of the western side; the results are shown in fig. 24. The lithology was partly deduced from the composition of the left lateral moraine. In this sequence also the calcareous conglomerate with red matrix occupies an elevated position in respect to the black slates; it could also overlie the marls which partly represent the Permian fossiliferous beds, and in part the beds immediately overlying (see below). Here the red conglomerate seems to underlie the Triassic calcareous sequence.

On the right hand side of the lower Urdok valley, the mountain ridge dividing this valley from the Shaksgam, consists mainly of greyish massive limestone with some shaly intercalations. This range forming the left flank of the Shaksgam valley above the Urdok glacier will be discussed below. At the lower end of the valley, still on the right hand side, black shales alternating with green schists outcrop; they also compose the left hand side of the Shaksgam valley (figs. 25, 28 and pl. XVIII fig. 1).

In the middle and upper Urdok valley, part of the data collected derive from short distance observations of the flanks of the valley and in part from the composition and origin of the Urdok till (pl. XVII).

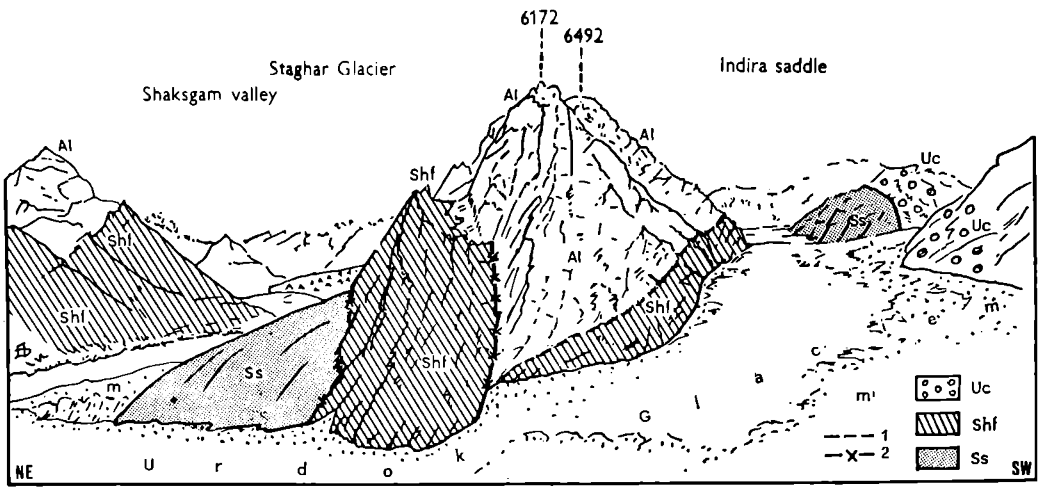

Fig. 25 – *Geologic view of the ridge between the Urdok (right) and the Shaksgam (left) valleys*
Al Aghil Limestone; Uc Urdok Conglomerate; Shf Shaksgam Formation; Ss Singhié Shales; m moraine; m' floating moraine; x fault or slide surface.

The left lateral Urdok moraine consists of pebbles of calcareous conglomerate with red matrix and grey limestone, both derived from the western side of the valley, that is from the ridge dividing the Urdok glacier from the East Nakpo glacier and from the Sgan glacier basin. Therefore they, at least in part, originate from the north-eastern slopes of Gasherbrum I (8068 m). Grey limestone, similar to the Aghil Limestone, compose numerous pebbles of the left floating moraine (fig. 26).

From the mouth of the Sgan valley, I was able to observe the lithology of the eastern side of Gasherbrum I. It consists, from just above the base to the summit, of thick beds of light coloured limestones or dolomites, dipping moderately. The limestones are underlain by very dark-coloured rocks, probably black slates or gneiss (pl. XX fig. 1).

The two median moraines originate in the Urdok glacier catchment area, which I was able to examine from a short distance. The left floating moraine, being in contact with the other, is prevailingly composed of grey limestone fragments and then of « green rocks » and black shales, while the other moraine is almost completely composed of black shales (pl. XX fig. 2).

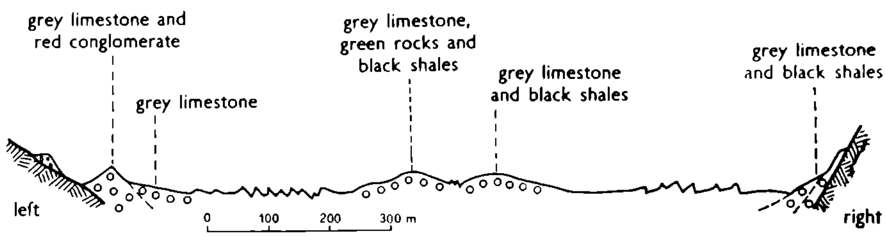

Fig. 26 - *Distribution of the rocks in the moraines of the upper Urdok Glacier.*

In the upper Urdok glacier the spur from which the left hand ridge of the median moraine starts, is built of black shales overlain with marked unconformity by a dark red calcareous conglomerate. The conglomerate is mainly made of pebbles of white, grey and black massive and waxy limestones, cemented by a red marly-arenaceous matrix. The conglomerate outcrops along the western side of the isolated spur whence the moraine starts. The lower eastern side of the Urdok valley head is composed of black shales which are directly overlain, without conglomerate insertions, by a thick sequence of limestones, grey in the lower part and black in the upper one. These limestones form the ridge dividing the Urdok from the Staghar and the Urdok from the Siachen valleys. The beds dip 75° east-northeast. According to DAINELLI (1934) the black shales outcrop also to the east of Indira-la, in the Siachen basin, below the Turkestan-la, which is a saddle 5855 m high (1) (fig. 27) on the ridge dividing the Siachen and the Staghar glacier basins.

It is intersting to notice the presence of frequent slickenside both in the limestone and in the shale fragments.

The clasts of the other median moraine (left ridge) are composed — as

(1) In the original map of the Siachen glacier at the scale 1:175 000 by G. PETERKIN of BULLOCK-WORKMAN's expedition (1914) the Turkestan-la is drawn between the Siachen and the Urdok glaciers. The same location appears in the MASON's map at the scale 1:253 440 (1928). The official altitude is the one measured by PETERKIN.

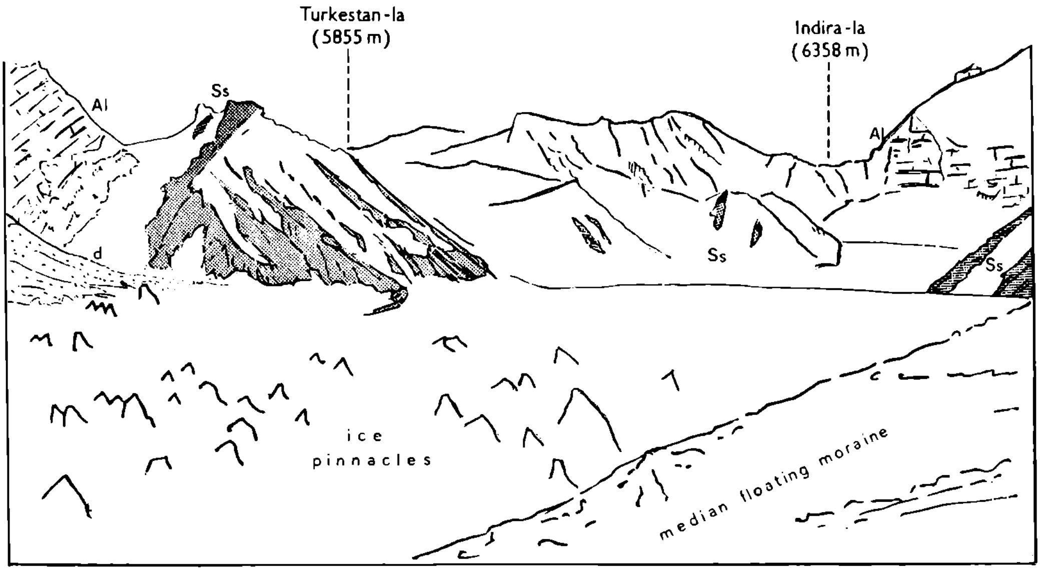

Fig. 27 – *Geologic view of the head of the Urdok Valley.*
Al Aghil Limestone; Ss Singhié Shales; d debris.

already mentioned — of grey limestone and secondarily of black shales and a green volcanic rock derived from the Urdok Kangri, the ridge separating the upper Urdok glacier from the Abruzzi glacier (Baltoro basin).

The volcanic rock is almost certainly a pyroxene porphyritic dacite which outcrops also in the southern flank of Urdok Kangri and, more precisely, in the north-east side of the Abruzzi glacier valley. (See the geologic map enclosed in the DESIO & ZANETTIN memoir on the geology of the Baltoro basin, 1970, and page 60).

8. The Shaksgam Valley from the Urdok to the Kyagar Glaciers.

The ridge dividing the Urdok glacier from the Shaksgam valley ends towards the north in an acute angle and is composed on the north-eastern side by well-bedded dark limestone dipping steeply east-northeast (figs. 25, 28) pl. XXI). These beds compose both the walls of the Urdok valley and the highest part of the ridge. The limestones, which I was not able to observe from close up, are overlain by a sequence of black and green shales, with rather thick intercalations of another limestone bed. The dip of the beds is conforming with the slope. Possibly there is a tectonic contact between the limestones and the shales.

Further upstream the shaly formation wedge out and the left flank of the valley is entirely composed of limestones exposed on high walls. The left hand slope between the Rdzing glacier entering only for a small portion the Shaksgam and the Staghar glacier blocking it transversely, is built up of grey massive limestone with numerous large calcitic veins, looking like those of the walls of the Marpo Rgyang near the front of the Kyagar glacier (Marpo Rgyang limestone). The red brecciated limestones associated with red calcareous breccia, probably intercalated with grey limestone (I observed only rare fragments carried down by torrents), give a reddish colour to the rocky walls. This massive limestone seems to form the lower part of the Aghil Limestone and probably belongs to the Middle Triassic.

The above mentioned limestones are underlain by blackish-grey and black limestones, very thinly bedded, with yellowish marly veils similar to the Permian fossiliferous beds.

Just upstream from the Urdok glacier the bottom of the Shaksgam narrows and some big cliffs, which we called « Porte dell'Urdok » (Urdok Doors), rise from it. These rocks are composed of well bedded grey chert-bearing limestones dipping very steeply north (pl. XXIV fig. 2).

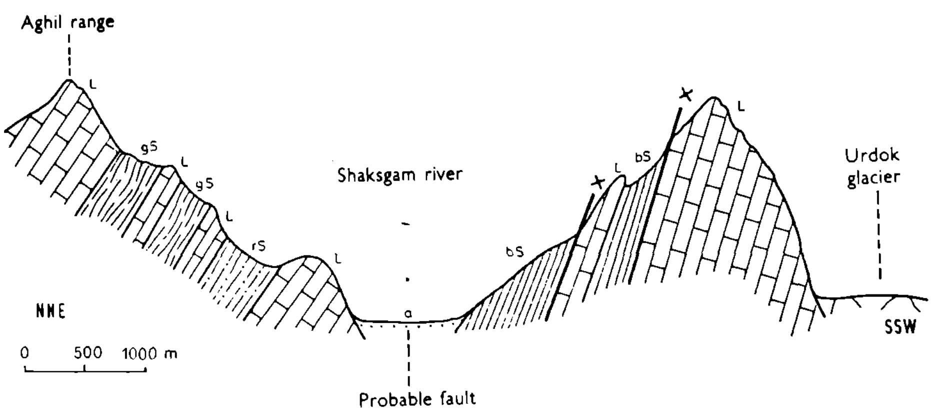

Fig. 28 – *Geologic section across the Shaksgam Valley and the ridge between the Shaksgam and the Urdok valleys.*

L limestone; bS black shales; rS red shales; gS green and black shales; a alluvial deposit; x fault or slide surface.

One geologic cross-section was cursorily surveyed, slightly further upstream, on the right hand side of the valley (fig. 28) almost in front of another section shown in the same figure surveyed on the left hand side a little upstream. The lower limestone probably belongs to the same beds outcropping further upstream, which yielded a Permian fauna. The upper beds must be referred to the Aghil Limestone.

In 1929 we camped on a small rock lying just below the Staghar glacier composed of a white limestone particularly interesting for the fauna, mainly of Permian brachiopods, yielded by it (pl. XXVI fig. 1).

The species determined by N. Fantini Sestini (1964) are the following:

Schizophoria sp.
Orthotichia morganiana (Derby)
Enteletes dieneri Gemmellaro
E. dieneri darvasicus Renz
E. cf. *elegans* Gemmellaro
E. meridionalis Gemmellaro
E. subaequivalvis Gemmellaro
E. waageni Gemmellaro
Enteletina cf. *acuteplicata* (Waagen)
Tschernyschewia typica typica Stoyanow
Marginifera cf. *typica* Waagen
M. cf. *typica elongata* Huang
Paramarginifera cf. *gobiensis* (Chao)
P. cf. *himalayensis* (Diener)
Echinoconchus fasciatus (Kutorga)
E. punctatus (Sowerby)
Waagenoconcha cf. *abichi* (Waagen)
W. humboldti (d'Orbigny)
Chaoiella grünewaldti (Krotow)
Costiferina spiralis (Waagen)
Reticulatia moelleri (Stuckenberg)
R. cf. *transversalis* (Tschernyschew)
Linoproductus sp.
Compressoproductus sp.
Cancrinella cancriniformis (Tschernyschew)
Uncinunellina timorensis (Beyrich)
Terebratuloidea davidsoni Waagen
Stenoscisma biplicata (Stuckenberg)
S. pinguis (Waagen)
S. purdoni (Davidson)
Stenoscisma sp.

Neophricodothyris asiatica (Chao)
Elivina cf. *tibetana tenuisulcata* (Merla)
Purdonella merlai Fantini Sestini
Neospirifer fasciger (Keyserling)
Martinia cf. *glabra* (Sow.)
M. cf. *semiplana* (Waagen)
Martinia sp. II
Whitspakia cf. *biplex* (Waagen)
Hemiphtychina cf. *carniolica* Schellwien
Gastrioceras sp.

In the same samples R. CIRY and M. AMIOT (1964) identified also not well defined species of *Paraschwagerina.*

The above listed fossils were collected in a very small area (a few square metres) and therefore almost all of them belong to the same bed.

According to FANTINI SESTINI's determinations and conclusions this fauna is certainly Permian and may be Early Permian. Dark grey fossiliferous biosparite outcrops in the opposite side of the valley. It contains crinoid ossicles and shell fragments (29KD-503)*.

I tried to determine on the spot the position of this grey limestone in the stratigraphic series of the Shaksgam valley, by a sight-reconstruction of the bed sequence exposed on the slope overlooking the front of the Staghar glacier to the north-northeast. This sequence is obviously approximate since it is deduced from field glass observations and from the composition of the detritus.

The stratigraphic sequence is given in fig. 29.

The red limestone is often brecciated and occasionally true breccia. The grey limestone is massive and crossed by large calcitic veins. This limestone probably corresponds to the Middle Triassic Marpo Rgyang limestone.

I was able to collect only little information on the geology of the *Staghar valley*, any how I consider it worth mentioning. For few kilometres the left flank of the valley consists of the same limestone which form the ridge separating the Shaksgam valley from the Urdok valley (page 58). The end moraine is composed mainly of fragments of grey limestone and black shales and secondarily of black and red limestones, red conglomerate and green shales.

Grey limestone compose most of the main ridge of the Karakorum, between the Staghar and the Siachen basins. Probably near the base of this limestone, there are thick beds of red limestone and red conglomerate, like on the right flank of the Shaksgam valley. The limestone sequence representing the Aghil Limestone — which will be discussed further on — overlies a shaly-calcareous formation consisting of black and green shales and black limestone. Apparently it prevails in the eastern slope of the Staghar valley.

Near the isolated cliff in front of the snout of the Staghar glacier the beds dip 75° north-northwest and consist of grey limestone with rare stripes of brown chert and dark grey limestone with rare nodules of chert. The bulk of the rock is strongly brecciated and traversed by calcite veins. In front of this cliff there is a rocky spur which bears the right hand side of the glacier tongue (pl. XXV fig. 2). It is composed of black shales with the same dip of the overlying limestones. The black shales are interbedded with fine-grained green arkose, thick beds of brown weathered fossiliferous protoquarzite (29KD-650')* and grey and whitish arkose sandstone with shell marks (pelecypods and gastropods), spines of *Productidae*, probable bryozoa, rare *Lagenidae* and probable *Archaeodiscidae* belonging to the Permian.

Just upstream from the Staghar glacier the shales are overlain by grey cherty limestone, in very thinly folded beds a few centimetres thick, very rich in chert, which occasionally replaces the limestone (fig. 29).

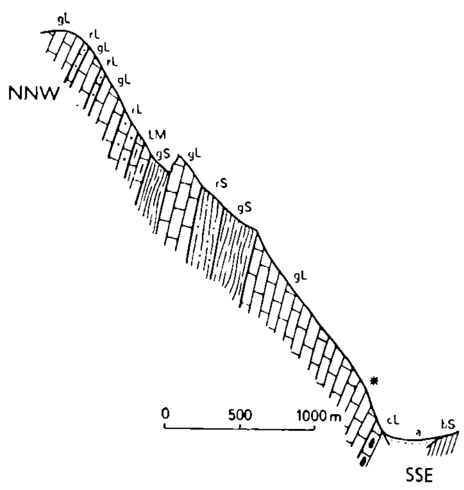

Fig. 29 – *Geologic section across the 6648 m peak on the right hand side of the Shaksgam Valley between the Staghar and the Singhié glaciers.*
bS black shales; cL cherty limestone; gL grey limestone; gS green shales; rS red shales; LM marly limestone; rL red limestone; a alluvial deposits; * Permian fossils.

Near this outcrop on the left hand slope of the Shaksgam valley I collected a sample (29KD-560)* of brown protoquarzitic biocalcarenitic sandstone with calcitic cement containing fragments of pelecypod shells and echinoid plates. It is interesting to notice that among the grains of the rock there are clasts of a devitrified acid lava and chert.

Another sample coming from the same locality (29KD-412)* is a fine-grained light brown-reddish arkose containing small pelecypoda casts. The presence of some grains of feldspar suggests that they are derived from metamorphic rocks.

On the right hand side of the valley the black shales with dark green veins, which seem to form the core of an anticline, continue on the right hand side of the valley for a long while still dipping 75°-80° north-northwest. About two kilometres upstream from the Staghar glacier, at the foot of a steep slope on the left hand side, I found a block of cherty limestone with fossil remains similar to *Daonella* or *Halobia*. The layer of cherty limestone from which the block came could not be identified. Further up on both slopes of the valley there are remarkably thick beds of limestone separated by a band of shales and forming two parallel ridges.

Around one of our camps, which was pitched 6,5 km downstream from the Singhié glacier, the slopes of the valley are built up of grey cherty limestone crossed by numerous calcitic veins. On the right hand side the chert is black and is settled in numerous stripes. The beds near the camp dip 80° towards south.

Between the camp and the end of the glacier on the right hand side I tried to reconstruct on sight a sequence which should be composed as follows:

7. Green, brown and blackish marly calcareous shales: not less than 50 m;
6. Yellowish arenaceous limestone, about 10 m;
5. As for bed 7, 25 m;
4. Limestone as for bed 6, 8 m;
3. Shales similar to bed 7, 30 m;
2. Purplish-red nodular shales with rare chert, about 15 m;
1. Grey limestone with lenses and stripes of chert, several metres.

The red and green shale beds are also repeated on the opposite side of the valley a few hundred metres from the river and they represent the other limb of the above mentioned anticline.

Just downstream from the Singhié glacier on the right hand side the beds dip 70° north. While the shales disappear under the gravel of the river bed, red and purplish slightly brecciated limestones associated with green and purplish limestones in beds a few centimetres thick outcrop in front of the glacier. Here the beds dip from 10° to 30° east-northeast or north-east and are intensely fractured.

I collected only a small amount of information on the Singhié glacier valley. The till near the front of the glacier and on it is composed essentially of black shales. These rocks form most of the slopes and the base of the Teram Kangri massif at 4503 m, from which also the debris of the median moraine derives. The imposing walls of Teram Kangri (7468 m) are made of limestone or dolomitic limestone (pl. XXVII and XXIX fig. 1).

Immediately above the Singhié glacier on both sides of the river bed, there are some fluvio-lacustrine terraces and, on the bottom, sand deposits (pl. XXXI fig. 1) being the remains of a barrier glacial lake.

About two kilometres upstream from the glacier a section was surveyed on sight and is shown in fig. 30. The beds dip 70° north on the right slope of the valley; on the opposite side they dip less steeply. It seems that the core of an anticline formed by black shales with limestone intercalations passes on this slope. Just above it the left side of the valley, near the two isolated cliffs composed of grey cherty limestone, is made of an alternation of brown marl and brown marly limestone (biosparite) (29KD-V19)*, rich in fossils, chiefly corals,

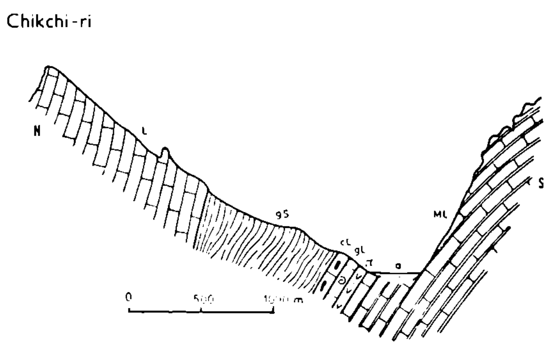

Fig. 30 – *Geologic section across the Shaksgam Valley about 2 km upstream from the Singhié Glacier.*

ML dark limestone interbedded with marls; π porphyritic dacite; gL grey fossiliferous limestone (Permian); cL cherty limestone; gS black and greenish shales; L limestone; a alluvial deposits.

plates and ossicles of crinoids. Apart from these poorly preserved and unidentifiable fossils, in a dark limestone FANTINI SESTINI recognized *Derbya regularis minor* Waagen, and *Rhombopora* sp., belonging to the Permian. Among the foraminifera there are also casts of *Lasiodiscus*, *Glomospira*, *Nodosaria*, *Endothyra* (?). Superiorly there is a thinly-bedded grey limestone with crinoids, which in turn is overlain by cherty limestone.

The beds outcropping downstream on the left slope of the Shaksgam valley belong to strata lower than the former ones. They are brown marl, black shales and marly limestone, alternating with beds of green-grey, grey-brown and yellowish-white arkose (29KD-20)*, arenaceous biomicrite with algae (29KD-5V/504)*, and white sandstone. The whole sequence is very fossiliferous. The marl and marly limestone contain mainly brachiopods, among which FANTINI SESTINI found *Juresania* sp. The sandstone contains numerous internal moulds of *Schizodus* cf. *dubiiformis* (Waagen), *Janeia biarmica* (Verneuil) and numerous valves of *Neochonetes varidatus* (d'Orb.). In these sandstones G. MERLA pointed out also the presence of an indeterminate *Spinomarginifera* and a *Spirifer* (?). Besides crinoid plates and ossicles there are also algae belonging to the *Dasycladaceae*. The beds dip 30°-40° toward north and are locally contorted.

The arenaceous-marly-calcareous sequence is overlain on the right hand flank by a thick sequence of grey limestone forming the highest ridges of Chikchi-ri (Island Ridge). The cherty limestone between two beds of shales and brown and blackish marly horizons overlain by the red rock horizon (limestone and conglomerate?) underlie the grey limestone.

Between the Singhié and the Kyagar glaciers R. WYSS (1939) of 1935 VISSER's expedition collected fossils at two localities: one (No. XXXIX) near the front of the Singhié glacier, according to the small-scale map showing the sample places (fig. 36); the other (No. XL) along the right slope of the same glacier valley, but just a little higher. Probably the last spot was reached by WYSS during his attempt to find a passage across the Singhié glacier, riddled with numerous ice pinnacles.

From the sample collected in the first place H. RENZ (1939) identified the following species:

Productus (*Linoproductus*) *cora* d'Orb.
» » *cancriniformis* de Terra (non Tschern.)
» (*Echinoproductus*) *elegans* M'Coy
Marginifera himalayensis Diener
Spirifer tibetanus Diener.

RENZ ascribed the species to the Uralian (Karachatyrian). It is not known from what lithotype they were collected.

The second place No. XL yielded the following forms recognized by RENZ:

Polypora biarmica Keys.
» *transiens* Waagen & Pichel
» sp. ind.
Derbya senilis (Phill.)
Chonetes variolata (d'Orb.)
» sp. ind. aff. *vishnu* Salter
Productus sp. ind.

Spirifer sp. ind.
Dielasma tymanicum Tschern.
Allorisma sp. aff. *sulcata* (Phill.)
Pleurophorus? sp. ind.
Sanguinolites sp. ind.

RENZ ascribed this fauna to the Uralian, but considering it younger than the previous one, referred it to the Early Uralian (Karachtyrian). The second fauna was ascribed to the Late Uralian (Darvasian); anyhow it certainly belongs to the Early Permian.

I would like to point out that the fauna of place No. XXXIX shows greater affinities with the fauna that I collected near the Staghar front glacier camp which, according to FANTINI SESTINI, can be referred to the top of the Early Permian, or, more probably, to the base of the Late Permian. The fauna from place No. XL perhaps is more similar to the one collected just above the Singhié glacier; FANTINI SESTINI referred it, on the whole, to the Permian. According to the attitude of the beds (fig. 30) it seems improbable that the fauna from place No. XL should be younger than the other; probably they are coeval.

In the same area WYSS (1939) collected also two rock samples which he summarily examined from a petrographic point of view. Sample No. 12 was collected on the right hand moraine of the Singhié glacier above its end and near the above mentioned locality; so we infer from its location on the map. This is a pebble of fine-grained grey-white biotite granite of unknown provenance. Possibly there are granite outcrops, which may be under the shape of a large dyke, at the base of the Teram Kangri walls. I must record here the outcrops of granite on the opposite side (Siachen side) of Teram Kangri (see the geologic map enclosed at the end of this volume).

The other sample, No. 157, is a grey-green feldspathic quartzite (greywacke). It was collected in the southern side of the valley, roughly half-way between the Singhié and the Kyagar glaciers and was associated with sandstones and limestones. It is the same lithotype, but slightly more metamorphosed of the arenaceous quartz-feldspathic rock which yielded fossils (mainly molluscs) and that I collected further downstream, as I mentioned above.

Further upstream, on the right hand side at the contact with the grey cherty limestone, there is a light brown coarse oolitic limestone associated with a fine-grained grey calcareous breccia. More precisely the limestone is a fossiliferous oointrasparite with superficial oolites containing bryozoa and echinoidea and, among the commoner fossils, remnants of completely recrystallized small shells of gastropoda and some foraminifera (29KD-V17/255)*. Still further uphill, on the left hand side, some green schistose rocks outcrop; P. Comucci (1938) classified them as *epidosites* (29KD-231), overlain by a complex of brown marls with calcareous intercalations. These are in turn overlain by cherty limestone. The repetition of the limestone appears to be due to a fold and the marly sequence seems to correspond to the above mentioned sequence containing *Juresania.*

The attitude of the calcareous formation composing the northern ridges overlooking the Shaksgam valley is clearly defined near the eastern end of the Chikchi-ri. This formation overlies the black and brown shale formation with unconformity. At the base of the calcareous formation there are reddish limestones and red conglomerate (fig. 31).

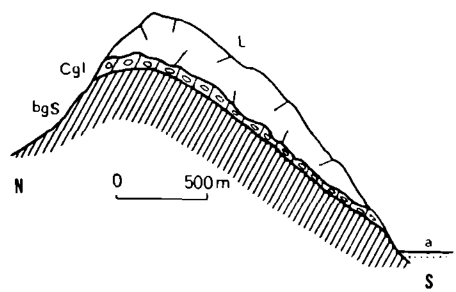

Fig. 31 – *Geologic section across the eastern end of the Chikchi-ri range.*

L grey massive limestone; Cg red limestone and conglomerate; bgS black and green shales. (The dip of the beds is unknown).

On the opposite side of the valley, at the foot of the Dra Gang (a mountain covered by a flat ice sheet, pl. XXXIII fig. 1), the grey cherty limestone is in contact with the Permian shaly-marly-calcareous fossiliferous formation.

The beds form an anticline the core of which trends along the left hand side of the Shaksgam valley, as can be seen in fig. 32. This anticline is the continuation of another one shown in fig. 30 (right side) which was surveyed further downstream.

Further uphill the grey cherty limestone, bent in another small anticline near the bottom of the valley (fig. 33) and contorted here and there, is followed by a thick bed of conglomerate. The conglomerate is in part reddish, due mainly to the abundant brick-red matrix and to fragments of red limestone, but in part grey. The conglomerate continues as far as our 1929 Kyagar front camp situated on the left side of the snout of the glacier and consists of fragments of grey and black limestone, red limestone and red chert occasionally very abundant. The matrix is a yellowish or red arenaceous-marly limestone. Together with the fragments of the size of a nut, there are also well rounded pebbles. The whole mass is crossed by numerous calcitic veins.

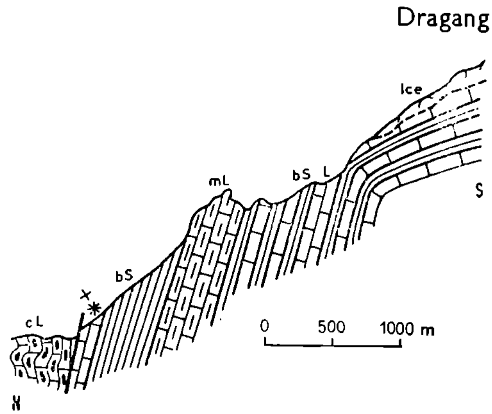

Fig. 32 – *Geologic section across the northern slope of the Dragang peak.*
bS black shales; cL cherty limestone; mL marly limestone; * fossiliferous limestone; x fault.

A direct examination the rock outcrop was made on the 5076 m peak above the glacier snout on the left hand side of the Shaksgam valley (1). The beds are almost vertical.

Descending from the summit composed of grey limestone with stripes of horny chert towards the Shaksgam river that is northwards, one meet a grey

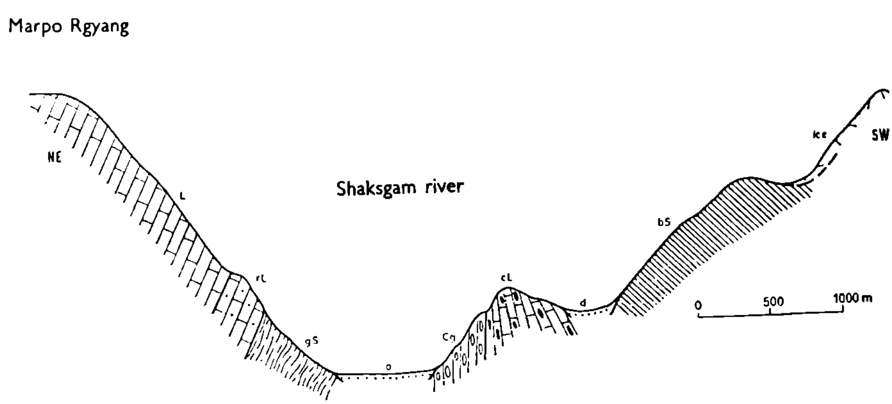

Fig. 33 – *Geologic section across the Shaksgam Valley downstream from the snout of the Kyagar Glacier.*
bS black shales; cL cherty limestone; Cg red and grey conglomerate; gS brown and blackish marly shales and green schists; rL reddish limestone shales and conglomerate (?); L reddish and light grey limestone; d debris; a alluvial deposit.

(1) In 1929, a big cairn was built on this summit, just in front of the one built by the 1926 MASON expedition on the opposite side of the glacier.

conglomerate with calcareous matrix, very rich in small nodules and fragments of brown or light brown chert (29KD-V15)*. Further on northwards there are bedded conglomerates and coarse breccia (29KD-V15')* composed mainly of nut-sized clasts of grey and black limestones, quite rich in angular fragments of chert, and with less abundant red limestone fragments. The matrix is yellowish marly limestone and the rock, which contains numerous fossil fragments, is crossed by numerous calcitic veins. Another variety of the same conglomerate is represented by a polymictic conglomerate (29KD-V 16)* mostly composed of flat and poorly rounded pebbles of reddish or brownish chert with minor amounts of very fine-grained grey and light brown limestone with some echinoid spines. The conglomerate beds dip 75° north and continue as far as the base of the peak, where they disappear under the gravels in the bottom of the valley.

The lower part of the opposite side of the Shaksgam valley, just downstream from the Kyagar glacier, is composed of black and green shales overlain by a very thick bed of limestone covered by red conglomerate, which in its turn is overlain by the Marpo Rgyang limestones. Just downstream that black limestone and grey cherty limestone underlie the shaly formation.

The relationship between these rocks is not clear: the cherty limestone of the cairn peak is in contact towards the south with a very thick fan-folded complex of black shales. The contact seems tectonic, but perhaps it is only a « detachment » of beds and not a real fault, while towards the north the contact between the cherty limestone and the conglomerate seems to be stratigraphic. It was not possible to verify whether the conglomerate of the cairn peak, which is at least one hundred metres thick, is the same outcropping on the opposite side at the base of the calcareous formation or if they are different. In this case two different conglomerate horizons would be present here.

The black shales which form the mountain side above the cairn undoubtedly belong to the lower part of the Permian fossiliferous formation which also outcrops downstream and which, upstream from the Kyagar glacier, yielded fossils to Wyss (1939). The black and green shaly formation underlying the Marpo Rgyang limestone seems, on the other hand, to be inserted between the beds of cherty limestone and red conglomerate outcropping at the base of the previous limestone.

As far as the tectonics is concerned, which are responsible for the attitude of the different beds, I collected a few data which in part can be deduced from the sections shown in figs. 33-35. The black shales core of the anticline exposed downstream passes on the southern flank of the Shaksgam valley, south of the

Kyagar cairn. It can also be easily seen on the right flank of the Kyagar valley (pl. XXXIV fig. 1). Its axis has a west-northwest trend. In the bottom of the valley there is a faulted syncline, formed in part by cherty limestone. Upstream from the Kyagar glacier the core of this syncline is folded and the limestone forms a small anticline near the valley floor.

On the right hand side of the Shaksgam valley the Marpo Rgyang limestone beds dip north, but are strongly fractured and form an anticline together with the Chikchi-ri beds in the Chikchi-ri valley.

These scanty observations make the reconstruction of the stratigraphic sequence quite difficult; however a hypothetical sequence can be compiled. From top to bottom we have (see figs. 33-34):

7. Marpo Rgyang (Red Wall) reddish and light grey limestones,
6. Reddish limestone shales and conglomerate (?),
5. Brown blackish marly shales and green schists with some calcareous beds,
4. Red and grey conglomerate,
3. Cherty limestone,
2. Limestone interbedded with marls (Permian).
1. Black shales (Carboniferous)

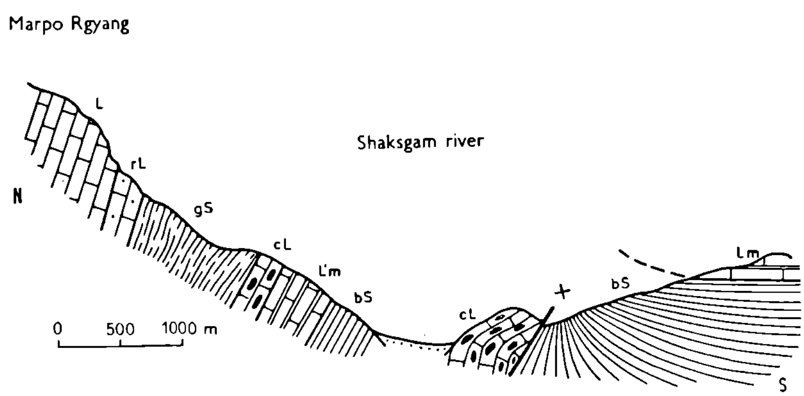

Fig. 34 - *Geologic section across the Shaksgam Valley near the snout of the Kyagar Glacier.* bS black shales; Lm limestone interbedded with marl; cL cherty limestone; gS dark marly shales with epidosite; rL reddish limestone and conglomerate (?); L light grey limestone; x fault.

Further downstream sandstone and yellowish arenaceous limestone seem to replace almost completely the conglomerate outcropping in the left flank.

According to our summary observations the *Kyagar valley* is almost completely hollowed in the black and brown shales and cherty limestones (fig. 35).

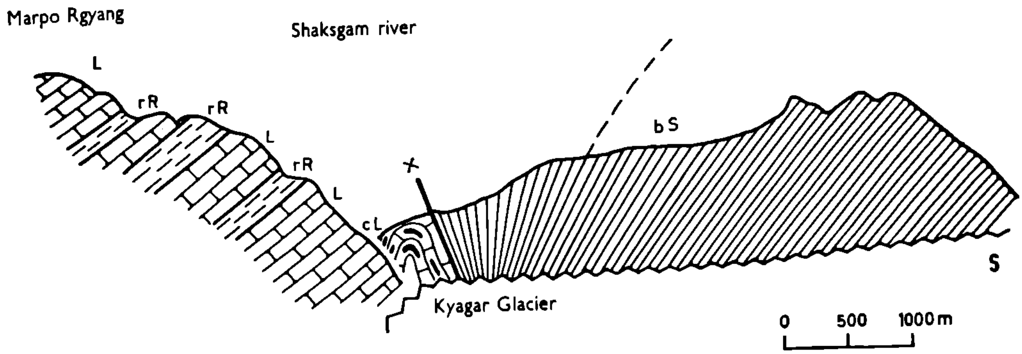

Fig. 35 – *Geologic section across the Marpo Rgyang and the right hand side of the Kyagar Glacier.* bS black shales; cL cherty limestone and conglomerate; L limestone and dolomite; rR red rocks.

The shales compose most of the two flanks of the valley, as can be seen in the photographs (plate XXXIV, fig. 1), the cherty limestone outcrops in various localities, among which there is the lower spur at the confluence of the Kyagar and Shaksgam valleys (pl. XXXII). The Apsarasas group, as seen from a distance, seems to be composed of Norian limestone and, possibly, of dolomite similar to the rocks of the Teram Kangri; the beds dip 50°-60° south-southeast.

9. The Shaksgam Valley upstream from the Kyagar Glacier.

I was not able to visit the section, about 28 km long, of the Shaksgam valley included between the Kyagar glacier and the Shaksgam-la. I only observed the lower part from a distance. Moreover taking into consideration the east-southeast trend of the tectonic axes and the similar direction of the valley, it might be assumed that the previously described formations should outcrop also there.

Some data on the geology of this part of the valley can be deduced from the descriptions of the rock samples and the fossils collected by Wyss (1939) (fig. 36). Smaller interest have few petrographic data reported by the 1926 Mason expedition.

The Shaksgam valley immediately above the Kyagar glacier which, like the previous ones dams it completely, shows a different geologic composition on each side. On the left hand side there is a group of not very rugged peaks dividing the Kyagar valley from the valley of the first left hand tributary of the Shaksgam river, which are clearly visible from the left side of the Kyagar valley. They are composed of black shales and marly calcareous rocks of the Permian. WYSS collected fossils at two localities, one (No XXXVIII) lies near the eastern side of the Kyagar glacier, just above its front; the other (No XXXVII) further upstream lies south-east of Kyagar-tso. Sixteen species from the first locality were determined by RENZ (1939) (five doubtfully) who considered them coeval of those of the already mentioned locality No. XXXIX, situated between the Singhié and Kyagar glaciers.

Productus intermedius Abich var. *minor* Schellwien, *Productus* (*Krotovia*) sp. aff. *pustulatus* Keyserling, *Productus* (*Linoproductus*) *cora* D'Orbigny, *Productus* (*Linoproductus*) *simensis* Tschernyschew, *Productus* (*Linoproductus*) *cancriniformis* De Terra, *Productus* (*Echinoconchus*) *elegans* M'Coy, *Productus* (*Horridonia*) *incisus* Schellwien, *Marginifera schellwieni* Tschernyschew, *Camarophoria purdoniformis* Grabau, *Pugnax elegans* Girty var., *Pugnax* cfr. *elegans* Girty, *Pugnax* cf. *swallowiana* (Shumard?), *Terebratuloides* sp. aff. *triplicata* (Kutorga), *Hustedia remota* Eichwald, *Athyris* sp. aff. *planosulcata* (Phillips), *Terebratula* (*Dielasma*) *elongata* (Schlotheim).

According to RENZ the fossils mentioned above belong to the Early Permian.

In the second locality, which lies further upstream, a considerable number of fossil species were found; some were fusulinids (new species) identified by M. REICHEL (1939), others were brachiopods and pelecypods.

Parafusulina visseri nov. sp. Reichel, *Parafusulina visseri* var. *lata* nov. var. Reichel, *Parafusulina shaksgamensis* nov. sp. Reichel, *Parafusulina japonica cincta* nov. subsp. Reichel, *Parafusulina japonica* var. *densa* nov. var. Reichel, *Parafusulina* cf. *kaerimizensis* (Ozawa), *Pseudofusulina* (*? Triticites*) aff. *subobsoletus* (Ozawa), *Pseudofusulina* aff. *chihsiaensis* (Lee), *Palaeofusulina* cf. *delicata* (Colani var.). *Yanchienia iniqua* Lee, *Schubertella simplex* Lange, *Endothyra* sp. indet., *Glomospira pusilla* Geinitz. *Calzitornella*, *Geinitzina*, *Pachyphloia* sp. indet., *Fenestella elusa* Reed, *Polypora* sp. indet., *Rhipidomella cora* (d'Orbigny), *Rhipidomella michelini* (Léveillé), mut. *orientalis* (Mansuy), *Schizophoria* cf. *supracarbonica* Tschernyschew, *Schizophoria juresanensis* Tschernyschew, *Enteletes obesa* Grabau, *Enteletes oehlerti* Gemmellaro, *Enteletes tschernyscheffi* Diener, *Enteletes tschernyscheffi* Diener var. *darwasica* nov. var. Renz, *Enteletes meridionalis* Gemmellaro, var. *karakorumensis* nov. var. Renz, *Meekella striatocostata* (Cox), *Meekella* (*Orthothetina*) *baschkirica* Tschernyschew, *Chonetes uralica* Moeller, *Chonetes sinuosa* Schellwien, *Chonetes* cf. *latesinuata* Schellwien, *Chonatella nasuta* Waagen, *Productus semireticulatus* Martin var. *transversalis* Tschernyschew, *Productus semireticulatus* Martin, *Productus uralicus* Tschernyschew, *Productus inflatus* Tschernyschew (non MC. Chesney), *Productus gratiosus* Waagen, *Productus moelleri* Stuckenberg, *Productus moelleri* Stuckenberg var. *latus* Tschernyschew, *Productus pseudomedusa* Tschernyschew, *Productus* (*Linoproductus*) *cora* d'Orbigny var. *waagenianus* Girty, *Productus* sp. *a* (aff. *P. mexisanus* (Shumard?) (White), *Productus* (*Linoproductus*) *koninckianus* Verneuil, *Productus (Linoproductus) keideli* nov. sp. Renz, *Productus (Linoproductus) kayseri* (Chao), *Cancrinella (Linoproductus) cancriniformis* (Tschernyschew), *Productus (Echinoconchus) punctatus* Martin, *Productus (Echinoconchus) punctatiformis* (Chao), *Productus (Waagenoconcha) abichi* Waagen, *Productus (Waagenoconcha) abichi* Waagen mut. *cambodgiensis* Mansuy, *Productus (Juresania) juresanensis* Tschernyschew, *Productus (Dictyoclostus) margaritatus* Mansuy, *Productus (Striatifera) mytiloides* Waagen, *Productus (Horridonia) incisus* Schellwien, *Marginifera juresanensis* Tschernyschew, *Marginifera sintanensis* Chao, *Marginifera* cf. *involuta* Tschernyschew, *Marginifera spinosocostata* (Abich), *Aulosteges* cf. *dalhousii* Davidson, *Camarophoria superstes* (Verneuil), *Camarophoria mutabilis* Tschernyschew, *Camarophoria* sp. aff. *affinis* Gemmellaro, *Uncinulus (Uncinunellina) timorensis* (Beyrich), *Uncinulus (Uncinunellina)* cf. *timorensis* Broili (? Beyrich), *Rhynchonella hustediaformis* nov. sp. Renz, *Rhynchonella* ? nov. sp. aff. *hoffmani* Krotow, *Spirifer lyraeformis* Tschernyschew, *Spirifer lyraeformis* Tschernyschew var. *elegantulus* nov. var. Renz, *Spirifer fasciger* Keyserling, var. *moosakhailensis* Davidson, *Spirifer (Neospirifer) wynnei* Waagen, *Spirifer tibetanus* Diener var. *occidentalis* Schellwien, *Squamularia asiatica* Chao, *Squamularia inaequilateralis* (Gemmellaro), *Squamularia rostrata* (Kutorga), *Squamularia dieneri* Gemmellaro, *Squamularia waageni* (Loczy), *Squamularia transversalis* nov. sp. Renz, *Martinia corculum* (Kutorga), *Martinia semiplana* Waagen, *Martinia elegans* Diener, *Martinia sinuloba* nov. sp. Renz, *Martinia squamularioides* Huang var. *shaksgamensis* nov. var. Renz, *Martiniopsis aschensis* Tschernyschew, *Ambocoelia planoconvexa* (Schumard), *Ambocoelia* nov. sp. Renz, *Spiriferina multiplicata* (Sowerby), *Spiriferina cristata* Schlotheim var. *octoplicata* (Sowerby), *Spiriferina toulai* Gemmellaro, *Spiriferina margaritae* var. *dilatata* Gemmellaro, *Hustedia remota* (Eichwald), *Hustedia indica* (Waagen), *Athyris acutomarginalis* Waagen, *Terebratula (Dielasma) elongata* (Schlotheim), *Terebratula (Dielasma)* sp. indet., *Hemitychina dieneri* Gemmellaro var. *quinqueplicata* nov. var. Renz, *Notothyris nucleolus* (Kutorga), *Notothyris nucleolus* (Kutorga) var. *simplex* Waagen, *Notothyris? taveli* nov. sp. Renz, *Notothyris? wyssi* nov. sp. Renz, *Aviculopecten karakorumensis* nov. sp. Renz, *Aviculopecten tristriatus* nov. sp. Renz, *Aviculopecten* cf. *hiemalis* Mansuy (? Salter), *Aviculopecten* cf. *alternatoplicatus* Chao, *Aviculopecten* nov. sp. Renz, *Aviculopecten* sp. indet. *a* (aff. *samarensis* Stuckenberg), *Aviculopecten* sp. indet. *b*, *Conocardium uralicum* (Verneuil), *Euchondria(?) engelhardti* Etheridge & Dun., *Streblopteria magnini* Mansuy, *Lima* cf. *striatoplicata* Chao, *Allorisma* cf. *elegans* King, *Edmondia* cf. *nyströmi* Chao, *Euomphalus (Phymatifer)* cf. *sumatrensis* Roemer, *Strobeus* cf. *elegans* Gemmellaro, *Capulus abundans* Wanner, *Luciella huangi* nov. sp. Renz, *Trachydomia tuberculato-lineata* nov. sp. Renz, *Phillipsia* cf. *middlemissi* Diener, *Phillipsia* sp. indet.

According to Reichel and Renz this Permian fauna represents a horizon slightly higher than the previous one and must be referred to the Artinskian (Darvasian).

These data seem to indicate that the strata are disposed normally since they become younger and younger towards north. This ascertainment agrees with the fact that still further towards the north the massive limestone of the Marpo Rgyang belongs to the Middle Triassic. Just upstream from the Kyagar glacier, Wyss collected two samples of green schists (No. 97 and No. 98) which were also found in the Shaksgam valley below the Kyagar glacier; they seem to belong to the Chikchi-ri or to the Shaksgam formations.

In the upper Shaksgam valley Wyss found two more fossiliferous localities (No. XXXVI and No. XXXV). The first occurs in the middle reaches of the valley on the left hand side and yielded the following species (Renz 1939): *Marginifera himalayensis* Dien., *Martinia semiglobosa* Tschern., *Spirifer tibetanus* Dien., *Temnocheilus* (*Metacoceras*) sp. ind. These fossils were ascribed by Renz to the Early Uralian (Karachatyrian), that is to the same age of the sample from locality No. XXXVIII, situated on the left bank of the Shaksgam river.

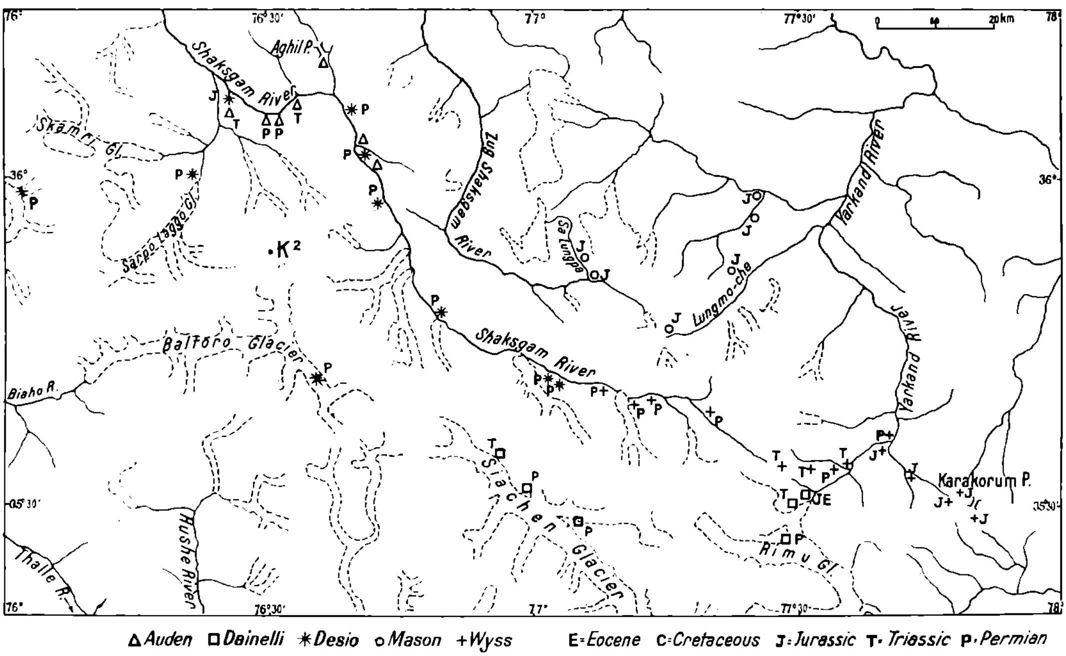

Fig. 36 – *The fossiliferous localities in the Shaksgam and surrounding valleys.*

The second locality is situated to the west of the Shaksgam-la. It yielded the following species: *Productus uralicus* Tschernyschev, *Marginifera himalayensis* Diener, *Martinia nucula* Rothpletz, and *Euomphalus* sp. Enderle. The age of this small fauna is the same of the preceding one.

Particularly interesting are the few fossils collected in locality No. XXV further upstream on the right bank near the Shaksgam-la. They are one

Rhynchonella sp. ind., of no chronostratigraphic utility, the other, a valve of *Monotis salinaria* (Schloth.) of Late Triassic, found in a massive grey-yellow limestone. This limestone probably derived from the limestone formation outcropipng on the steep valley sides; it too can be referred to the Aghil Limestone, belonging to the Late Triassic.

Another fossiliferous locality (No. XXXIV) lying outside the Shaksgam valley, is situated just beyond the Shaksgam-la, in the upper left tributary valley of the headwaters of the Yarkand river. In this locality a specimen of *Heterastridium* cf. *pustulosum* was collected; it belongs to the Carnian and is very common in other localitis further to the east. Unfortunately we do not know what kind of rocks outcrop in this locality, but presumably they are the same of those yielding other *Heterastridium* in the upper Yarkand valley and in the Karakorum pass. We will deal with this question further on.

In the Shaksgam valley, upstream from the Kyagar glacier, Wyss found also an outcrop of « green schist » on the south-west slope of the valley, south-west of the Kyagar glacier, and in the underlying gorge. The rock, which seems to be a metamorphosed quartz diabase or a melaphyric tuff, is inserted between the Permian limestone (below) and an arenaceous conglomerate (above) about 100 m thick, referred by Wyss to the Late Carboniferous, but probably Triassic.

In conclusion it can be assumed that the southern slope of the Shaksgam valley, upstream from the Kyagar glacier, probably is made of the lower member of the Shaksgam Formation, while to the north on the right bank of the river there are the beds of the upper member. The rocky walls overlooking the upper part of the Shaksgam valley to the north consist of Aghil Limestone. Probably there is another argillitic formation with *Heterastridium* of the Late Triassic (Carnian), intercalated between the upper beds of the Shaksgam Formation and the base of the Aghil Limestone, at least near the Shaksgam-la.

Along the upper Shaksgam valley the anticline with the black shaly core continues along the southern side of the valley between the Kyagar and Singhié glaciers. The axis of the fold dips east, with the result that towards the east the Aghil Limestone beds, which form the high ridges of both sides of the valley, come sensibly closer together.

IV. THE LITHOSTRATIGRAPHIC UNITS OF THE SHAKSGAM VALLEY

1. Preliminary Stratigraphic Scheme.

On the basis of the previously recorded data it is now necessary to attempt to establish a general sequence from the partial stratigraphic sequences, in order to define the sedimentary units outcropping in the Shaksgam valley.

I want to mention here that only the stratigraphic units with normal sedimentary facies outcropping in the main valley and its tributaries, upstream from the Shaksgam-Sarpo Laggo confluence, will be examined in this review.

I omitted the units outcropping in the Sarpo Laggo and Skamri glacier valleys as they mostly show metamorphic and igneous facies and this facies is only exceptionally present in the upper Shaksgam valley. Beside that the available data on these rocks are much more scanty and they lack in the support of petrographic determinations which are very important in these rock types (1).

Moreover some information on the formations of the two above mentioned valleys and some comparisons with analogous formations of the surrounding valleys (Baltoro and Panmah) are contained in the descriptive sections.

The limestones and dolomites forming the Aghil ridges overlooking the Shaksgam valley can represent one lithostratigraphic unit that is the Aghil Limestone. Some Norian fossils occurring in the upper part of these limestones — although the exact positions of the fossiliferous beds are not well known — are significant markers.

Another sedimentary unit is the rather thick complex of black shales and slates with some intercalations of limestone, which outcrop extensively in the Singhié and Kyagar valleys and grades into a calcareous marly fossiliferous sequence. The markers of this unit are some Permian fossiliferous horizons in the upper part of the sequence. Between these two units there are others, part of which are poorly defined, especially as far as their lateral extent is con-

(1) As I have already mentioned that the samples collected in this area were lost by the porters.

cerned. However, some of these units are characteristic. One is the calcareous conglomerate with red matrix underlying the Aghil Limestone; it is well represented in the Urdok and Gasherbrum valleys, but we do not know whether it is the same conglomerate outcropping near the bottom of the Shaksgam valley mainly between the Singhié and Kyagar glaciers. Other units are represented by the grey cherty limestone outcropping extensively between the same glaciers.

From this brief account and from what I expounded in the descriptive sections, we can recognize the presence of the following sequence of characteristic lithostratigraphic units in the Shaksgam valley (Desio, 1964); I list them as follows (from top to bottom):

7. Limestone, marl, sandstone and conglomerate with Jurassic fossils, forming a poorly characterized sequence, seen only on Bdongo-la. This sequence represents a formation which, at present, is indefinite and will be called *Bdongo Formation*;
6. Aghil Limestone;
5. Urdok Conglomerate;
4. Chikchi-ri Shales;
3. Kyagar Cherty Limestone;
2. Shaksgam Formation (or Group);
1. Singhié Shales.

Only the Aghil Limestone and the Shaksgam Formation show well defined characters. The Urdok Conglomerate might represent the basal part of the Aghil Limestone, a homotaxial deposit of the Chickchi-ri unit, but probably in the Shaksgam valley there are more than one conglomerate horizon similar to each other; they seem to represent a separate formation like in the upper Urdok valley. The same could be true for the Kyagar cherty limestone, which could represent a separate formation, at least in the area between the Staghar and Kyagar glaciers.

The Shaksgam Formation (or Group) consists of shaly-marly-calcareous-arenaceous rocks (generally fossiliferous) and these include mainly black shales in the lower part and green, black, brown and red shales and green schists with rare limestone intercalations in the upper part. According to our present knowledge it can be assumed that the Shaksgam Formation consists of three lithostratigraphic units: the upper one is prevailingly an arenaceous unit, the middle one is prevailingly a calcareous unit, the lower one is a marly-calcareous unit inferiorly grading into black shales.

At present we do not sufficiently know the Shaksgam stratigraphic unit to decide whether it is a formation or a group. Temporarily we prefer to classify it as a formation and to consider the three internal subdivision members of it.

Now we will briefly record the chronostratigraphic nomenclature employed by the authors who studied the Karakorum and Aghil fossils, in order to compare it with the terms used at present by Russian authors who studied the regions to the north, particularly the Pamirs.

In the table below the various terms are compared:

G. Merla (1934) and H. Renz (1939)	A. D. Mikluko Maklay (1963)	
Late Permian: Lopingian	Late Permian	Pamirian Murgabian
Middle Permian: Artinskian Early Permian: Uralian (1)	Early Permian	Darvasian Karachatyrian

Taking into account the differences of opinion on the division of the Permian and its relations with Carboniferous, it is not necessary, in view of the limited aims of this section, to go into greater details. I would like to remark only that the Russian stratigraphic terminology seems more suitable for classifying our Asian formations than the European ones.

Now the stratigraphic units will be described separately, starting from the lower one.

2. The Singhiè Shales.

This unit was briefly described by Desio (1963) and the description is given below:

« Thick sequence of black, foliated shales often grading into black slates, with thin beds of dark coloured limestone or marl and quartz-sandstone intercalated.

The Singhié Shales underlie the Permian fossiliferous beds, but black shales are also interbedded in the more recent formations and it is difficult

(1) At present the Uralian is enclosed in the Late Carboniferous and come after the Gzhelian and before the Sakmarian (Early Permian) in the Eastern Europe. Previously the Uralian was considered as the oldest partition of the Permian, but some paleontologic markers present also in our country like *Parafusulina* and *Neoschwagerina* and contained in the terrains once referred to the Uralian, belong to the Permian fossil fauna.

to identify one from the other when the stratigraphic sequence is disturbed by folds and faults.

Thickness: more than 500 m. Age: probably Carboniferous ».

I have to add that many lithotypes like argillite, silicite, mudstone, siltstone, fine-grained sandstone and also calcarenite and marl are included under the name of shales and slates, but the argillaceous and silty components are the prevailing ones. All these lithotypes have in common a black or dark colour.

Sandstone of different grain size and limestone are usually associated with the above mentioned lithotypes. I was not able to make distinctions in the field and the collected samples are very few.

The normal type of shales grades into slightly metamorphic types like slates, and then, by degrees, to phyllites and gneiss. These transitions are very evident in the Baltoro basin where they were examined in detail and afterward the samples have been submitted to a petrographic investigation (DESIO & ZANETTIN, 1970).

From the previous sections it can be easily seen that black shaly rocks are widespread throughout the Shaksgam valley. They occur as beds of varying thickness in several members of the Shaksgam Formation and they become more and more extensive from the Gasherbrum glacier front towards east.

The largest diffusion of these rocks occurs in the valleys of the Singhié and Kyagar glaciers where they are some 1000 m thick; for this reason they were called Singhié (black) Shales. The investigation carried out in the Shaksgam valley was too cursory to enable me to provide a stratigraphic sequence and therefore this name is rather conventional. It refers to a complex of black shales with intercalations of calcareous, marly and dark arenaceous rocks which underlie the Permian fossiliferous shaly-marly-calcareous formation (Shaksgam Formation).

The unit is characterized by a smooth topography, by gentle slopes, by rounded summits and by the lack of rocky walls. Where the hights are more rugged, there are outcrops of limestone or quartz sandstone.

In the Shaksgam valley this morphology occurs also in the area to the south of the Singhié and Kyagar glaciers and the spread of the black shales here is confirmed by the prevalence of these rocks among the debris of the moraines.

Between the Singhié Shales and the lower fossiliferous calcareous-marly unit of the Shaksgam Formation there is a gradual passage which, however, has not been sufficiently defined in the field. The lowest beds of the Singhié Shales are unknown. In the anticlinal core passing through the southern side of the Shaksgam valley between the Kyagar and Singhié glaciers, I saw only black shales and, at present, this is the lowest sedimentary unit seen in the Shaksgam valley. Nevertheless a bed of cherty limestone outcrops in the core of a small anticline near the Kyagar glacier snout and its position in respect to the Singhié black shales is not quite clear. Among the possible interpretations of the local tectonics we may assume the cherty limestone as underlying the black shales. In this case they may represent the lowest beds of the local stratigraphic sequence and its age would be pre-Carboniferous.

As we will see later (p. 85) the stratigraphic sequence of the upper Hunza valley seems to support a similar interpretation, but also in that area the tectonic implications make uncertain the relationship between the Permian black shales (Gircha Formation) and the Kilik cherty limestone (? Devonian). Moreover other stratigraphic elements in the Eastern Karakorum do not confirm that interpretation (p. 86).

The lack of information on the base of the Singhié shales prevents us from ascertaining the total thickness of the black shales.

The Singhié black shales have not been paleontologically dated for lack of fossils. However we must take into account that in the middle and upper Shaksgam valley the oldest fossiliferous beds, referred to the Early Permian, are underlain by black shales. Therefore, it is likely that these shales belong to the Carboniferous. In order to verify this assumption we should seek more information in the neighbouring regions and particularly in the eastern one, where the folds coming from the Shaksgam are more open and less incomplete.

3. Comparison between the Singhiè Shales and Similar Formations in the Eastern Karakorum.

The region nearest to the Shaksgam valley whose geology is better known is the area between the Karakorum pass and the Siachen glacier.

This region is particularly interesting because is approximately located along the eastern tectonic axes of the Shaksgam valley. The geologic sections and stratigraphic sequences illustrated by various authors who studied the above mentioned region, reveal that rocks similar to the Singhié Shales, are known in several localities.

The first locality near the Shaksgam valley, along the same line of strike, is the one described by DAINELLI (1934, p. 486) near the front of the principal tongue of the Rimu glacier. Unfortunately a complete lithologic sequence is not exposed, but a record is here reconstructed on the data given by DAINELLI and MERLA (1934, p. 184). The stratigraphic units are, from top to bottom, as follows (fig. 37):

7. Dark unfossiliferous limestone, 30 m;
6. Crinoidal limestone, 6 m;
5. Limestone and dark marly shale with *Productus*, 16 m (Lopingian = Late Permian);
4. Crinoidal limestone, 26 m;
3-1. Reddish and light-grey marly limestone, very fossiliferous, 76 m (Uralian = Early Permian) (1)

(01). Blackish shales, 54 m;	Carboniferous (148 m)
(02). Dark sandstones, 54 m;	
(03). Blackish shales, 16 m;	
(04). Dark sandstones, over 24 m.	

In the sequence there are dykes and sills of rhyolite. The Singhié Shales are obviously correlatable with the beds underlying level 1.

As far as we know this is the only area outside our territory in which the black shales are in direct contact with a dated fossiliferous sequence.

Another outcrop of black shales nearer to our area, though less helpful for the reconstruction of the stratigraphy, is located, according to DAINELLI (1934, p. 573), in the Siachen glacier valley. In this valley there are several outcrops of « black slates » which he considers similar to those of the Gasherbrum group in the Baltoro basin and « probably Carboniferous » like the former ones. The same author also says (p. 513), still with reference to the « black slates » of the Gasherbrum group, that « they seem to represent one of the commonest lithofacies of the Upper Paleozoic — but we may say — especially Permian — throughout the Eastern Karakorum ». Let us accept the attribution to the Carboniferous, with reference to the surest data collected by DAINELLI in the neighbouring Rimu basin. It should be mentioned that in the Upper Baltoro basin these rocks have slate instead of shale facies, but many rocks in that region are more highly metamorphosed (DESIO & ZANETTIN, 1970).

Black shales similar to those of the Shaksgam valley, but slightly more arenaceous, are scattered mainly in the left moraine of the Siachen glacier and in the right central moraine of its left hand tributary, the Teram Sher glacier. It can be assumed that these black shales outcrop extensively in the northern slopes of the upper Siachen valley, considering also that they occur in the upper

(1) See page 79.

Urdok valley — as we have already mentioned — and, probably, also at the southern foot of the Teram Kangri and Singhié Kangri mountain groups.

Probably they outcrop also in the Hawk peak, where they are near the granites and, therefore, we may suppose that they grade into hornfels and/or gneiss.

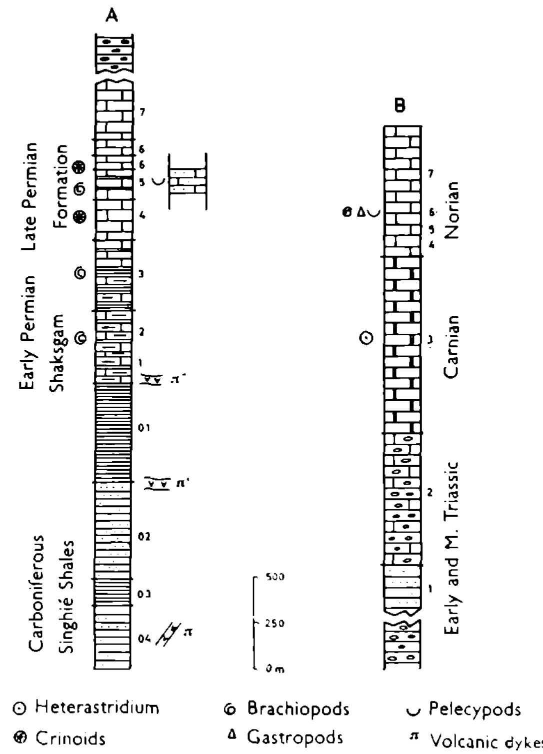

Fig. 37 – A. *Stratigraphic sequence of the Singhié Shales near the right snout of the Rimu Glacier by* DESIO, *from* DAINELLI'S *description.* B. *Stratigraphic sequence by* DESIO *near Qizil Lungur from* DAINELLI'S *description.* (After Dainelli this sequence is upset). See in the text (p. 82 and p. 121) the explanation of the numbers.

The black slate outcrops in the upper Siachen valley are confirmed also by some samples of this rock collected by DAINELLI'S assistants during his 1930 expedition and exhibited in the collections of the Institute of Geology, University of Florence. One sample of black slate, bearing the No. 37, comes from Turkestan-la, which is a pass located between the Siachen and the Staghar valleys. Evidently it is the same black slate horizon which outcrops in the opposite slope of the saddle, that is in the Staghar valley and presumably also in the upper Urdok valley, as we have previously said (p. 57).

A sequence of black shales similar to the former ones was reported by

DAINELLI (1934, p. 484) in the upper Shayok valley at the confluence with the Chip-Chak valley; it has been attributed to the Carboniferous. It seems to underlie the cherty limestones referred to the Early Triassic: the Permian fossiliferous beds are not visible in this area.

Additional scattered outcrops of black shales similar to the Singhié Shales in the eastern region do not provide better information for comparison, since also in this region black shales, not easily distinguishable from the above mentioned ones, appear in other formations — above all in the Late Permian ones — like in the Shaksgam valley.

MERLA (1934, p. 199) described « arenaceous shale » which « is distinguished by its dark to black colour », together with a dark marly limestone, collected in one of the Rimu moraines, in which Late Permian fossils occur and also another dark to pitch-black arenaceous shale with Permian fossils found in the Depsang Plains.

Towards east, in Western Tibet, a black slate horizon was described by E. NORIN (1946) under the name of *Horpatso Formation*; it shows remarkable affinities with the Singhié Shales. The Horpatso Formation is estimated 1-2 km thick and referred to Carboniferous-Early Permian, but did not supply fossils. Recently the same author made a thorough petrographic and stratigraphic investigation on many samples of black slates and shales coming from Pamirs, Karakorum and Western Tibet (1976). In his study NORIN correlated the occurrences of these rocks in the three regions and found large similarities among them. He confirmed also the great affinity of the Singhié Shales with the Horpatso Formation.

In the South-eastern Pamir the Bazardar Suite, investigated by E. Y. LEVEN (1967) and S. B. RUZHENTZEV (1968) and examined petrographically by NORIN in 1976 along the Boz-Tere section, shows evident affinities both in the petrographic composition and in the geological age (Carboniferous-Early Permian) with the Singhié Shales.

In conclusion, it can be assumed that the same black shale stratigraphic unit, present in the Siachen and Rimu glacier basins, in the upper Shayok valley, and in some other localities, is represented in the Shaksgam valley by the Singhié Shales and must be referred to the Carboniferous and probably to the upper part of it.

4. Comparison between the Singhiè Shales and Similar Formations in the Western Karakorum.

The nearest occurrence of black shales to the west of the Shaksgam valley is the one forming large tracts in the Sarpo Laggo and Skamri valleys, the lower left hand tributaries of the Shaksgam valley. We have already examined the lelationship of these slates with the Singhié shales at page 30.

We must go as far as the Hunza valley to find a formation similar to the Singhié Shales. This is the formation, which was called *Misgar Slate* (DESIO & MARTINA, 1972), outcropping in the Kilik valley, a tributary of the Hunza valley. It is a monotonous formation composed of black argillaceous and arenaceous slates with a few intercalations of greyish quartzite and sills of porphyritic dacite. This formation has a composition very similar to the one of the formations exposed near the northern front of the Rimu glacier, but it must be noted that the Misgar Slates are about 5000 m thick, while the Rimu black shales are only 94 m thick. Nevertheless the basal beds of the Rimu black shales, the Singhié black shales and other similar sequences of the Eastern Karakorum are not known.

The age of the Misgar Slates is not known with certainty; we only know that they are pre-Eocene, since they were intruded by quartz-syenite of that age. They have tentatively been referred to the Carboniferous, but they may be older.

The Pasu slates of the Hunza valley will not be discussed since we do not know their stratigraphic position (DESIO & MARTINA, 1972).

Isolated outcrops of black slates, possibly comparable to the Singhié Shales, were recorded by P. H. KUENEN (1928) in the little known area between the upper Hunza valley and the Shaksgam valley. Neither their age nor their stratigraphic position are known, but probably there is a certain continuity between the outcrops of the two regions.

* * *

Before closing the comparative review of the Singhié Shales I would like to draw some conclusions.

Although the peculiar characteristics of this formation are rather well defined on account of the large prevalence of black argillitic material in the stratigraphic sequence, some facts are to be underlined. They are:

a) As black shales are frequent also in the overlying Shaksgam formation, sometimes with relevant thickness, it is not easy, during a rapid exploration, to ascribe — in default of fossils — the isolated black shale outcrops to the Singhié Shales or to the Shaksgam Formation.

b) As the passage from one formation to the other is gradual, it is difficult to define a precise limit between the two formations. This uncertainty is reflected also in the geologic map and in the cross-sections enclosed in the present work.

c) The Singhié black shales show a facies very similar to the flysch one. It is characterized by frequent lateral and vertical transitions from one lithotype to another and also this fact makes less clear the separation of the two formations.

d) Since in our region the bottom of the formation is not exposed, the thickness of the beds belonging to this formation is uncertain. If in my initial definition I said that it is greater than 500 m, not knowing the bottom of it, the meaning of this figure remains very vague. I presume that, at least in the Kyagar area, the thickness should be much more than double, as it can be deduced also from my geologic cross-sections.

In the Baltoro basin the black slate sequence underlying the Shaksgam formation, at Chochordin can be evaluated more than 1000 m (DESIO & ZANETTIN 1970). But the same black slate outcrop continues under the ice on the opposite side of the upper Baltoro valley (see the geological map enclosed in the above mentioned work) and its thickness might amount to several thousand meters, provided that it is not crossed by any fault and it is not repeatedly folded.

The southeastern Pamir Bazardar suite which was correlated by E. NORIN (1976) with the Singhié Slates, is exposed for a thickness of 1500 - 2000 m and also here its base is not known.

We may then conclude that the Singhié Shales are mostly thicker than a thousand metres and probably amount to some thousand metres.

I will deal with the paleoenvironmental meaning of this formation in another section (page 149).

5. The Shaksgam Formation.

5.1. INTRODUCTION. Our knowledge of this formation is still incomplete since no type-section was described. We know only some partial sections reported in the former sections of this chapter; they may provisorily fill that gap.

In volume III, No. 8 of the « Lexique Stratigraphique International », this « formation » is defined as follows:

« *Shaksgam Series.* - Permo-Carboniferous.

Name given by J. AUDEN (Him. Journ., vol. 10; p. 43, 1938) to a group of rocks predominantly limestones with shales, etc. from Central Shaksgam in Karakorum. AUDEN (1938) assigned Permo-Carboniferous age to the Series. His collections of fossils was examined by M. R. SAHNI, who found *Martinia*, sp. nov., *Fusulina* and Productids (" Rec. Geol. Surv. India ", vol. 73, pt. 1, p. 22, 1939). See also A. DESIO (Geogr. Journal, vol. 75, p. 402, 1930) ».

Owing to the vagueness of the above definition it was re-defined by DESIO (1963) as follows:

« Brown to black and grey limestone and shaly marl associated with beds of brown and yellowish quartz-sandstone. Some light-coloured beds of limestone in the upper part of the sequence. The Shaksgam formation is generally very fossiliferous. The most frequent fossils are: brachiopods of the genus *Productus*, pelecypods, bryozoans, corals, crinoids and foraminifera (mostly *Parafusulina*). Thickness: not less than 1000 m. Age: Permian and Upper Carboniferous ».

We may add that inferiorly the Shaksgam Formation grades into the Singhié Shales increasing the shale intercalations within the limestone beds. Superiorly the formation shows two differen kinds of transitions: a) the formation grades into the Chikchi-ri shales formation because of the increase of the marly content; b) the formation is truncated by an erosional unconformity of the Urdok conglomerate. We know that the a and b stratigraphic units are coeval.

5.2. THE CHRONOSTRATIGRAPHIC PARTITION OF THE SHAKSGAM FORMATION. No good section of the Permian fossiliferous beds was surveyed in the Shaksgam valley. We can attempt to reconstruct the stratigraphic sequence by the paleontologic markers which, anyhow, are scarce too.

We may divide the Permian beds into two chronozones, one referable to the Early Permian, the other to the Late Permian.

5.3. EARLY PERMIAN. The oldest beds dated paleontologically are those « Near Gasherbrum Jilga Signal Camp »: they yielded a rather rich fossil fauna, attributed to the Uralian (1) (= Karachatyrian) that is to the lowest beds of the Early Permian by MERLA (1935) and mainly by FANTINI SESTINI (1964). Among the significant forms found in that locality there are the following genera: *Marginifera*, *Spirigerella* and *Chonetinella*. The fossiliferous beds are black (sometimes reddish) limestones, alternating with marly limestones and brown marls with some chert nodules. The fossils are commonly found in a slightly argillaceous grey-brown limestone containing very fine organic fragments in an argillaceous limonitic matrix. A good local stratigraphic section is lacking.

As recorded in page 50, the fossiliferous limestone and marl are in contact with grey cherty limestone and with red and green shales.

Further downstream, near the confluence of Bya Lungma, but on the opposite side of the Shaksgam valley, a dark grey and yellow arenaceous limestone yielded *Parafusulina shiptoni* Dunbar with indeterminate brachiopods and crinoids.

According to recent studies by A. D. MIKLUKHO-MAKLAY (1963), the Parafusulinids of Darvas and Pamir are mostly widespread in the Darvasian beds. Taking into account this statement it is probable that this horizon occurs not only in the above mentioned locality, but also further downstream, below Durbin Jangal, where the type of the species *shiptoni* was collected. C. O. DUNBAR (1940) considered that the species probably fell in the horizon of the upper part of the « Leonard » or the « Word Formation » of Texas; on the whole they correspond to the Darvasian.

In the Shaksgam valley the stratigraphic position of this *Parafusulina* horizon is poorly known. However the section on page 49 including this horizon is noteworthy. Under it there are cherty limestones alternating with marls which could possibly represent, together with the underlying conglomerate with crinoids and brachiopods, the fossiliferous limestone of Karachatyrian age in the Gasherbum Jilga.

Below are black shales and marly limestone while above the *Parafusulina* limestone there are red, green and black shales underlying the Aghil limestone.

Additional localities, the beds of which yielded fossils referred to the oldest sections of the Early Permian (Karachatyrian), were recorded by RENZ (1939). He examined the fossils collected by WYSS of the 1935 VISSER expedition. However the fossils collected here and there are generally too rare and often lack significant species to enable us to accept the indicated chronostratigraphy,

(1) See page 79.

while some should be referred to younger horizons. The lithostratigraphic divisions of RENZ (id., p. 243) were not based on mapped sections, but deduced from the samples. They are, however, rather significant, but we must take into account the fact that the lithostratigraphy of the Permian in the Shaksgam valley is rather variable on account of the repetitions of the same lithotypes in different stratigraphic units.

However some comment based on the most recent classifications of the Permian of Central Asia (A. D. MIKLUKHO-MACLAY, 1963) should be made on the beds attributed by RENZ to the Uralian (1). These localities, starting with the oldest, will be reviewed below (fig. 36).

a) *No. XXXII. Base of the north slope of peak* 6252 *m* (20512 *ft.*), *east of the Shaksgam-la.* Early Uralian. Early Artinskian (blue-black, very hard limestone. Yellow-brown arenaceous limestone) (2). The few species identified belong to the Early Permian, therefore they could represent the Karachatyrian, without excluding the Darvasian.

b) *No. XXXV. West of the Shaksgam Pass.* Lower Uralian. (Blue-black very hard limestone).

Among the few species recognized, *Marginifera himalayensis* Diener occurs; now it is considered exclusive and frequent in Early Permian beds. Thus an outcrop of Late Permian beds in this locality seem improbable.

c) *No. XXXVIII. East bank of the Kyagar glacier.* Lower Uralian. Blue-black very hard limestone.

This is Early Permian, but the stage cannot be deduced from the species identified.

d) *No. XXXIX. Shaksgam valley, between the Singhiè and Kyagar glaciers.* (Blue-black very hard limestone).

Among the species identified there are Early Permian forms, such as *Spirifer tibetanus* Diener, and Late Permian forms, such as *Marginifera himalayensis* Diener. All that can be said is that either the Early and the Late Permian or the passage-beds are represented in that area.

e) *No. XXXIII. Valley to the east of the Shaksgam-la.* Late Uralian. (Blue-grey limestone and marly limestone).

I am not able to give any assesment, since the only reported species was determined with uncertainty.

f) *No. XXXIV. Valley to the east of the Shaksgam-la.* Late Uralian. (Grey arenaceous limestone).

There are species which begin to occur in the Late Darvasian and become frequent in the Late Permian, such as *Derbya eusarkos* (Abich), *Marginifera spinosocostata* (Abich),

(1) See page 79.
(2) All the lithologies are taken from H. RENZ (1939, p. 243).

M. intermedia helica (Abich) (corresponding to *shaksgamensis* n. var. Renz). These beds seem to belong to the Late rather than to the Early Permian.

g) *No. XL. East bank of the Singhié glacier.* Late Uralian. (Blue-grey limestone and marly limestone. Grey arenaceous limestone). The fauna is too poor for an exact chronologic determination; we can only say that it is Permian and may be Late Permian.

h) *No. XXXVII. Shaksgam Valley, south-east of the Kyagar-tso.* Late Artinskian. (Light-grey limestone. White limestone).

This locality which yielded a rich *Parafusulina*, brachiopods and pelecypods fauna, can be attributed to the upper part of the Early Permian (Darvasian), because of the presence of Parafusulinids and of the composition of the brachiopod fauna.

According to what has been said about these fossiliferous localities, only a), c) and h) represent the Early Permian. However, in the first locality the yellow-brown arenaceous limestone facies, considered Artinskian, since it is the youngest, by RENZ, is also present. The Late Permian shows this facies also in other localities. Possibly the Early and Late Permian are present in that locality, like in locality d), although the Early Permian is represented only by three species of *Productus*, not even significant. The Early Permian is present in locality h).

The remaining localities are either Late Permian, like b) and f), or their chronostratigraphic position cannot be determined.

5.4. LATE PERMIAN. The paleontologic evidence on the presence of the Late Permian in the Shaksgam valley is rather scarce. Late Permian fossils were collected by DESIO at « Camp Staghar glacier front (24, 6, 1929) » and in both the above mentioned localities by WYSS and RENZ. These, anyhow, lie upstream from the area investigated by our expedition, just outside the Shaksgam valley. The fossils are preserved in white-yellowish aphanitic limestone with fractures infilled by calcite. Besides numerous brachiopods there are also some *Paraschwagerina* (p. 61), which, according to R. CIRY, M. AMIOT and N. FANTINI SESTINI's determinations, can be attributed to the end of the Early Permian or, more probably, to the beginning of the Late Permian (1).

The *Paraschwagerina* limestone outcropping at Camp Staghar glacier front was placed as well as I could in the stratigraphic section cursorily surveyed.

As shown in figure 29 on page 62, the above-mentioned limestone is underlain by grey cherty limestone, which is, in turn, underlain by black shales. On top there are grey limestones and the complex comprising green and red

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(1) See vol. IV-I, Scientific Reports of DESIO's expeditions etc.

shales, brown marls and marly limestones, with some calcareous intercalations which underlie the Aghil Limestone.

The stratigraphic position of this horizon is very similar to the one of the *Parafusulina* limestone, which occurs further downstream. It might also be homotaxial, but perhaps the first represents a slightly higher horizon in the Shaksgam valley stratigraphic sequence. The lack of precisely surveyed stratigraphic sections prevents a more detailed account.

The Murgabian, between the Singhié and Kyagar glaciers, where DESIO and WYSS (see p. 65) collected some fossils, seems to be represented by a particular facies. At the locality «slightly above the Singhié glacier (29-6-1929)» the fossils occur in three different lithotypes:

a) blackish marly and shaly limestones with unclassifiable fossils;

b) green-grey sandstone with abundant calcit cement with *Juresania* sp. and *Neochonetes variolatus* (d'Orb.);

c) grey-brown very fine-grained feldspathic sandstone with clay-calcite matrix with *Schizodus* cf. *dubiiformis* Waagen, *Janeia biarmica* (Verneuil) and numerous indeterminable pelecypods.

The sequence that I surveyed is as follows (see p. 65):

5. Grey cherty limestone;
4. Grey limestone in thin beds with crinoids and corals;
3. Brown marl alternating with brown marly limestone rich in crinoids and corals;
2. Alternations of marly limestone with brown marl with brachiopods, black shales and white, yellowish-white, grey, grey-green, brown-grey, feldspathic quartz-sandstones, very fossiliferous, containing mainly pelecypods;
1. Black shales associated with dark brown shaly marls, green-grey shales, green rocks and some beds of marly limestone.

The fossiliferous sandstone of bed 2 contains the fossils mentioned at b) and c), which MERLA (1935) doubtfully attributed to the Late Permian, while FANTINI SESTINI, who reexamined this fauna (1964), states that it is not possible to determine its age.

I collected fossils also in another locality, between the Singhié and Kyagar glaciers, 4 km downstream from the latter glacier. According to FANTINI SESTINI (1964), the identified fossils *Derbya regularis minor* Waagen and *Rhombopora* sp., are Permian without any further specification. The fossiliferous rock is a dark, marbled limestone which, according to my field observations, occurs in bed 3 of the following sequence:

4. Grey cherty limestone;
3. Thinly bedded grey and dark limestones with yellow marly veils containing fossils, mainly bryozoa;
2. Green shales;
1. Black shales associated with grey-green shales, green rocks and some beds of marly limestone.

The two sequences have the same lithologies both at the base and at the top; the middle beds may be correlated. However, we must take into account that the field data are rather generic.

Bed 2 of the first sequence, with an arenaceous-marly facies, is missing in the second one.

Wyss mentioned two other fossiliferous localities in the same area and Renz illustrated their fauna . These localities have already been discussed in the previous section (p. 65, 72). One XXXVIII) is probably older since it is nearer than our sample to the core of the Shaksgam anticline; the other (XXXIX) contains both Early and Late Permian species. The blue-black very tough limestone cannot be accurately identified in the two sections.

I would like to draw the attention on the arenaceous-marly horizon characterized by the presence of quartz sandstone, or quartz-felspathic sandstone beds, mainly fine-grained, grading into light yellow to white quartzite with yellowish reddish and brown weathered surfaces, rich in pelecypods and brachiopods; the last ones are contained also in the marls. This facies, represented by bed 2 of the fossiliferous locality just upstream from the Singhié glacier, where identifiable fossils were collected, is widespread throughout the Shaksgam valley and, as will be seen later, also further to the east and southeast.

The relationship of this bed to the *Paraschwagerina* and brachiopod limestone of Camp Staghar glacier front was not clarified in the field, the only certain feature being that both are in contact with grey cherty limestone, intercalated between the two fossiliferous horizons. The *Paraschwagerina* and brachiopod limestone overlies the cherty limestone, which is underlain by the pelecypod sandstone and marl. If the sequences were normal, the *Paraschwagerina* limestone would be younger than the pelecypod sandstone and marl, but, as I stated above, on this horizon we should come to the opposite conclusion, since, as will be discussed below, further data concerning the eastern region confirm that the arenaceous horizon belongs to the Late Permian.

These members of the Permian stratigraphic sequence of the Shaksgam valley, arranged according to the most probable sequence suggested by the fossils, cannot be easily included in a general stratigraphic record. We know that the Singhié Shales occur at the base of the sequence; at the top there is the thick body of the Aghil Limestone underlain by red conglomerate or argillites. The above mentioned units certainly occur between the Aghil Limestone and the Singhié Shales. Between the pelecypod sandstone and the Aghil Limestone there are mainly green, brown, black or even reddish shaly beds, as seen in the sections reported on pp. 44-50. We do not know whether these beds still represent the Permian or are younger, since they were not examined closely. Lithotypes apparently very similar to the former ones are associated with the *Paraschwagerina* beds, and the arenaceous pelecypod beds. These will be discussed in the section dealing with the relationship between the Shaksgam Formation and the ones of the neighbouring territories.

6. Comparison between the Shaksgam Formation and Similar Formations in the Eastern Karakorum.

Although formations with similar lithologies and age occur in the eastern region, at present we know few sections describing the lithotypes in detail and with certainty. Of these the locality nearest to our region is the one near the front of the Rimu glacier, in the upper Shayok valley, briefly described by DAINELLI (1934, pp. 486 and 547), and recorded here (p. 82). On it we know a section composed by stratigraphic units, most of which were dated paleontologically.

On the ground of the data reported by DAINELLI and integrated by MERLA's lithologic and paleontologic studies of the samples (pp. 188-194), I reconstructed the following sequence:

7. Dark unfossiliferous limestone, 30 m;
6. Crinoidal limestone, 6 m;
5. Limestone and dark marly shales, both fossiliferous, the first with *Productus cancriniformis* Tschern., *P. purdoni* (Dien. non Dav.), *P.* cf. *gangeticus* Dien., *P. abichi* Waag., *P. dorsigerus* Merla, *P. jisuensis* Chao, *P. cardinalis* Merla, *P. spinocostatus* Abich, *P. typicus elongatus* Huang, *Chonetes substrophomenoides* Huang, *C. tenuilirata* Chao, *C.* cf. *rothpletzi* Broili, *C. glabellipunctatus* Merla, *C. huangi* Merla, *Schizophoria coral-*

lina Waag., *S. parenteletiformis* Huang, *Streptorynchus* (?) aff. *pelargonatus* Schloth., *Ombonia girtyana* Merla, *Derbyia haemisphaerica*? Waag., *Sicelia* n. sp. ind., *Pseudomonotis garforthensis* King, *Fenestella* sp. ind., *Acanthocladia* sp. ind., 16 m;

4. Crinoidal limestone: dark-grey (more or less dark) tight limestone, rich in fragments of shells and crinoid ossicles, occasionally with small pyrite crystals arranged on the bedding planes, 26 m;

3. Dark, very fossiliferous limestone and marl, with *Productus pseudograziosus* Merla, *P. tenuistriatus* Vern., *P. nicisus* Schellw., *P. curvirostris* Schellw., *P. grünewaldi* Krot., *P. aagardi* Toula, *P. waagenianus* Girty, *P. rimuensis* Merla, *P. altimontanus* Merla, *P.* cf. *praelectus* C. Reed., *Martinia uralica longa* Tschern., *M.* cf. *uralica* Tschern., ? *Martiniopsis orientalis* Tschern., *M.* n. sp. aff. *convexa* Tschern., *M. laticollis* Merla, *Reticularia lineata* Mart., *Spirifer tibetanus latus* Merla, *S. strangwaysi latus* Chao, *S. psittacus auriculatus* Merla, and *planus* Merla, *Spiriferina cristata* Schloth., *S.* cf. *ornata* Waag., *S. labiata* Merla, *Athyris royssii* L'Ev., *A. pectinifera* Sow., *A.* cf. *globulina* Waag., *Hustedia* aff. *indica* Waag., *H. pelargonium* Merla, *H. nasuta* Merla, *Camarophoria superstes inhornata* Merla, *C. mutabilis* Tschern., and var. *umbonata* Merla and *columba* Merla, *C. constricta* Merla, *C.* cf. *crumena* Mart., *C. biplicata* Stuck., *Pugnax connivens* Eichw., *Schizophoria* cf. *indicaeformis* Hamlet, *Terebratuloidea trochus* Merla, *Dielasma* cf. *juresanense* Tschern., *Notothyris minima* Merla, *N. nucleolus* Kut., *Hemiptychina pseudodieneri* Merla, *H. sublaevis* Waag., *Tegulifera* sp. ind., *Fenestella* aff. *lahuseni* Stuck., *F. eichwaldi* Stuck., *Polypora* sp. ind., *Fistulipora craterina* Merla, *Lophophyllum pendulum simplex* Huang, *L.* aff. *proliferum* McChesney, *L. inaequale* Merla, *Orthophyllum*? *calamus* Merla, *Tachylasma*? *praecursor* Merla, *Barrandeophyllum columnare* Merla, *B. incertum* Merla, 38 m;

2. Limestone, soft marly limestone of various colours ranging from light grey to reddish, and marl, less fossiliferous than 3, but with the following fossils, generally well preserved with their shell: *Productus puntatus* Mart., *P. tenuistriatus* Vern., *P. aagardi* Toula, *P. depressus* Mansui, *P. rimuensis* Merla, *P. altimontanus* Merla, *Martinia semiglobosa* Tschern., *M. subtriquetra* Merla, *Martiniopsis uralica* Tschern., *Spirifer tibetanus occidentalis* Schellw., *S. tibetanus latus* Merla, *S. psittacus* Merla, *Spiriferina cristata* Schloth., *S. labiata* Merla, *Camarophoria mutabilis* Tschern., *C. superstes inhornata* Merla, *C. superstes* Vern., *C.* cf. *crumena* Mart., *Reticularia rostrata* Kut., *Nothothyris nucleolus* Kut., 22 m;

1. Limestone and friable ashy marl, looking earthy and containing fossils preserved mostly as internal casts, mainly of *Productus*, i.e. *P. tenuistriatus* Vern., *P. pseudograziosus* Merla, *P. semireticulatus* Mart., *P. aagardi* Toula, *P. rimuensis* Merla, *P. altimontanus* Merla, *Spiriferina* cf. *ornata* Schloth., *Camarophoria mutabilis* Tschern., 16 m.

This sequence is underlain by the black shales mentioned on page 82.

The fauna of beds 1-3 was ascribed, on the whole, to the Uralian (= Karachatyrian); the one of bed 5 to the Lopingian (Late Permian). MERLA does not mention bed 4.

The thicknesses are approximate, and judging from the total thickness (160 m), it can be deduced that the sequence at the Rimu glacier front represents only a part of the Shaksgam Formation; moreover the uppermost beds are unknown. Anyhow we should point out that the faunal and lithologic affinities of the Rimu beds 1-3 and the Gasherbrum Jilga bed 2 are clear. Among the over- and underlying beds at the two localities a comparison is not possible.

According to MERLA (1935), level 5 of the Rimu sequence should approximately correspond to the fossiliferous marly calcareous beds outcropping 4 km below the Kyagar glacier.

A horizon equivalent to the one outcropping at the « Rimu Base Camp » and the « Rimu front, left flank », both rich in pelecypods (besides other fossils) and characterized by pale reddish-yellow, or reddish-brown sandstone containing weathered feldspar granules and calcareous matrix, can easily be identified in the pelecypod sandstone outcropping in the Shaksgam valley between Singhié and Kyagar glaciers. The respective faunas do not have species in common although their biofacies are similar.

MERLA (1934) identified the following species among the samples from the Rimu Base Camp locality:

Schizodus pinguis Waag., *Cypricardella* cf. *amarassiensis* Wanner, *Allorisma perelegans* Waag., *A. simplex* Merla, *A. eupholis* Merla, *A. tellinoides* Meral, *Pleurophorus* aff. *bicarinatus* Keys., *P. caudatus* Merla, *Sanguinolites subundatus* Merla, *Pachydomus? cyrtos* Merla, *Palaeolima eulyrata* Merla, *Aviculopecten hiemalis* Salter, *Spirifer alatus* Schloth., *S. musakheilensis* Dav., *Schuchertella? anonima* Merla, *Derbyia regularis* Waag., *Orthothetina flabellum* Merla, *Dielasma* cf. *truncatum* Waag.

At the Rimu front, left flank locality, the following species have been recognized:

Bellerophon cf. *squamatus mongoliensis* Grabau, *B. rotularis* Merla, *Euomphalus* aff. *crotalostomiformis* Wanner, *Naticopsis khoovensis* Waag., *N. gastridia* Merla, *Atomodesma leonardii* Merla, *Sanguinolites subundatus* Merla, *Schizodus pinguis* Waag., ? *Productus wallacci burmensis* Dien., *P. spinosocostatus* Abich, *P. mongolicus* Diener *Streptorynchus pelargonatus* Schloth., *Orthothetina flabellum protractra* Merla, *O. convergens* Merla, *O.* cf. *armeniaca* Art., *Spirifer musakheilensis* Dav., *Martinia* sp., *Chonetes* cf. *tenuilirata* Huang, *C. substrophomenoides* Huang, *Fenestella jabiensis?* Waag. and crinoids.

According to MERLA (1934) the above-mentioned Rimu faunas can be ascribed to the Late Permian, and thus the same age can be attributed to the faunas from the Shaksgam valley.

The same stratigraphic horizon occurs in the upper Shayok, where MERLA (1934) identified:

Productus typicus elongatus Huang, *P. chengyaoyenensis* Huang, *Spirifer musakheilensis* Dav., *Spiriferina cristata* Schloth., *Orthis* aff. *parenteliformis* Huang, *Atomodesma leonardii* Merla, *Aviculopecten* sp. ind.

In the Murgo area DE TERRA (1932, p. 109) recorded grey arenaceous shales with brachiopods, pelecypods, and bryozoans intercalated in a crinoidal limestone. In the same area the DE FILIPPI expedition collected fossils among which MERLA identified:

Metacoceras reedianum aff. *warchense* C. Reed, *Bellerophon jonesianus* De Kon., *Holopella* aff. *trimorpha* Waag., *Waagenophyllum* cf. *virgalense* (Waag.), *Gerthia? fasciculata* Merla.

A crinoidal limestone overlying the arenaceous beds with pelecypods occurs in the Shaksam valley (p. 64). Finally we should mention a yellowish-white, when fresh, reddish-yellow, when weathered, fine-grained siliceous sandstone with fusulinids (*Schellwienia erucaria caracorumensis* Merla); a sample of it was collected at a locality even nearer than the previous one to the Shaksgam valley, that is at « 13,000 feet from Rimu North camp (on the moraine) ».

This sandstone has a lithofacies similar to the one occurring between the Singhié and Kyagar glaciers. Furthermore the same *Schellwienia* was found by REICHEL among the samples collected by WYSS just to the east of the Shaksgam-la (locality XXXII); thus the continuity of this fossiliferous horizon throughout the whole Karakorum and Aghil ranges seems to be confirmed.

The fossiliferous rock occuring at a locality near the front of the Staghar glacier must be recorded. This rock does not have a lithofacies similar to any other in the Eastern Karakorum, except for the one mentioned by RENZ (1934, p. 243) at the Murgo locality (XVIII), where a « white limestone, with a very rich fauna (fusulines, doliolines, bryozoa, brachiopods, pelecypods, gastropods and crustacea) » outcrops. The same limestone may also be present in the upper Shaksgam valley and, like the previous ones, was assigned on the ground of their fossil content to the Late Artinskian (Darvasian) but to a horizon higher than the fossiliferous arenaceous horizon attributed to the beginning of the Late Permian or the end of the Darvasian.

In order to complete the review of the Eastern Karakorum Permian occurrences, I mention here other two fossils coming from the upper Siachen valley examined by PARONA (1933). It deals with a specimen of *Derbya grandis* Waagen

		SHAKSGAM VALLEY	EASTERN KARAKORUM
Late Permian	PAMIRIAN MURGABIAN	White, white-yellowish, grey, grey-green and brown quartz and feldspath sandstone with a rich pelecypod fauna (*Janeia*, *Schizodus*, etc.) with brachiopods (*Juresania*, *Neochonetes*, etc.) alternating with brown marly limestone and marls, black shales and grey limestone, between the Singhié and Kyagar glaciers (Malsa Byamo sandstone). (Some porphyritic dacite sills).	Light yellow-reddish, brown-reddish quartz, occasionally feldspathic sandstone with a rich pelecypod fauna (*Schizodus*, *Allorisma*, *Pleurophorus*, *Aviculopecten*, etc.) with gastropods, brachiopods (*Spirifer*, *Derbyia*, etc.) from the Rimu base camp, left bank of the Rimu glacier front, Upper Shayok, Depsang, etc. Grey hard crinoidal limestones and shales with brachiopods (*Productus*, *Chonetes*, *Orthotethyna*, etc.), bryozoa of bed 5 of the Rimu glacier front.
		White-yellowish aphanitic limestone with *Paraschwagerina*, brachiopods (*Stenoscisma*, *Neospirifer*, *Enteles*, *Orthotichia*, *Tschernyschewia*, etc.) of the camp Staghar glacier front.	
Early Permian	DARVASIAN	Light yellow and brownish arenaceous limestone and dark grey hard limestone with *Parafusulina shiptoni* Dunbar, from above the Bya Lungma junction and below Durbin Jungal. White limestone with a very rich fauna including *Parafusulina*, brachiopods (*Enteles*, *Productus*, *Chonetes*, *Marginifera*, *Spirifer*, *Squamularia*, etc.) pelecypods (*Aviculopecten*), gastropods and crustacea of the upper Shaksgam valley: south-east of Kyagar Tso.	? Crinoidal limestone from bed 4 of the Rimu glacier front. Ash-coloured marl, light grey and reddish marly limestone with a rich fauna of brachiopods (*Productus*, *Spirifer*, *Camarophoria*), bryozoa, corals (*Lophophillum*, *Barrandeophillum*, etc.) from beds 1-3 of the Rimu glacier front.
	KARACHATYRIAN	Black and reddish limestone alternating with brown marly limestone and marls, with some chert nodules, containing brachiopods such as *Marginifera*, *Spirigerella*, *Chonetinella*, etc.: Gasherbrum Jilga.	

of the Early Permian, which is contained in a black marly limestone, and of a *Pseudomonotis* sp. contained in the quartzitic sandstone.

It may be useful to emphasize that both fossils originate from the moraines or from a rock outcrop (it is not specified) on the southern extension of the Permian beds of the Shaksgam valley. The mentioned species are not contained in the fossil fauna of that valley.

A comparison between the Shaksgam Formation and the Permian formations of the Eastern Karakorum, does not supply data more useful for the reconstruction of the stratigraphic sequence than the ones already collected in the Shaksgam valley. However, important affinities between the various members of the Shaksgam Formation and the stratigraphic units of the eastern region can be recognized. At the present stage of our knowledge, it is not possible to establish correlations more precise than the ones outlined in this section.

The table at pag. 97 summarizes the information on the Shaksgam valley, and on the Eastern Karakorum.

This table requires some comments. In the first place it must be pointed out that the lithotypes cannot be considered representative of whole fossiliferous horizons, since only the fossiliferous beds were reported in the table and these have a reduced thickness and are often included in different rock sequences. Then we must take into account that the series is based only on paleontologic data and that the *Paraschwagerina* limestone may continue till the Pamirian.

In the Shaksgam valley the pelecypod arenaceous beds (Malsa Byamo Sandstone) included in the Murgabian seem to occur in a position lower than the one of the white-yellowish aphanitic limestone outcropping at Camp Staghar glacier front. This, however, is not so much confirmed by the fauna of the fossiliferous beds of the above mentioned locality in the Shaksgam valley, as by the ones of the eastern region. MERLA ascribed the latter faunas to the Lopingian, that is to a stage which seems to correspond to a horizon certainly Permian and therefore to the Late Murgabian or to the lower part of the Pamirian.

7. Comparison between the Shaksgam Formation and Similar Formations in the Western Karakorum.

We know that there are Permian fossiliferous outcrops in the Baltoro and Panmah valleys which are contiguous to the Shaksgam valley. Fossil foraminifera were found in some samples coming from the Gasherbrum group (DESIO & ZANETTIN, 1970) attributed to *Neoschwagerina*. Among them CIRY & AMIOT (1964) identified *Hemigordiopsis renzi* Reich. which is a species known from the uppermost Early Permian (Darvasian).

The fossils are contained in a white limestone comparable to the Murgo limestone mentioned by RENZ (1939).

The only Permian occurrence of the Panmah valley is based on one *Fenestella* remnant contained in a sample of a dark calcareous shale coming from the southern slope of the Skamri ridge (DESIO, 1936) (plate XXXIII fig. 2).

In 1962 a few Permian fossils were collected in the upper Hunza valley and its tributary, the Chapursan valley (DESIO and MARTINA, 1972). The fossils were studied by FANTINI SESTINI and PREMOLI SILVA (1964). The fauna, consisting of foraminifera, among which *Nankinella*, *Pseudofusulina*, *Lasiodiscus*, *Globovalvulina*, and brachiopods, among which *Neochonetes carboniferous* (Keys), *Linoproductus lineatus* (Waagen) and *Elivina tibetana* (Diener), and bryozoa, belongs to the Early Permian, more precisely to the passage beds between Karachatyrian and Darvasian.

In the Shaksgam valley I did not find any paleontologic data which could be considered certain representatives of this horizon, because the Gasherbrum Jilga horizon is certainly older, and those between the Singhié and Kyagar glaciers are slightly younger.

It must be recorded that both the litho- and biofacies of this formation, which was called Gircha Formation (DESIO and MARTINA, 1972), are more similar than any other to the arenaceous-marly beds of the middle Shaksgam valley between the Singhié and Kyagar glaciers, and to the ones of the Eastern Karakorum. They have in common not only the extensive occurrence of white quartzsandstone, but also a similar fauna, which includes numerous pelecypods, among which the genus *Schizodus* is very frequent.

A comparison between the Gircha and Shaksgam formations shows that the first includes only a part of the second; this assumption seems to be confirmed by the smaller thickness of the Shaksgam formation in comparison with the thickness of the Gircha formation (4600 m). The relationship between the two formations leads us to assume that the Gircha formation represents not only the Shaksgam formation, but also the Singhié black shales or the most part of them.

If we examine the lithostratigraphy of the Gircha formation (DESIO and MARTINA 1972) we see that the black shales with sandstone interlayers are very developed in the lower Gircha sequence and the facies is very similar to that of the Singhié Shales.

8. The Cherty Limestones.

The cherty limestone from Kyagar was preliminarily defined by DESIO (1963) as follows: « It is a cherty grey limestone thin-bedded unfossiliferous.

The chert nodules and lenses are often large and frequent; their colour is blackish and grey, but sometimes also white.

The limestone can be substituted by chert beds.

The stratigraphical position of the Kyagar limestone is not quite clear. It is generally seen to overlie brown and black marls, slate, and limestone with Upper Permian fossils. It is covered by a complex of dark shales with limestone beds probably belonging to the Triassic.

Thickness: some hundreds of meters. Age: probably Lower Triassic ».

Cherty limestones, mostly grey, thinly-bedded, more or less rich in cherty stripes and nodules occasionally so abundant that the chert almost replaces the limestone, outcrop repeatedly near the thalweg of the Shaksgam, mostly upstream from the Urdok glacier.

The cherty limestones did not yield any fossils. In my notes, however, mention is made of « a block of cherty limestone with a *Daonella* (?) or *Halobia* (?) » outcropping on the left hand side of the Shaksgam valley, at the foot of a cliff, about 2 km upstream from the Staghar glacier. Unfortunately the sample was lost and I cannot assert that the fossil really belonged to one of those genera. The cliff overhanging the locality where the fossil was found consists of grey cherty limestone, often so rich in black chert that the limestone is occasionally almost completely replaced by chert in beds several centimetres thick.

At the present stage of our knowledge it is not easy to establish whether it is a question of only one horizon or several horizons of cherty limestones since not all the outcrops have the same lithofacies and do not seem to be in the same stratigraphic position.

With reference to the lithofacies at least three lithotypes can be distinguished: a) grey limestone, rather thinly-bedded, with stripes, nodules and beds of horny-black chert frequently very abundant; locally the chert substitute the limestone. This type is more frequent upstream from the Singhié glacier. Near the Kyagar glacier end the thickness is about 300 m. b) Dark grey limestone with some chert nodules occurring on the large isolated rocky hillock near the Staghar glacier front; c) grey or black limestone alternating with brown marls with some chert nodules outcropping on the Gasherbrum Jilga spur and on the right hand flank just downstream from the mouth of the Bya Lungma (both localities are downstream from the Gasherbrum glacier).

The stratigraphic position of the three lithotypes will be considered now. Unfortunately the available stratigraphic field data on the three lithotypes are rather scarce and occasionally uncertain and incomplete.

I will try to establish first which are the overlying beds of the cherty limestone a and which the underlying ones. The above mentioned beds with the supposed *Daonella* (or *Halobia*) seem to belong to this horizon.

A significant chronostratigraphic reference is represented downstream from the Kyagar glacier by the Late Permian fossiliferous arenaceous-marly horizon underlying the cherty limestone (p. 64). Also further upstream as far as the Kyagar glacier such limestone overlies mostly the black shales of the Shaksgam Formation (page 70). Near the fronts of the Urdok and Gasherbrum glaciers the position of the cherty limestone of type a) is not quite clear.

A crinoidal limestone was seen in some of the sections underlying the above mentioned cherty limestone. In the upper Shaksgam valley, near the Kyagar glacier front, the cherty limestone seems to form the core of the anticline of black shales and this very probably is the result of a local contorsion due to the different coefficients of plasticity of the two lithotypes.

The cherty limestone a) is overlain by a greater variety of rocks. Near the Kyagar glacier front there is a cherty multicoloured conglomerate partially made of the debris of the cherty limestone.

In other sections of the upper Shaksgam valley, the cherty limestone is intercalated between beds of black and brown shales, as can be seen on p. 65. Where the stratigraphic conditions seem to be normal, the cherty limestones are prevailingly overlain by a sequence of more or less arenaceous grey-red and black shales and argillites with limestone intercalations. The sequence is overlain by the Aghil Limestone.

According to the surest available data, in the Shaksgam valley overall upstream from the Staghar glacier we can recognize the presence of a grey cherty limestone horizon with black or horny chert in stripes and nodules that are frequently very abundant.

This unit is over a hundred metres thick and overlies the Late Permian fossiliferous Shaksgam Formation. This is the stratigraphic unit which has been called the «Kyagar cherty Limestone» (Desio, 1964), but I cannot assume definitively this name as a formational name. It is too uncertain for representing a real stratigraphic unit.

The cherty limestone b) will be examine now. The large isolated rocky hillock near the Staghar glacier front is composed of dark grey limestone with some chert nodules overlying the Late Permian arenaceous-marly horizon.

However, just downstream the same limestone is overlain by and cream-whitish limestone with Permian *Paraschwagerina* and brachiopods (p. 61). Therefore a cherty limestone horizon is included in the sequence of Permian age. We can see a similar situation just upstream from the Bya Lungma confluence, still on the right flank of the Shaksgam valley, where a bed of cherty limestone b) underlies black and yellow *Parafusulina* arenaceous limestone (p. 47). According to the few date by which we can judge, it seems that there are at least two horizons of cherty limestones. Unfortunately, the available data provide only one section, where two layers of cherty limestone, one overlying the other, are present. The inclusion of cherty limestones in the Permian sequence is also known in other sites of the Eastern Karakorum (p. 103).

The cherty limestone c) will be considered now. The presence of Early Permian fossiliferous beds with cherty nodules and the notable difference in their lithologic characteristics suggest that this cherty limestone is not coeval with the previous ones, but older. If this is true, at least three cherty limestone should be recognizable in the Shaksgam valley stratigraphic sequence. The uppermost one is grey, rich in cherty nodules and stripes (probably Triassic); the lowermost one is black, alternating with brown marls and with a few chert nodules (Early Permian); the middle one has rare cherty nodules and is intercalated between the pelecypod and brachiopod arenaceous-marly horizon and the Late Permian *Paraschwagerina* light coloured tight limestone.

We have no reliable elements to judge if besides the three above mentioned horizons there are any other ones. I will add some considerations, on the Shaksgam cherty limestones after having examined similar lithotypes in the surrounding regions.

9. Comparison between the Shaksgam Cherty Limestones and Similar Rock Units in the Eastern Karakorum.

The presence of cherty limestones has been pointed out in several localities of the eastern region, and DAINELLI referred them sometimes doubtfully (p. 400), sometimes with certainty (p. 405) to the Early Triassic (1).

In order to avoid the influence of the tectonic interpretations on the in-

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(1) The local names used in his reports by DAINELLI are transcribed in Italian, but, in order to avoid mistakes in their interpretation, they are trascribed here in English, according to the more common topographic maps of Karakorum.

terpretation of the cherty limestones stratigraphic position, and to try to recognize wheter in that region there is one or more cherty limestone horizons, a short list of the main lithotypes with a description of their beds is shown below:

1) Dark thin-bedded cherty. Murgo limestone, included between blackish, fossiliferous limestone with fusulinids, corals and molluscs of Late Permian age (p.501) and a well-bedded light coloured, veined, locally reddish, dolomitic limestone attributed to the Triassic and occurring in the neighbourhood of Murgo (p. 400).

2) Isolated outcrop of reddish cherty limestone intercalated between thin beds of reddish marl and a brecciated dolomitic limestone. It was found near the base camp of the De Filippi expedition on the Depsang Plains (p. 409). It is lithologically different, but equivalent to the Murgo beds.

3) Isolated outcrop of reddish cherty limestone, at a certain distance from a light coloured dolomitic limestone: found on the Depsang Plains towards Yapchen (p. 413); different from the Murgo one.

4) Isolated outcrop of dark cherty limestone near floury dolomite followed by well-bedded dolomite, massive dolomite and reddish limestone: on the left flank of the upper Shayok valley just below the Chip Chaq confluence (p. 420).

5) Isolated outcrop of reddish calcareous breccia with rare chert nodules; on the right hand side of the Shayok river, just below the Chip Chaq confluence, not far from 6) (p. 420). Perhaps outcropping at the base of the Murgo beds.

6) Isolated outcrop of greyish cherty limestone near dolomites and dolomitic limestones, rather thick, referred to the Middle Triassic, and sandstone and siliceous dark-coloured arenaceous shales, attributed to the Late Paleozoic. These occur on the right hand side of the Shayok valley in front of the Chip Chaq confluence (p. 421). At this locality the cherty limestone underlies Paleozoic sandstone and arenaceous shales, but, according to Dainelli, this sequence is probably inverted. Moreover Dainelli said that: « the dolomite and more or less dolomitic limestones do not follow the cherty limestones, but these limestones are in direct contact, without any intermediate bed, with the Qizil Langur Conglomerate ». The relationships between the various beds cannot be established with certainty because in fig. 40 the conglomerate is not shown. (We will deal with this subject in the following paragraph).

7) Two beds of light coloured cherty limestone separated by reticulate crinoidal limestone. Two outcrops of light coloured and red cherty limestone which, according to Dainelli, are repeated on the limbs of a syncline (fig. 41). On one side he indicated (p. 423) « cherty limestones, firstly red, then light-grey, associated with a limestone veined with calcite »; the first are in contact with Paleozoic arenaceous shales. On the other side (p. 423) « in the immediate vicinity of the contact, the Paleozoic arenaceous shales show a thin fossiliferous beds, then another thin beds of dark limestones which is followed by a light coloured not very thick cherty horizon and this, in turn, is followed by a moderately thick reticulate limestone with thin crinoidal beds; then a thicker bed of light

coloured cherty limestone and finally the red Qizil Lungúr conglomerate ». The description does not exactly agree with the information given on fig. 41: upper Shayok valley, between Japchen and the Great Kumdan glacier front.

8) Cherty limestone (not better specified) intercalated between dark coloured Paleozoic shales (not better specified) and dolomitic limestone: near the front of the Little Kumdan glacier (p. 423).

9) Blackish thinly bedded rather thick cherty limestone included between a light coloured thick bed of limestone overlying an alternation of thinly-bedded calcareous shale, brownish sandstone, and uniform dolomitic limestone poorly stratified: left bank of the Central Rimu glacier (p. 427).

10) Cherty dolomitic limestone, apparently in contact with dolomite and reddish dolomitic limestone occasionally vuggy: northern tongue of the North Rimu glacier (p. 429).

11) Cherty calcareous breccia in contact with a red limestone: near th north-eastern front of the Rimu glacier (p. 431).

12) Dark reddish cherty limestone interbedded between ash-grey marls: upper Yarkand valley (p. 433).

On the ground of the rather scanty lithologic data available, we are induced to distinguish at least three lithotypes, that is: a) a dark grey cherty limestone in thin beds (Murgo cherty limestones); b) a reddish or red cherty limestone (Depsang red cherty limestone); c) a reddish, calcareous breccia (of Rimu) with rare cherty nodules.

If we try to assign the listed cherty limestones to the three above mentioned lithotypes and their uncertain position in the stratigraphic sequence is checked, we achieve no positive result. It may be concluded that if all the cherty limestones belong to the same horizon it shows notable facies variations and is in contact with different stratigraphic units because of tectonic reasons. DAINELLI followed this interpretation for the above mentioned outcrops and therefore for the three lithotypes.

This author believed that 2) and 3) are exceptions, but as far as the first is concerned, although it does not have similarities with any others, he concluded that it is equivalent of the Murgo one. Regarding the second, which he considered « dissimilar » from the Murgo ones he, however, states it is « similar » to 2) and this means that he thought it comparable to the Murgo one.

The beds of the above mentioned outcrops are assigned without paleontologic evidence, as already said, to the Early Triassic.

The locality and sequence most favourable to a comparison between the Shaksgam valley and the eastern region seem to be the Murgo ones n. 1 of our list. Both the lithotypes and stratigraphic position of the « Kyagar cherty limestones » (p. 101) outcropping in the Shaksgam valley, correspond to the Murgo n. 1, rather well. In both cases the dark grey thinly-bedded cherty limestone overlies a sequence of dark fossiliferous Late Permian marly-calcareous beds associated also with fossiliferous quartz-sandstone. At Murgo, above the cherty limestone there is a reddish dolomitic limestone, while in the Shaksgam valley there is a thick bed of conglomerate. This will be discussed in the next paragraph.

A better correlation between the Shaksgam valley and the eastern region is provided by the cherty limestones outcropping at the Kyagar glacier front and the lithotypes b and particularly 7 in the eastern region. At the first locality the grey cherty limestone is intercalated between red and grey calcareous conglomerate and a sequence of Permian fossiliferous black shales, brown limestone and marl. At the second locality (upper Shayok valley) the cherty limestones are included between Qizil Lungur-type red conglomerate and Permian limestone, arenaceous shales, and sandstone.

In the eastern region there are no elements for a comparison with our Early Permian cherty beds, but in the Shaksgam valley there are some lithotypes corresponding to the Depsang reddish cherty limestone and to the reddish breccia with rare chert nodules. The first is comparable to the lower horizon which contains also cherty purplish-red marl outcropping just downstream from the Singhié glacier; the reddish breccia with chert nodules is comparable to that of the Kyagar glacier front.

10. Comparison between the Shaksgam Cherty Limestones and Similar Rock Units in the Western Karakorum.

I will compare the Shaksgam valley cherty limestones to the ones outcropping to the west of them, but only to the north of the Karakorum axial batholith, that is along the strike of the beds exposed in our region. Of this territory we have rather ample details only for the Hunza valley.

In 1962 a stratigraphic sequence, in which cherty limestone are included, was surveyed (Desio & Martina, 1972) near the bridges upstream from Sost and in the lower Chapursan valley, which is the right hand tributary of the upper Hunza valley. In this sequence, less disturbed by tectonics, there are two cherty limestones, one belongs to the Gircha Formation, the other to the Kilik Formation.

It is useful to give an outline of this sequence (DESIO & MARTINA, 1972) since it will be discussed again further on.

The summary sequence of the Gircha and Kilik Formations, in the lower Chapursan valley between Khodabad and Raminj, is the following:

7. Black cherty limestone, very thick;
6. Black shales;
5. Whitish subcrystalline limestone;
4. Black thinly to thickly bedded limestone;
3. Black limestone with flattened white pebbles, inferiorly grading into calcareous conglomerate with black calcareous matrix and with black and white calcareous clasts;
2. Black limestone with some chert nodules;
1. Black limestone with brown-yellowish marly veils with Permian fusulinids, crinoids, bryozoans and brachiopods, and intercalations of tight whitish quartz-sandstone in the lower part.

I think it is obvious that bed 7 is identifiable with the Kyagar cherty limestone of the Shaksgam valley and bed 2 with the limestone with some chert nodules of horizon b) exposed near the Staghar glacier front.

Also in the Chapursan valley the cherty limestone mostly overlies the black shales overlying, in turn, a sequence of beds which include Permian fossiliferous layers. This evidence supports the previous correlation which, according to the statement made on page 102, can be extended to the eastern region.

Another cherty horizon outcrops below the Gircha formation upstream from those mentioned above. It is included in the « Kilik Formation » (DESIO & MARTINA 1972) and composed of light grey marly limestone, with dark chert nodules. It overlies a white limestone and underlies a grey dolomitic crinoidal limestone. I want to mention here that a similar association of cherty limestone with crinoidal limestone is also present in the upper Shaksgam valley, but while in this valley the cherty limestone overlies the crinoidal one, in the Hunza valley the crinoidal limestone seems to overlie the cherty limestone. Nevertheless the stratigraphic position of the last one is uncertain because of the tectonic complications.

I cannot say anything on the age of this unfossiliferous horizon (1) because the relationship with the Gircha formation is not clear. The « formation » was hypothetically dated as Devonian.

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(1) One sample of chert was microscopically examined but no fossils were found.

Further to the west, in the Yasin valley, R. CASNEDI (1976) found another cherty horizon (1) below the Permian Gircha formation. According to this author the age of this horizon « could be referred to the transition between Carboniferous and Permian. »

11. The Chikchi-ri Shales.

This stratigraphic unit was introduced by DESIO (1963) for a sequence of black, brown, green and red beds, mainly argillaceous, occasionally arenaceous and with intercalations of grey or dark limestone beds generally occurring between the Late Permian fossiliferous beds and the Aghil Limestone especially in the norhern side of the Shaksgam valley. The thickness was estimated to some hundred of metres; the age Middle or Late Triassic or both.

The contact with the Aghil Limestone is frequently marked by a calcareous breccia or by a red conglomerate or only by red shales, while the contact with the Shaksgam Formation is not well marked because of some lithotypes that the two stratigraphic units have in common and of the frequent local tectonic complications. In order to define this calcareous-argillaceous horizon we should try to identify it in the best sections, and then to correlate it with similar beds in other regions.

One of the best sections is the one on fig. 14, which clearly shows that under the Aghil Limestone there are first red marly shales and then, lower down, green shales and grey limestone. We do not know for sure if the latter is already Permian fossiliferous limestone, but we think it is probable. An analogous sequence can be recognized in section of fig. 17B with additional black shales and intercalated limestone beds. Possibly in the previous section there are also some limestone beds. The green schists contain « green rocks » which have partially been identified as porphyritic dacite. Almost all the upstream sections on the right flank of the Shaksgam valley show some blackish, green or red shales underlying the massive dolomite forming the walls overlooking the Shaksgam river. They can be seen in the sections of the figs. 13, 29, 30, 33, 34.

To define the lower limit of this horizon is much more difficult. Apparently the most favourable section is reproduced in the fig. 30, where a black and greenish shale sequence is underlain by a bed of grey cherty limestone which is, in turn, un-

(1) CASNEDI writes: « dark grey bedded limestone with a lot of nodules and lenses of blackish chert. It is a level of very limited thickness (some ten meters) ».

derlain by upper Permian fossiliferous limestone. Here the brown and green shales are intercalated between the Aghil Limestone (above) and the cherty limestone (below). At this locality the shales are estimated some hundreds of metres thick.

Further upstream the same shale sequence continues unchanged and in section fig. 33 the cherty limestone still underlies the shales, but between the Aghil Limestone and the shales there is also a reddish layer apparently consisting of red limestone and probably also conglomerate with red matrix. The same red layer seems to be present also in section fig. 34.

A more complicated and therefore less useful sequence is the one surveyed on the opposite side of the Shaksgam valley, that is on the spur dividing the Gasherbrum from the Urdok glaciers (fig. 24). Here too, the red conglomerate is underlain by a sequence of green and black shales with sills of green volcanic rocks corresponding fairly well to the sequence exposed on the right flank of the Shaksgam valley. Under the shales there are grey and black limestones, which I was not able to examine at close range, and so I do not know whether they contain chert. The same sequence seems to be repeated further down and this may be the result of tectonic events.

At present it can be affirmed that in the Shaksgam valley between the overlying Aghil Limestone and the underlying cherty limestone or the fossiliferous Late Permian limestone, there is a rock unit consisting mainly of green and black or green, black and red shales with some limestone beds intercalated.

The age is not known because no fossils have been collected from these beds. Some information, however, can be deduced from their stratigraphic position, since they regularly underlie the Aghil Limestone which, as will be seen below, belongs to the Triassic and overlies the fossiliferous Permian beds. We should remember that identical or at least very similar lithotypes were intercalated also in the fossiliferous Permian beds, therefore it is not known if here the overlying shaly beds still represent the Permian. Some indications for these beds can, however, be found in the eastern region, where a shaly horizon with Triassic fossils underlying the Aghil Limestone or its equivalent was found.

12. Comparison between the Chikchi-ri Shales and Similar Rock Units in the Eastern Karakorum.

Although the variegated Chikchi-ri Shales do not have such distinctive lithological characteristics that make them easily identifiable elsewhere, I think that the « dull-grey, greenish and reddish marls with gypsum » about 100 m thick and the « multicoloured marls » outcropping for about 500 m, which DAINELLI (1933, p. 413) recorded in the lower Chip-Chaq (Shayok) valley, should be considered among the lithotypes more similar to ours.

The local stratigraphic sequence is not clear, because there is a repetition caused either by tectonics (syncline) or by sedimentation (« inverted repetition as a result of variations in the environmental conditions »).

According to DAINELLI, the sequence is as follows:

a) Conglomerate, like the one outcropping at Qizil Lungur;
b) Grey, green or reddish gypsiferous marls;
c) Thin beds of Norian brachiopod limestone;
d) Sandstone and breccias;
e) Multicoloured marls;
f) Conglomerate like at *a*).

Referring to the stratigraphic position and age of this sequence DAINELLI (p. 414) stated that « the Qizil Lungur Conglomerate and the gypsiferous sandstone and marly layer are approximately chronologically equivalent (probably Norian) ».

The correlations of DAINELLI are unclear. In connection with the Depsang Plateau (p. 408) he said: " under the Qizil Lungur Conglomerate there is a yellowish sandstone, which however... must be younger and may represent the Norian ". It seems to be the same sandstone of the previous sequence, but on the Depsang Plateau it seems to underlie the Qizil Lungur Conglomerate, as it does, at least locally, at the Qizil Lungur locality. DAINELLI, however, generally considers it overlying, as it can be deduced from what we have previously said.

If the Shaksgam valley conglomerate underlying the Aghil Limestone corresponds to the Qizil Lungur Conglomerate, the Chikchi-ri variegated argillites are not correlatable to the Chip-chaq ones, unless we infer that there is a fault. It could be assumed, for instance, that between beds *b* and *c* of the Chip-Chaq sequence there is a fault. In this case the original stratigraphic sequence in isoclinal attitude could be the following: *a*-*b*-fault plane — *c*-*d*-*e*-(that is *b*) — *f* (that is *a*).

According to this interpretation the multicoloured marls may be pre-Norian and may be underlain by the conglomerate.

In the eastern region there is another stratigraphic horizon similar to the Chikchi-ri shales. It is located in the area of the Karakorum pass and is represented by green tuffaceous shales, associated to black shales and also blackish and grey marly shales mentioned by STOLICZKA (in BLANFORD 1878, p. 45) and DE TERRA (1932, p. 107).

STOLICZKA said: « Leaving camp (north of the Pass), the greenstones are underlain by black crumbling shale, in mineralogical character like the Spiti Shales, but very likely triassic, like that near Ak-tash... Then follows an alternation of grey or whitish limestones and shales and the triassic red limestone; and on these rest blackish and grey marly shales which are overlain by almost horizontal strata of brown limestone... which contain fragments of *Belemnites* ».

DE TERRA mentions grey sandy shales between Balti Bransa and the Karakorum pass and further on green shales in contact with red beds consisting of red calcareous sandstones, red-grey oolitic limestone and thick crinoidal limestone with fish teeth and shells. Another section surveyed by DE TERRA south of Balti Bransa shows a sequence which cannot be easily reconstructed because of the presence of some (supposed) faults. However also at this locality he points out green tuffaceous shales in contact on one side with brown limestone with *Belemnites* (Stoliczka) overlain, in its turn, by grey-green sandstone and dark calcareous arenaceous shales and, on the other side, with breccias, conglomerates and sandstones.

In the Shaksgam valley green shales with volcanic rocks (mostly porphyritic dacite) are present, like, for instance, in the section fig. 24. Then it seems probable that in the green shales also tuffaceous shales are enclosed. Therefore I am inclined to compare these rocks with De Terra's green tuffaceous shales. This author seems to consider that the green tuffaceous shales are Triassic.

According to DAINELLI (1933, p. 390), the blackish and grey marly shales of STOLICZKA should be attributed to « the Virglorian, that is to the lowermost part of the Muschelkalk », specifying that it is Early Virglorian. Actually this amendment has been caused by the finding of some fossils near Chagos Jilga, about 7 km south of the Karakorum pass, « in a dark-grey limestone ». The age of the fauna, studied by C. F. PARONA (1933), is not quite sure. However the only two species determined with certainty are *Rhynchonella salteriana* Stol., and *Spirigera stoliczkai* Bittn., species characteristic of the Virglorian in the Central Himalayas. In the neighbourhood of the same locality DAINELLI (p. 389) collected a specimen of *Martolites* n. sp. which was examined by PARONA (1933); it was found in an isolated block, the lithology of which is not even described. Even if DAINELLI repeatedly speaks (p. 329) of « two small faunas suggesting the Norian and Muschelkalk » (but he writes later that « we do not consider it to be Norian on account of the fossil content »), the only species found are both new and unsure and so the presence here of a Norian fossiliferous horizon remains uncertain.

The fossils ascribed to the Late Virglorian were contained in a « dark grey limestone « of unknown stratigraphic position »; some « dark limestones », too, are attributed to the Norian (p. 391).

Taking into account that « the two small faunas » were collected very near Chagos Jilga I am induced to wonder whether it is the same horizon repeated tectonically all the more so because DAINELLI's tectonic interpretations are rather obscure, as will be seen below. However, now we are not interested in the limestones, but only in the blackish and grey marly shales, about which DAINELLI (p. 329) wrote that « they are not liassic, as believed by STOLICZKA, but are certainly representative of the Muschelkalk and it is also very doubtful whether the dark limestones, considered by him overlying the shales, are Liassic ». This statement is not clear, if we take into account that the fossils were collected from a dark grey limestone. It must at least be assumed that the limestone was intercalated within the blackish and grey marly shales. According to DAINELLI (p. 390-391) the same horizon outcrops on both sides of the Karakorum pass, but the lithofacies does not seem to agree with what STOLICZKA wrote. DAINELLI said « a real marl, slightly calcareous only locally outcrops as a greyish argillaceous mass ranging from ash-greyish sometimes very light, to whitish in colour »; and later he records « shales and marls », and « ash-greyish, argillaceous marls » (p. 433).

Anyhow the Chikchi-ri shales are much more similar to the ones indicated by STOLICZKA and DE TERRA, than to the above mentioned ones. It can be assumed, however, that both lithotypes are present and that their differences represent only lateral or vertical variations since they have lagoonal facies.

The correlation between the shaly and marly horizon of Chogos Jilga and the one of Chikchi-ri could correspond to the geological situation of the north side of the Shaksgam valley. There are no proofs, however, since a true lithostratigraphic identity cannot be recognized, and also because there are few data for both regions, which are not far from each other though not located on the strike line.

Another dated horizon which could correspond to the Chikchi-ri shales is the one — according to DAINELLI (1933, p. 403) — composed of « clays and argillaceous limestones with gastropods and heterastrids », indicated as Burtze II, outcropping near that locality (east-northeast of Murgo). The lithology of that horizon is not sufficiently known. The only information that we have indicate that it consists of « marly limestones which locally pass and weather into proper clays ». They are dark grey or light grey in color according to PARONA (1933) who examined the fossils. As far as the age of its fauna is concerned PARONA is rather uncertain, but considered it Carnian. According to DAINELLI it belongs to the Early Carnian on account of the remarkable affinities with the Ladinian faunas. Of the 8 species identified, 5 are new, 2 doutfully determined and the last of uncertain provenance. On the whole Burtze II horizon does not seem to be very similar to the Chikchi-ri, at least as far as the lithofacies is concerned. It is particularly interesting both because it lies on the eastern strike-line of the Shaksgam valley beds and because of a hint of the existence in the Shaksgam valley of Carnian beds overlying the Permian ones. The presence of Carnian fossils is demonstrated by two species of *Heterastridium* collected by WYSS (1939, p. 282) to the east of the Shaksgam-la, near the confluence of the melt waters of North Rimu glacier and the Yarkand river, and by another fossil of uncertain determination found further to the west in the small valley descending from the same pass. The fossils were determined by RENZ (1939, p. 248).

The same localities yielded also Permian fossils and therefore it can be assumed that both fossiliferous horizons are near each other. It must be pointed out that the second locality (No. XXXIV of WYSS) lies on the strike line of the upper Shaksgam valley beds, which dip north-east; and also that in the explored area the presumed Carnian horizons as well as the Norian one outcrop near the Permian horizons. Another indication is the presence of fossils, among which there are two species of *Heterastridium*, collected by F. DE FILIPPI near the North Rimu glacier front (DAINELLI, 1934, p. 429) and determined by PARONA (1928, p. 5).

Regarding the Burtze locality, it must be mentioned that just downstream from the Singhié glacier front the grey cherty limestone is overlain by purplish-red, nodular marls with some chert nodules, in contact with the blackish-green shale (p. 63). The latter may hint at the presence of another fossiliferous lithotype, also assigned to the Late Triassic, that is the Burtze I of DAINELLI (1933, p. 401).

In conclusion, at the present stage of our knowledge it can be said that probably at least part of the multicoloured shales (called Chikchi-ri) belongs to the Triassic and particularly the one of the upper Shaksgam valley, while part are probably intercalated in the Late Permian fossiliferous beds.

13. Comparison between the Chikchi-ri Shales and Similar Rock Units in the Western Karakorum.

The only area where there are stratigraphic sequences to be compared with the described ones occur to the west in the Hunza valley. In this area, however, there is no horizon of multicoloured shales between the Permian fossiliferous beds and the Gujhal Dolomite; the latter is comparable to the Aghil Limestone. Black shales are intercalated within the dolomite, together with red conglomerate, but no real correlation can be seen between the Chikchi-ri Shales of the Shaksgam valley and other rock units of the Hunza valley.

14. The Conglomerates of the Shaksgam Valley.

In order to establish possible correlations among the calcareous conglomerate outcrops in the Shaksgam valley and recognize their affinities and differences, we will derive a list of them from the descriptive paragraphs. I must mention that in some cases the lithologic data are scarse because samples or/and detailed field data are lacking.

The following lithotypes occur downstream from the upper Shaksgam:

1. Red and grey conglomerate and breccia composed of clasts, partly rounded, of grey black and less frequently red limestones. Horny chert nodules and fragments are also abundant. The matrix is marly yellowish in the grey conglomerate, brick-red and abundant in the red conglomerate. The first grades both vertically and horizontally into the second one. The conglomerate overlie grey cherty limestone, which in turn seems to be overlain, either directly or with the interposition of green and black marly shales, by dolomitic limestone and reddish dolomite.

They outcrop near the Kyagar glacier front or further downstream with a thickness of few hundred of meters.

2. Calcareous breccia and red limestone underlying very thick grey limestones: Chikchi-ri (p. 67).

3. Red calcareous breccia associated with brecciated limestone and red limestone underlying tight grey limestone and overlying thinly-bedded blackish-grey and black limestones with yellowish marly veils. On the left hand side of the valley, near Rdzing glacier (p. 59).

4. Conglomerate and dark red calcareous breccia consisting mainly of clasts of white-grey and black limestones cemented by red abundant arenaceous matrix and overlying black shales. Arête at the head of the Urdok valley. The thickness is many hundred of meters (Urdok conglomerate).

5. Red conglomerate, breccia and shales overlying a sequence of green and black shales with sills of green volcanic rocks: Ridge between the Gasherbrum and Urdok glaciers (p. 55).

6. Shales and conglomerate or red breccia: above the Red Fan Camp (Marpo Chholong), at the base of a very thick grey limestone (p. 46).

7. Fossiliferous calcareous conglomerate with crinoids and brachiopods intercalated between black shales and brown marly limestone, below; and alternating with cherty limestone and brown marl, black and yellow thinly-bedded arenaceous limestone and with fossiliferous marly beds (*Parafusulina shiptoni* Dunbar), above. Just upstream from the confluence of the Bya Lungma (p. 48).

8. Multicoloured conglomerate and breccia composed of partly angular and partly rounded clasts of black, white and red limestones, with fragments of red shales and cherty nodules. They are cemented by yellow and reddish marly-arenaceous limestone. They underlie red arenaceous shales with green volcanic rocks (rhyolite). At the same locality. but not in situ, there are multicoloured metamorphosed conglomerate (Bdongo-la) (p. 42), Moreover, blocks of conglomerate and breccia were observed in the following moraines:

8*a*) Red calcareous conglomerate and breccia: they were observed in the Staghar glacier terminal moraine; they are associated with red and black limestone, green shales and with more abundant grey limestone and black shales (p. 61).

8*b*) Red calcareous conglomerate and breccia: left-hand moraine of the Urdok glacier. They are associated with grey limestone (p. 57).

8*c*) Red conglomerate and breccia: median and right moraines of the Gasherbrum glacier. They are associated with black shales in the first one; and with white and grey limestone, black shales, and gneiss in the second one (p. 54).

In the first place we should try to establish whether the conglomerates outcropping in various localities of the Shaksgam valley belong to a unique horizon or to different ones. There are no appreciable differences in their lithology and macroscopic appearance. Unfortunately we have no samples coming from every bed, therefore it is impossible to carry out an accurate petrographic investigation.

I would like to draw the attention on the fact that the conglomerate contain chert nodules only at localities 1) and 8). It can also be said that the chert can be interpreted either as clasts or as nodules deposited during the sedimentary process of the conglomerate. In the first case, which seems to be the most probable, the conglomerate would be younger than the chert derived from the cherty limestone which underlie the conglomerate near the Kyagar glacier front.

The first problem is to know what is the significance, from the stratigraphic point of view, of the isolated Jurassic corals contained in a rock similar to the one composing the matrix of the Bdongo-la conglomerate. In this case the conglomerate would have the same age of the corals, that is it would belong to the Jurassic. If they were considered to belong to the same stratigraphic horizon, this would contradict the stratigraphic position of other outcrops of red conglomerate. At localities 1, 2, 3, 5, the red conglomerates underlie the Aghil limestone in which the Norian is represented. Therefore, it must be concluded that at least two different conglomerate horizons exist, even though with similar lithologic characteristics, or that the identity between the matrix of the Bdongo-la conglomerate and the Jurassic rock with corals and ammonites is only apparent. This problem cannot be solved because the conglomerate samples were lost.

The identity of the cherty Kyagar conglomerate and the cherty Bdongo-la conglomerate is very uncertain. A conglomerate in contact with cherty limestones, both similar to those exposed on the Kyagar glacier front, is known also in the Eastern Karakorum and, as will be seen in the next paragraph, in that area both layers (conglomerate and chertly limestone) belong almost certainly to the Triassic.

However the Bdongo-la conglomerate (probably Jurassic) must not be mistaken with that exposed at the front of the Kyagar glacier and the others outcropping in the Shaksgam valley.

Another conglomerate layer with a different stratigraphic position is the one recorded at 7). Although samples and detailed data are lacking, the presence of crinoids and brachiopods and the fact that it underlies Late Permian fossiliferous beds (p. 48) suggest that it is part of the Shaksgam Formation.

The problem of the different age of the Bdongo-la and Bya Lungma conglomerates having been solved, nothing suggests that the other conglomerate outcrops already described among the ones of the Shaksgam valley, belong to more than a single conglomeratic horizon; this results from the fact that the lithologic composition and the stratigraphic position of all the conglomerates immediately underlying the Aghil Limestone are rather analogous. This rock unit which represents also a definite stratigraphic horizon was called the « Urdok Conglomerate » by DESIO (1963).

In order to find support to this interpretation and to define the stratigraphic position of these conglomerates more precisely, we should compare them with the ones outcropping in the neighbouring regions, the geologic knowledge of which is more advanced. This is also necessary because DAINELLI (1934, p. 511) gave a pre-Permian age to the Shaksgam valley conglomerates; this is in contrast with our field investigations.

15. Comparison between the Conglomerates of the Shaksgam Valley and the ones of the Eastern Karakorum.

Conglomerates more or less similar to the ones outcropping in the Shaksgam valley have been pointed out by several authors in the region to the south-east of our area. Among the most common conglomerates of that region, the « Qizil Lungur Conglomerate » should be mentioned first. It was referred to the Triassic by previous authors, e. g. STOLICZKA (in BLANFORD, 1878); later DAINELLI (1933, p. 395) is inclined to attribute it to the Norian or the Carnian.

The lithology of the typical Qizil Lungur Conglomerate is described in detail only by STOLICZKA (id., p. 46). According to this author, it is a calcareous conglomerate composed of well rounded and worn boulders of white, grey or black limestone cemented by a stiff bright red clay. DE TERRA mentions a red stratified conglomerate; DAINELLI (p. 394) records a conglomerate with large clasts « mostly made of old rocks » with a bright red marly matrix, 750 m thick. It is not clear what the author means by « old rocks ». However, we are inclined to think that these rocks are mainly crystalline schists, similar to those which he believes compose the oldest layers of the Eastern Karakorum.

However, before comparing the red conglomerate of the Shaksgam valley with the Qizil Lungur Conglomerate, it has to be recorded that DAINELLI mentioned a calcareous conglomerate much nearer to the Shaksgam valley, in the Siachen glacier, a part of which — as we know — is adjacent to the Urdok, Staghar and Singhié glaciers and therefore particularly interesting for us. According to DAINELLI (1934, p. 426 and pp. 571-572) « in the moraine at the extreme edge of the Siachen glacier front, and further upstream, at least as far as the middle of the basin, numerous blocks of tight calcareous conglomerate, with multicoloured fragments and very resistant matrix occur ».

The colour of the matrix is not specified, but a sample exposed in the collection of the Geologic Institute, University of Florence, and coming from the moraine between Camp I and Camp II, is composed of clasts of whitish waxy limestone and dark grey limestone with an abundant red arenaceous matrix. It seems that it is the above mentioned conglomerate; however, the most interesting thing is that in the Siachen valley there is a conglomerate quite similar to the red one of the Shaksgam valley. In particular it looks like that outcropping widely in the upper parts of the Gasherbrum and Urdok valleys and also in the Staghar valley. At the heads of these valleys the calcareous-dolomitic ridges of the Teram Kangri and Singhié Kangri rise and the watershed separating the Siachen from the other basins runs along them. As mentioned before (p. 61), this calcareous-dolomitic sequence is underlain by a conglomerate horizon.

It will be seen further on that the identity between the fossiliferous Triassic dolomites of the Siachen side and those of the Shaksgam side supports the hypothesis that the conglomerates outcropping in the mentioned valleys belong to the same horizon. However DAINELLI seems to exclude a provenance of the conglomerate blocks from the ridges between the Siachen and Shaksgam basins, that is from the left hand side of the valley.

In this connection it must be stated that the author first affirmed (p. 572) that " the small rare fragments which can be found in the moraines, *at least*, in the middle Siachen, evidence that the conglomerate must outcrop in some parts of the upper basin, but certainly not on its left hand side ". Later he recorded " the fact that on the extreme limit of the glacier tongue large blocks abound, this seems to prove that these did not come from the upper basin ". He excluded also " that they come from the left flank downstream from the half of the glacier ". In his opinion they may be derived only from the ridge between the Gyong-la and Bilafon-la. He correlates the Siachen conglomerates — which he assumes to be Silurian — with the multicoloured Baltoro conglomerate (p. 573); we will deal with this further on.

I think that DAINELLI's interpretation is wrong. First it should be recorded that the region from which the conglomerate derives cannot be the ridge between the Gyong-la and Bilafon-la. A copy of the geological map of the area was kindly given to me by Professor P. T. STEVENSON of Brisbane University; he explored and mapped it in 1960, and as a result of the survey the above mentioned region appears to be composed entirely of gneiss and granite.

We have only scanty data on the range between the Bilafon-la and the Sia-la. The group of Peak 36 is composed of gneiss and granite and also the Hawk peak seems to be composed of gneiss, granite and black schists, but not conglomerate. Probably between these two groups and the Bilafon-la the geologic composition is not very different.

DAINELLI did not describe the lithologic composition of the blocks in the various Siachen moraines; from what he wrote it seemes that the conglomerates are spread only in the right and central moraines and not in the left hand moraines. In any event, from where could these conglomerates derive?

If the basin of the Lolofond glacier is excluded there is only the Peak 36 Glacier valley which, from that we said, probably does not reveal any rocks of this type, but only crystalline schists and granite together with the ridges and the main spurs around the head of the Siachen basin.

The possibility that the conglomerate blocks are directly derived from the Baltoro Kangri or its south-eastern spurs can be discarded since they open into the Kondus glacier, not into the Siachen (1). The only other probable area of origin of the conglomerate is the region between Sia-la and Indira-la. This hypothesis can be supported by the fact

(1) The conglomerate of Baltoro Kangri is Cretaceous (see DESIO & ZANETTIN, 1970).

that a similar conglomerate, as we have already mentioned (p. 57), outcrops on the northern side of Indira-la, a saddle which opens on the upper Siachen glacier and/or on the upper basin of the Staghar glacier which is connected with the Siachen through the Turkestan-la, and also on the western side of the Urdok Kangri (Baltoro basin) a ridge on which the watersheds between the Urdok, Baltoro and Siachen basins converge (DESIO & ZANETTIN, 1970).

It is not difficult to imagine that in a branched glacier like the Siachen, the morainic material from the upper parts of the basin can be displaced to the right hand side of the middle and lower Siachen glacier, since in its central part it receives an important tributary (the Teram Sher) from the left hand side. This glacier entering the principal valley tends to push with its enormous mass the ice and the floating moraines coming from the upper basins towards the opposite side of the valley.

Perhaps the conglomerate is present also on the left hand moraines of the Siachen since DAINELLI collected a sample of it between his camp I and II, and he travelled only along the left hand side of the Siachen glacier (p. 573).

However, it is important to have established that the conglomerates with mainly red matrix in the Shaksgam valley, and particularly those of the upper basins of the Staghar, Urdok and Gasherbrum glaciers, are the same as those found in the Siachen glacier moraines and which outcrop on the ridges between those glaciers. Also, it seems certain that in all these basins the conglomerates with mainly red matrix occur at the base of a calcareous-dolomitic formation which contains Norian *Megalodon*.

The possible identity between the red Shaksgam conglomerate and the Siachen and Qizil Lungur ones will now be discussed. Incidentally, it should be pointed out that the Qizil Lungur type-locality lies on the Depsang Plains, that is in the region situated on the eastern extension of the strata of the territory covered by our 1929 expedition.

This identity is rejected by DAINELLI for two reasons. The first is that the matrix of the Qizil Lungur conglomerate is marly and not very dense, thus each rock fragment protrudes from the eroded surface of the conglomerate, while the matrix of the Siachen conglomerate is much more resistant, thus the rock fragments never protrude but are always eroded like the matrix.

Secondly and of greater importance, among the fragments composing the Qizil Lungur conglomerate there are also small blocks of « an older conglomerate », very tightly cemented, multicoloured, which should be represented in the morainic debris of the Siachen; thus also the Siachen material would be pre-Triassic, namely Paleozoic.

I think that the argument based on the matrix is rather artful and not very reliable since conglomerates often vary from place to place not only in type and in degree of cementation, but also in their lithologic composition.

This kind of identity might be more acceptable if the lithologic identity of the pebbles of the Siachen conglomerate and of the pebbles of the conglomerate included in the Qizil Lungur one together with their matrices could be demonstrated.

However, DAINELLI does not seem to attach much importance to the composition of the clasts since he identifies with the Qizil Lungur conglomerate both calcareous conglomerates, like those outcropping east of the Depsang base camp (p. 410), the Lingzhi Thang conglomerate (p. 318), etc., and also another conglomerate of the same region (p. 438), recorded, like the latter, by DE TERRA (p. 98-101), and made of sandstone, schist, quartz and quartzite clasts. As far as the composition of the Qizil Lungur conglomerate is concerned, it seems that the lithology of the pebbles and in part also their shape vary considerably from place to place; this feature can be observed also in the Shaksgam valley, as previously mentioned.

In connection with the matrix it has to be remembered that when dealing with the Triassic rocks, DAINELLI (p. 408) affirms that in « the Galwan Valley, which opens out near the Shalung camp locality » the torrent transports blocks of a tight conglomerate (together with « evidently Triassic » dolomitic limestones) which has been recorded in his field notes as « ancient, in the sense that it is not Quaternary ». He concludes that it might correspond to that of Qizil Lungur.

In this case, therefore, the matrix must be very resistant since the author called it a tight conglomerate. In spite of that, however, he associates it with the Qizil Lungur conglomerate as, however, he does with almost all the other conglomerates which he mentions in the region between Chang-chen-mo range and the Karakorum pass (1).

DAINELLI later (p. 572), when dealing with blocks of tight multicoloured conglomerate « transported by the Galwan torrent near the Shalung-camp locality », mentioned that this conglomerate is associated with wine-coloured sandstone (and does not mention the dolomitic limestone again), which he identifies with the Siachen conglomerate, though assigning it and those of the Baltoro basin to the Ordovician.

Since it is the same locality and in both instances he mentions a tight conglomerate, it is difficult to understand how the two chronostratigraphic attributions can be compatible, since the first should be Late Triassic and the second is Early Silurian.

We will now consider the second point, which concerns the « small blocks of an older conglomerate » which were found among the clasts of the Qizil Lungur conglomerate. However these were not mentioned by DAINELLI when describing the rocks of that region and its thick conglomerate (par. 40, pp. 392-407), but they were discussed only later when he dealt with the Siachen conglomerate (pp. 426 and 571).

We cannot understand the petrographic characteristics of the « older conglomerate » because, in spite of its importance, he did not describe its composition and no sample of the DE FILIPPI or DAINELLI expeditions exists in the collections of the University of Florence. The only data state that it is a tight multicoloured conglomerate which exactly corresponds to the one of the Siachen moraines. Multicoloured means that it is composed of fragments of rocks of different colours, but also the Qizil Lungur and Shaksgam conglomerates (including the conglomerate associated with the Jurassic Bdongo-la) and those of Baltoro comprise rocks of different colours and therefore are multicoloured.

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(1) See, for instance, the conglomerate of Depsang, mentioned by DAINELLI on p. 410.

The Qizil Lungur conglomerate is called « red conglomerate » mainly because of the colour of its matrix, as in the case of the above mentioned ones. The fact that DAINELLI called this conglomerate *red* may suggest that the matrix of the old conglomerate was of a different colour; however also the only known sample from the Siachen has a red matrix, similar to the one of the Baltoro conglomerates which DAINELLI considered equivalent to those of the Siachen (p. 573).

In conclusion the multicoloured calcareous conglomerate with a mainly red matrix from the Shaksgam valley, the analogous one in the Siachen and the one which is present in the pebbles of the Galwan river, can be considered stratigraphically equivalent.

Probably the Qizil Lungur conglomerate can also be linked to these, though it is much thicker and, at least in part, different in composition.

Certain comparisons should now be made between the stratigraphic position of the conglomerate outcrops of the eastern region and the Shaksgam conglomerates.

It has to be noticed that the association of multicoloured calcareous conglomerate with red matrix and limestones and grey dolomites, which generally form high cliffs (in which Norian *Megalodon* beds are frequently seen) is a fact repeatedly observed also in the region to the east of the Shaksgam valley.

Mention must be made of the Qizil Jilga locality in the upper Qaraqash valley, where, according to E. NORIN (1946, p. 84), there is « a breccia of more or less angular fragments of dark grey limestone embedded in a red matrix. Higher in this horizon, which dips 70° N. E., the fragments become distinctly water-worn and in part well rounded and smoothed. Above follow calcareous shales and then multicoloured Mesozoic limestone, which forms a sharp-edged high ridge 5950 ». The author adds that « this thick conglomerate is very similar to the basal Triassic conglomerate in the valley of Chang-chen-mo ».

The Chang-chen-mo conglomerate has also been mentioned by R. LYDEKKER (1880, p. 34) who observed that the « rocks on right bank of the river are to a great extent composed of the characteristic white Triassic dolomitic limestone... The higher beds exposed in this synclinal are hard and crystalline, while the lower beds consist mainly of a soft white dolomite like that of Amrnáth cave in Lidar valley of Kashmir; some soft reddish shales and a brecciated red conglomerate occur locally in the lower beds ».

He added that « *Megalodon* is of common occurrence in these limestones, and Dr. STOLICZKA also obtained from them *Dicerocardium*; there can, therefore, be no doubt as to their age ».

In the latter region, near Lumkang, also DE TERRA (p. 95) described a red brecciated conglomerate composed of clasts of limestone and shales, lying at the base of a sequence of reddish-white massive, subcrystalline limestone, ascribed to the Triassic. Further north, the conglomerate unconformably overlies graywackes and quartz schists which have been referred to the pre-Permian. In the Lingzhi Thang region, lying between the above mentioned ones, south the Sarigh-Yilganing Köl lake, according to DE TERRA (p. 98), a conglomerate outcrops. However, it is apparently different from those previously mentioned, but any how underlies dark fossiliferous Norian dolomite and apparently overlies Late Paleozoic beds.

Near Qizil Lungur STOLICZKA (BLANFORD, p. 46) mentions the presence a calcareous conglomerate with red matrix. According to the author, it is covered by white massive dolomitic limestone overlain, in turn, by bluish schists and well-bedded massive limestone, which he considers Triassic.

Il think it is useful to report here the words of Stoliczka.

«At the last we descended into a narrow gorge, the sides of which for fully a mile consisted of a limestone conglomerate, the boulders of white, grey, or black limestone being well rounded and worn and cemented together by a stiff bright red clay. Upon this followed dolomitic limestone, rather indifferently bedded, massive and white, and this was overlain by bluish shales, well-bedded limestone, extending for about 6 miles north of Burtsi to the camp. These limestones appear to be triassic: they are compact, with layers full of small gasteropods, among which I recognised a *Nerinea*. The socalled Karakoram stones, i.e. corals [N. B. it deals with *Heterastridium*] occur in dark shales below the limestones, which are capped by a yellowish, brown limestone, well bedded, but of unascertained age. The whole series dips south-west, at a moderate angle».

The same area was mentioned also by DAINELLI (1934, p. 394); his information, however, does not seem to agree completely with the position of the above described conglomerate. The question is quite important, however, and so it is useful to report the sequence based on the succession surveyed in the field (fig. 37):

1. Yellowish tight fine-grained sandstone, with siliceous cement;
2. Conglomerate with large clasts mainly derived from old rocks, in a bright-red marly matrix (750 m);
3. Grey and reddish well-bedded limestones with large pelecypods, echinoid radioles, brachiopods (750 m). It includes a large lens of red oolitic limestone;
4. Grey thin-bedded limestone with traces of fossils (brachiopods and pelecypods);
5. A very thick bed of massive dolomite apparently unfossiliferous;

6. Grey limestones with brachiopods and fine-grained calcareous breccias with various fossils (from 4 to 6, the thickness is about 300 m);
7. Red schistose argillaceous limestones alternating with floury dolomites, greenish limestones, sandstones and breccias (about 400 m);
8. Vuggy dolomite alternating with massive light coloured dolomite (very thick).

The conglomerate, therefore, occurs at the base (below 1) of a very thick calcareous-dolomitic sequence and Carnian fossils have been found in the beds 3, 4 and 6. However, according to DAINELLI, the sequence is inverted; thus the two lowermost members were considered to be younger than the others, that is either Norian (p. 395), or Carnian (p. 405). The structure seems to be rather complicated. Certainly the sequence indicated by STOLICZKA (p. 46) does not involve any inversion; if we compared the Qizil Lungur sequence with the previously recorded sections we would have the same opinion.

We should mention a locality where a red conglomerate of the Qizil Lungur type is in contact with a very thick dolomitic limestone. This sequence was mentioned when we dealt with the cherty limestone, which is also present (p. 103). This is the sequence described by DAINELLI in the upper Shayok valley, between Yapchen and the front of the Great Kumdan glacier. DAINELLI drew also a geologic sketch of this area (p. 422); it shows an eroded fold (fig. 41), the core of which is composed of Paleozoic sandstone and arenaceous and siliceous schists flanked by a band of red cherty limestone. This band is, in turn, in contact with a conglomerate of the Qizil Lungur type, and, at least along the south-eastern side, is overlain by dolomitic limestone.

It coud be an anticline with a core of Paleozoic rocks with red conglomerate at the base of a calcareous-dolomitic sequence. However, DAINELLI interpreted it as reverse, that is as a syncline with conglomerate in the core, because on the south-eastern limb the above mentioned rocks are associated with lenses (at least apparently) of other limestones, as can be seen in the above quoted figure.

This was explained by DAINELLI as follows (p. 422): « It is evident that the conglomerate represents the core of the syncline; however, even if the southern limb can be imagined to be complete — although the marly or nodular limestones and argillaceous beds which elsewhere represent the Carnian, are not visible — certainly incomplete is the northern limb, where the cherty limestones are in direct contact with the Qizil Lungur conglomerate, that is the strata attributed to the Early Triassic and in direct contact with the layers which probably represent the Norian. The corresponding lacuna — found in the northern limb, and which probably exits also in the southern limb, though perhaps affecting only the Carnian — can be explained only by the presence of a fold fault, or two fold faults, that is by the lamination of the syncline limbs ».

The suggested explanation of the structure based on the drawing of the fold, which is closed to the south-west and is not supported by a cross section, is not acceptable. It is sufficient to construct several cross-sections to prove the mistake. The problem of the structural interpretation of the limestone « lenses » of the south-eastern limb is not clear even for an anticline and it cannot be solved on the map. However, the general interpretation of an eroded anticline is the most likely explanation, as mentioned above.

It could be added that similar relationships between cherty limestone, red conglomerate and dolomitic limestone, as we have already mentioned (p. 70), occur also in the Shaksgam valley, near the front of the Kyagar glacier. There, the geology does not seem to be as complicated as imagined in the upper Shayok valley.

Before ending the comparisons between the Shaksgam calcareous conglomerates and the conglomerates of the eastern region it is necessary to summarize the ages of the latter briefly. As already stated, DAINELLI (p. 405) attributed a Norian or Carnian age to various occurrences of conglomerate grouped with that of Qizil Lungur.

The excluded ones are: a) the very tight multicoloured « older conglomerate» which composes small blocks in the Qizil Lungur Conglomerate; b) the Siachen « tight calcareous conglomerate with multicoloured clasts and very resistant matrix »; c) the « tight multicoloured conglomerate » of the Galwan valley, also attributed in a different paragraph (p. 408) to the Norian or Carnian; d) the multicoloured conglomerate with red matrix of the Upper Baltoro.

The arguments on which he bases these age determinations, besides the problematic identity of the conglomerates b), c) and d) with conglomerate a), consist in an imagined equivalence with the basal conglomerate of the Spiti Ordovician sequence.

« The apparent equivalence, which is preferred to any other explanation, depends on the fact that the Late Paleozoic in the area between the Siachen and the Aq-sai-chin appears certainly in its entirety even if the Carboniferous layers could not be distinguished; in spite of its being complete no conglomerate was observed. The Lower Ordovician, on the contrary, is not known. We, therefore, imagine that in the Eastern Karakorum it has the same basal conglomerates of those observed at Spiti ».

In the first phase I would like to point out that the Late Paleozoic sequence is not entirely known, because little is known on the Carboniferous series. However, before the Ordovician, the entire Devonian and Silurian should be present, but neither of these are known to be represented in the Karakorum except at the western end (see section 22.1.).

The sequence of beds attributed by DAINELLI to these stratigraphic systems, in the Western Karakorum, belong, at least in large part, to the Cretaceous (DESIO 1964, 1976) and to the Eocene. As far as the others are concerned, the attribution is not based on any paleontologic evidence. The fact that at the Qizil pass the fossiliferous Ordovician outcrops, represented predominantly — it should be noted — by limestones, secondarily by clayey schists and, it seems, by a layer of wine-red coloured sandstone (1), cannot support the hypothesis that conglomerates in quite different parts of the region should be Ordovician, since at Spiti the Ordovician series starts with conglomerates. Moreover this is confirmed by the fact that the Spiti conglomerate have lithologic characteristics rather different from those of the Siachen, the Shaksgam, the Baltoro, etc. (2).

Anyhow, DAINELLI (p. 573) himself calls the first « quartz-conglomerates at the base of the Ordovician of Spiti »; the second (Siachen) — mentioned earlier — (p. 571) », a tight calcareous conglomerate, with multicoloured fragments ». The presence in the Upper Baltoro moraines of red sandstones associated with red conglomerates does not signify (as will be seen later) that in that area the Ordovician must outcrop, just as no Silurian or Devonian beds outcrop (DESIO & ZANETTIN 1970). Moreover, it is not even understood how the presence of red sandstones — which, as far as is known, occupy a very limited portion of the Qizil Pass sequence — could be used as evidence for the presence of the Ordovician, while red sandstones and red arenaceous argillites are present at several other stratigraphic units of the Permian, Triassic, Jurassic, and Cretaceous series.

In any case, the hypothesis that the calcareous conglomerates with red matrix, from the Shaksgam, Siachen, Baltoro, Galwan, etc., are Ordovician, cannot be considered valid and should be rejected. They are mostly Triassic conglomerates, certainly post-Permian.

On the whole, these conglomerates seem to represent a considerable part of the Early and Middle Triassic in the western part of the Shaksgam valley, while farther to the east, other Triassic beds outcrop together with the conglomerate. These beds are the more numerous and complete the more one proceeds towards the east. In the region examined the conglomerate compose an epicon-

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(1) « it seems » has been used because where the sequence has been reconstructed for the first time (p. 560) in the " layer Y " no red sandstone is indicated; but instead « a slightly arenaceous argillite fine-grained brownish-grey ». Only later on (p. 596) the author mentions for the first time « vine-red sandstones » in the same " layer y ": it is not known whether it is the same slightly arenaceous argillite or a quite different rock.

(2) See R. D. OLDHAM: A Manual of Geology of India, vol. II, Delhi 1969 (pp. 598-599).

tinental — perhaps partly continental — deposit which may logically substitute others which are certainly marine. Presumably the conglomerate are repeated, mainly in the eastern region, and sometimes show different petrographic characteristics. The differences in the interpretations of the local events can be explained in this way, even considering the various conglomerate outcrops generally representing the Triassic, and excluding those connected with the above mentioned Jurassic or younger rock-units.

Finally, the conglomerate contained as small blocks within the Qizil Lungur Conglomerate cannot be identified until further investigation enable us to establish its petrographic characteristics.

16. Comparison between the Conglomerates of the Shaksgam Valley and the ones of the Western Karakorum.

Mention has already been made in the preceding paragraph of the multicoloured conglomerate of the Upper Baltoro being equivalent to the Urdok Conglomerate (Desio & Zanettin, 1970).

Further to the west — but to the north of the Karakorum axial batholith — in the upper basin of the Hunza river I found a few conglomerate autcrops similar to those of the Shaksgam valley. They have the following characteristics (Desio e Martina, 1972):

a) Calcareous conglomerate composed of flattened clasts of black and white, but also coloured limestones in a black calcareous matrix. The Kilik Formation of the lower Chapursan valley and near the bridge upstream from Mor Khun.

b) Very light coloured calcareous breccia, almost white, with calcitized massive fossil valves. Near the base of the Gujhal Dolomite between Mor Khun and Gircha.

c) Black and white calcareous conglomerate and breccia with a red marly-arenaceous matrix grading into conglomerate with grey-brown matrix and red veins, associated with sandstone and arenaceous shales, also red, included in the Gujhal Dolomite as lenses. Southern side of the middle Lupghar valley.

Only the conglomerate mentioned at c) may be compared with Urdok Conglomerate, but its stratigraphic position is fairly different.

17. The Aghil Limestone.

J. B. AUDEN (1938) grouped under the name « Aghil Series » the thick undifferentiated complex of rocks — mainly limestones and dolomites of Triassic and Jurassic age — forming the high ridges of the Aghil ranges and here and there reaching the bottom of the Shaksgam valley.

This name has been published in Vol. III, No. 8 of the " Lexique Stratigraphique International ", where it is defined as follows (p. 8):
" *Aghil Series.* - Trias-Jurassic.

Name given by J. B. AUDEN (Him. Journ., Vol. 10, p. 43, 1938) to a group of rocks constituting mainly limestone, and intruded by post-Triassic lamprophyre dykes, occurring in Aghil region of Karakorum. AUDEN (1938) has assigned the series to Triassic and Jurassic. M. R. SAHNI who examined AUDEN's fossil collection found *Megalodon* sp., ? *Ptyctothyris* sp. nov., and *Mytilus* (*Modiolus*) sp. nov. (Rec. Geol. Surv. Ind., vol. 73, pt. 1, p. 22, 1939). See also A. DESIO (Geogr. Journ., vol. 75, p. 402, 1930) ".

In a preliminary report by DESIO (1963) on the Karakorum formations a more comprehensive definition of the Aghil Limestone reads as follows: « A complex of thick limestone, dolomitic limestone and dolomite, of grey, white, blackish and also reddish colour, often alternated, with some mostly thin lenticular intercalations of red an black shales. The lower portion of the sequence is generally more poorly bedded than the upper one.

In the Aghil Limestone are included *Megalodon* and *Dicerocardium* grey dolomite which represent the most defined level of the sequence. It is to be considered as a real formation very similar to the Norian "Hauptdolomit" of the Alps.

Very frequently, at the base of the Aghil limestone we found a bed of red calcareous conglomerate or breccia (Urdok Conglomerate). We do not know the cap-beds since the fossiliferous Jurassic (Callovian) beds of the Aghil cannot be included in the Aghil Limestone because of their different lithofacies.

Thickness: some thousands of metres. Age: Middle and Upper Triassic. Liassic (?) ».

The only available paleontologic information on the Aghil Limestone concerns the Triassic *Megalodon* remains recorded by DESIO in 1936 (p. 457) in the Shaksgam valley, upstream from Tek-ri (see p. 43) and the same pelecypod and the two new species of *Ptyctothyris* and *Modiolus* mentioned above. In 1926 in the Aghil range K. MASON (p. 97-98) collected Jurassic fossils which were examined by G. H. TIPPER (ibidem); they belong to a different formation, overlying the Aghil Limestone.

All together the base of the formation seems rather well known; it is generally marked by more or less brecciated, locally red limestones overlying red conglomerate or red shales; the cap-bed of the formation is not known.

At present we have only preliminary data on the lithostratigraphic units forming the Aghil Limestone.

The commonest lithotype is a grey, partially well-bedded, but also massive dolomitic limestone, much more than 1000 m thick (about 3000 m in the Skam valley, 2000 m in the Teram Kangri). This dolomitic limestone originates very fractioned forms and a mountain landscape often similar to that of the Dolomites in the Eastern Alps (pl. XII fig. 2). In the western part of the Shaksgam valley, very close to the confluence with the Sarpo Laggo, there is an alternation of light grey to white and dark grey to black dolomitic limestone with a few lenticular intercalations of blackish and red shales. The light grey dolomitic limestone with *Megalodon* is part of this sequence and seems to form the uppermost level of the walls overhanging the Shaksgam valley downstream from the Gasherbrum glacier. Upstream from this point red limestone beds seem to be intercalated in the sequence of grey limestone, occasionally in the form of calcareous breccia and, here and there, associated with marls or red shales like those forming the cliffs against which the front of the Singhié glacier abuts. Possibly they are two different complexes, one overlying the other but I lack a marker which can define the local stratigraphy.

In this connection I must mention the previously recorded red conglomerate (or breccia) often found at the base of the Aghil Limestone. I have to add only that the red conglomerate is not always present and is occasionally replaced by red marls or red shales. However, locally it is missing because it was eliminated by the overthrust of the rigid calcareus dolomitic masses on the underlain plastic rocks, rather than because it did not deposit. The assumption cannot be discarded that some breccia occurring at the base of the calcareous-dolomitic formation were produced by tectonic movements.

On account of the poor paleontologic data it is not possible to establish the age of the whole Aghil Limestone. The only ascertained fact is that the Norian is present and is represented by the grey dolomitic limestone with *Megalodon*. Even more uncertain is the chronostratigraphic boundary in the upper part of the formation.

Some other information may be derived from the comparison with the formations of the neighbouring areas.

18. Comparisons between the Aghil Limestone and Similar Formations in the Eastern Karakorum.

In connection with the Urdok Conglomerate (p. 116) it has been recorded that the ridge of Teram Kangri and Singhié Kangri — on which the watershed between the Shaksgam and Siachen basins runs — is largely composed of *Megalodon* and *Dicerocardium* grey limestone and dolomite. These rocks were observed by DESIO (1929) from the northern side and by DAINELLI (1930) from the southern side.

DAINELLI (1933, p. 424) collected also fossils in the left hand moraines of the Siachen glacier, mainly *Megalodon* and *Dicerocardium* which were referred to the Norian by C. F. PARONA (1934).

The species described by this author are the following: *Dicerocardium mediofasciatum* Frech, *Dicerocardium dolomiticum* (Lor.) Loretz, *Megalodus böckhi* (Hoern.) Frech, *Megalodus hoernesi* Frech, *Megalodus* sp., *Omphaloptycha* ? n. sp.,

The lithofacies of this stratigraphic horizon is represented by grey limestone (91-96% of $CaCO_3$) locally also whitish-grey with white and grey bands. One of the samples collected between the peak quoted 20,770 feet and the 2nd Camp, is made of light-grey dolomite (30% $CaCO_3$ and 70% $MgCO_3$) (1). The limestone and the dolomite are very similar to the rocks of the so-called « Hauptdolomit » formation of the South-eastern Alps.

As briefly mentioned above, the same dolomite and limestone with the same fossils (*Megalodon*) are cut by the Shaksgam river downstream from the Gasherbrum Jilga; red shales and/or red conglomerate outcrop at its base.

Besides this formation, in the Shaksgam valley there is a more or less dolomitic grey and red limestone sequence. These limestones outcrop mainly upstream from the Gasherbrum glacier on the Aghil side and seam to be lacking on the ridges bearing the watershed with the Siachen basin. At least we found no fragments on the glaciers which descend towards the Shaksgam, neither do we know that any were found in the Siachen valley.

The lithotypes most similar to the ones described in the eastern region seem to be the reddish dolomite and dolomitic limestone which have been assigned to the Middle Triassic by some authors like DE TERRA, DAINELLI, etc., in spite of the fact that they did not find any fossils. The known sequence — which seem to be the most similar to the one of the northern flank of the Shak-

(1) These data were obtained from some samples of the Institute of Geology, University of Florence.

sgam valley — is the one recorded by DAINELLI (1933, p. 400), between Murgo and Burtze on the eastern extension of the Shaksgam valley tectonic structures.

According to DAINELLI, the serial arrangement reconstructed along a traverse is as follows (from top to bottom):

6. White and pinkish dolomitic limestone, small thickness;
5. Thick set of strata of greyish limestone, similar to 4 with frequent sections of large *Megalodon* and *Dicerocardium*;
4. Whitish or grey thick-bedded dolomitic limestone interlayered with thin argillaceous beds, less thick than 3.
3. Whitish, in part brecciated, poorly-bedded dolomitic limestone frequently spotted with red or red coloured. Very thick;
2. Light coloured well-bedded, not very thick, veined dolomitic limestone, with reddish spots;
1. Dark, thin-bedded cherty limestones.

This sequence is followed by the Burtze sequence (p. 401), which has in common with the above mentioned one the *Megalodon* and *Dicerocardium* strata. This sequence is as follows (from top to botton):

8. Red limestones;
7. Ash-grey marls with gypsum;
6. Red limestones;
5. Clay and argillaceous limestones with gastropods and *Heterastridium* (Burtze II);
4. White and reddish limestone with ammonites and brachiopods (Burtze I) (p. 405); red nodular thin-bedded limestone (1);
3. Greyish marly limestone with scarce *Heterastridium*;
2. Very thick layer of greyish massive dolomitic limestone with *Megalodon* and *Dicerocardium*;
1. Whitish and grey dolomitic limestone with thin argillaceous interbeds.

DAINELLI (p. 405) assigned bed 1 of the first sequence to the Early Triassic; beds 2-4 of the first sequence and bed 1 of the second sequence to the Middle Triassic. He assigned the younger beds to the Late Triassic; more precisely beds 5 and 6, and perhaps bed 2 of the second sequence «could represent the base of the Carnian»; beds 3-5, the Carnian; and, finally, beds 7-8 probably represent the Norian.

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(1) C. F. PARONA (p. 3) who examined the fossils, mentions a pinkish variegated limestone with a tight dark-red nodular marly limestone.

The paleontologic documentation is not very reliable. The beds which yielded determinable fossils are: Burtze I and II of the second sequence, but PARONA (1928, p. 3), who studied the fauna, was doubtful about the age of the fauna from Burtze I because it was composed of 9 forms, of which only three are already known and have been determined with certainty: 2 of them are Norian, the other Ladinian. In the case of Burtze II, 5 out of the 8 identified forms are new, 2 were determined with some uncertainty (cf.); one, *Rhynchonella laucana* Bittn. of Carnian age, according to DAINELLI (1933, p. 403), is of uncertain provenance. However, it seems to be Upper Triassic, but what is strange about DAINELLI's chronostratigraphic determination, is his attribution of the dolomitic limestone with *Megalodon* and *Dicerocardium* to the base of the Carnian, when, elsewhere, in particular in the Siachen area, as in the Alps and in the Himalaya, this dolomitic limestone is unanimously assigned to the Norian. Thus, it can be concluded that either the age of Burtze I and II is Norian, or even more recent, or — and this seems more logical — that the second *Megalodon* and *Dicerocardium* bed overlies the Burtze I and II strata. This might be connected with DAINELLI's not quite correct interpretation of the local tectonics as in other instances of which we have spoken already (p. 123). This interpretation raises the problem of correlations. If the two sets of strata are compared, that is the *Megalodon* and *Dicerocardium* beds of the two sequences, and the second sequence is considered to be inverted, it is necessary to postulate the existence of heteropic beds in the first and second sequences; they would underlie the horizon with *Megalodon* and *Dicerocardium.*

For attempting to offer a solution to these problems it is easy to imagine that the strata underlying the Norian are heteropic. This feature can be observed in the Southern Italian Alps — where the facies are similar to those discussed above — beneath the « Hauptdolomit », both in the Carnian, Ladinian and Anisian strata. In this case we have on one hand a predominantly calcareous-dolomitic sequence overlying cherty limestones, on the other a predominantly calcareous-argillitic sequence. The sequences have more or less the same age and both underlie the *Megalodon* and *Dicerocardium* dolomite. This is a possible solution but there may be others.

Further, the Murgo section published by DE TERRA (1932, p. 108) is very similar to the geologic section seen on the northern side of the Shaksgam valley. The sequence is as follows (from top to bottom) (1):

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(1) The range of the numbers employed by DE TERRA has been inverted here, in order to clarify the sequence.

5. Dolomite with *Megalodon* (Megalodonkalk) (Late Triassic);
4. Red and grey marly limestone;
3. Grey calcareous breccias;
2. Dark arenaceous shales;
1. Dark Late Paleozoic limestones.

In this sequence, the dolomite with *Megalodon* (Megalodonkalk) overlies red and grey marly limestones with various *Heterastridium* which were mentioned by DAINELLI. This suggests that DAINELLI's interpretation is not acceptable.

It is interesting to notice that the two facies might be present also in the Shaksgam valley, but there are insufficient data to prove this.

Another point which is useful for comparison is the following: WYSS (1939, p. 282) collected some specimen of *Monotis salinaria* (Schloth.) and one of *Rhynchonella* sp. ind. to the west of the Shaksgam-la; the fossils were referred to the Norian by RENZ (p. 251).

RENZ recorded also that the fossils were found in a grey-yellow tight limestone. The fossiliferous locality (XXXV) occurs in the highest tributary of the Shaksgam valley, along the strike-line of the beds which build the dolomitic limestone ridges of the Marpo Rgyang (see fig. 35). Since various fossils were collected from the same locality and have been assigned by RENZ and REICHEL to the Early Permian, it can be assumed that in the neighbouring area Paleozoic strata also outcrop just as further downstream between the Kyagar and Singhié glaciers. However, slightly further to the east, in the small valley descending towards the Yarkand valley to the north-east of the Shaksgam-la, WYSS collected fossils which were assigned to the Carnian (see p. 75). This locality, too, is on the eastern strike-line of the beds forming the Marpo Rgyang ridges; thus both the stratigraphic units referable to Carnian and to Norian are very probably present in the upper Shaksgam valley.

19. Comparison between the Aghil Limestone and Similar Formations in the Western Karakorum.

As for the formations previously described, we have to look for possible correlations of the Aghil Limestone with other rock-units in the upper Hunza valley. The formation immediately drawing our attention is the one C. A. MCMAHON (1900) called « Gujhal Limestone », and which I described in one of my papers (DESIO & MARTINA, 1972) as « Gujhal Dolomite », on account of the prevalence of this lithotype. The Gujhal Dolomite is composed of a sequence of dolomitic, calcareous-dolomitic and calcareous beds, about 5000 m thick; unfortunately its type-section is not known yet. It consists, however, of alternating white, grey and black dolomite and limestone with lenticular intercalations of black shales and red more or less arenaceous breccias. In the lower beds of the sequence there are fossils looking like sections of thick bivalves resembling *Megalodon* shells.

The Gujhal Dolomite seems to be much thicker (5000 m) than the Aghil Limestone (2000-3000 m), but the last datum is vague and is referred to a restricted outcrop of the Shaksgam valley.

About the stratigraphic position both formations overlie the Shaksgam or the equivalent Gircha Formation, but the Kyagar cherty limestone is not present in the Hunza suite. The overhanging formations seem to be similar, but we do not know any Jurassic red beds in the Hunza valley. In spite of these irrelevant differences the two formations can be assumed as being equivalent.

20. The Jurassic Fossiliferous Beds of Bdongo-la.

Little can be added to what has already been said about these beds. Its age was deduced from a small fauna of isolated corals collected on the Bdongo saddle (Desio & Fantini, 1960; Fantini Sestini, 1965).

The lithofacies and biofacies of the rocks outcropping in the neighbouring regions might provide some informations for a comparison with our stratigraphic unit. The biofacies, however, do not provide any; the Jurassic fauna of the eastern region and of the Aghil Limestone yielded only scarce corals. It must be pointed out, however, that the corals represent only a small part of the local fauna since most of the other fossils were lost.

The only ammonite specimen which I collected is indeterminable, but, anyhow, its presence calls to our mind the other Jurassic faunas of the eastern region and of the Aghil. No meaningful comparison is however possible since the only specimen from the Shaksgam valley, as I said, is indeterminable.

Regarding the lithofacies, some comparisons can at least be made with the nearest outcrop-areas located on the eastern strike-line of the Shaksgam valley beds.

Near the northern front of the Rimu glacier, Dainelli (p. 325) collected, in an « ochraceous, more or less marly limestone » a small fauna which Parona

(1932, p. 4) assigned to the Jurassic (probably Callovian). Nodular ochraceous beds of red and purplish marly arenaceous shales are exposed also on the Bdongo-la, but it is not sure whether they are of the same age as the rocks containing Jurassic fossils.

Nevertheless DAINELLI (p. 208) mentions a calcareous breccia with chert clasts which may be compared with the Bdongo-la conglomerate made not only of rounded clasts, but also of angular ones with some fragments of chert.

The scanty detailed information on the local stratigraphic sequences both of the Rimu glacier north front and of the Bdongo-la leave this correlation undecided. All the more so since a nodular red marl was found also further upstream from Bdongo-la and was compared with a similar bed. This marl seems more similar to the Burtze Triassic suite, already discussed on page 112 than to the Bdongo-la fossiliferous bed.

Another Jurassic fossiliferous rock outcrops further to the north-east, near the confluence of a small stream facing down from the Karakorum pass and the Yarkand river towards north-east. This locality was firstly mentioned by WYSS but we know only its fossils studied by RENZ (p. 285). They are pelecypods (*Ctenostreon proboscideum* Sow., *Spondylopecten* cf. *bouchardi* App.), and ammonites (*Perisphinctes*) and were attributed to the Callovian.

The same authors mentioned other fossiliferous localities near the Karakorum pass and the ammonites and the brachiopods found there were also dated as Callovian. The lithostratigraphy of these and other localities further to the south and south-east is not known, but it can be inferred on the ground of the lithologic data of another fossiliferous locality occurring nearby and mentioned by MARINELLI and DAINELLI (p. 320) to the north-west of Polu (Ammonite Valley). The rock is a dark-grey tight marly impure limestone generally red-speckled and occasionally with wine-red or blood-red spots. This rock does not look very different from the one outcropping at North Rimu and, probably, it outcrops extensively around the Karakorum pass. The « Ammonite Valley » fauna is characterised by ammonites, pelecypods and some brachiopods. G. STEFANINI (1928) attributed it to the Callovian like the above mentioned ones.

If we imagine to extend the folds including the Jurassic beds, towards the north-west or the west-northwest, the outcrop near the North Rimu glacier front should be the only one continuing into the Shaksgam valley. The others would be occur further to the north in the Aghil range. The Rimu suite could theoretically reach the valley between the Chikchi-ri and Marpo Rgyang, but taking into account that its elevation is much lower, its presence there is doubtful. The Callovian red marly limestone probably outcrops extensively in the Lungpa Marpo valley (Red Valley) which descends along the right hand side of the Shaksgam river, upstream from the Kyagar glacier. The Jurassic fossiliferous localities mentioned by K. MASON (1928, pp. 97-98) are probably on the strike line of the extensive fossiliferous outcrops of the Ammonite Valley. MASON (ibid., p. 87) vaguely mentions the lithology of those localities by saying: « The presence of *sandstone* and *shales* seems to indicate this sea was during Jurassic times growing shallower ». This agrees with the presence of Jurassic rocks at Bdongo-la and in the Aghil valley.

21. Comparison between the Shaksgam and the Pamirs Formations.

Although Pamirs is not on the lateral extension of the tectonic axes and the Shaksgam stratigraphic zones, since it lies further to the north and also belongs to different tectonic zones, a stratigraphic comparison — necessarily very synthetic — can be quite interesting for reasons that we will appreciate further on.

At a general glance of the stratigraphy of the various tectonic units into which the Pamirs has been divided (BARKHATOV, 1963), it is immediately obvious that only the South-east Pamirs can be usefully compared.

The stratigraphic sequence orf South-east Pamirs starts with a complex of quartzitic slates with intercalations of fine grained conglomerates and gritstones and with yellowish-white marbled limestones (Andar series), which has been ascribed to the Late Paleozoic (possibly in part to the Late Carboniferous) (1). The Permian series is particularly interesting because it is fossiliferous. It starts with dark grey and black shales with thin fine-grained quartz sandstone intercalations having a flyschoid facies. Rare intercalations of argillaceous, arenaceous and clastic limestones occur in the upper part of the formation and contain various fossils including, above all, fusulinids and brachiopods of Early Permian age. The genus *Parafusulina*, one of the most widespread foraminifer in the Shaksgam valley, together, with *Cancrinella cancriniformis* (Tschern.) a common brachiopod, occur here like in the Shaksgam valley.

The Early Permian formation in Pamirs (the Kubergand Formation of DUTKEVIC) has been referred to the Darvasian stage, while the Karachatyrian stage is probably missing.

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(1) A diligent investigation on the petrography of the Permo-Carboniferous and Triassic suites in South-east Pamirs and Karakorum was recently made by NORIN (1976).

There is an obvious lithofacies affinity between the Early Permian of South-east Pamirs and the Singhié black shales and the lower part of the Shaksgam Formation. Furthermore, when the faunas are better known also the paleontologic affinity will probably increase.

Regarding the Late Permian, the two stages, the Murgabian and Pamirian, are both present in South-east Pamirs.

The stratigraphic sequence is characterised by the occurence of numerous siliceous limestone beds followed by a green-purple siliceous complex and then by calcareous conglomerates. This part of the sequence has been assigned to the Murgabian. The Pamirian is represented by siliceous schistose rocks with thin calcareous intercalations in the lower part; they are overlain by tuffaceous sandstones and shales with some limestone beds. These alternate with layers of volcanic rocks among which there are also porphyritic dacite (Kutal and Takhtabulak formations). The Neopermian series of Pamirs has many similarities with the upper beds of the Shaksgam Formation in the Shaksgam valley, as we have already seen. Both the Murgabian and the Pamirian stages are present.

It is difficult to compare the Triassic series of the two territories since in the Shaksgam valley the Pamirian stratigraphic sequence has been only vaguely recognized except for the upper part. However, in South-east Pamirs the Triassic series is represented by two formations, one, essentially marly-arenaceous, is very thick (1500 m), the other is calcareous and much less thick (50 m). The Early Triassic is represented mainly by black oolitic tabular limestones and intraformational conglomerates. The Middle Triassic comprises mainly dark limestones interbedded with siliceous shales.

As far as the Late Triassic is concerned, while the Carnian is represented mainly by limestones and marls alternating with siliceous and arenaceous shales, the Norian and Rhaetian are represented by a very thick sequence of flyschoid marly sandstones (Istik Formation) overlain by limestones. However, it must be recorded that the Aqtash Formation, which is also Triassic, is much richer in carbonatic rocks. Certain fossils — in particular pelecypods — made it possible to date various stages in Pamirs; this has also been possible in south-eastern Karakorum, to the south-east of the Shaksgam valley.

A favourable event for comparative purposes could be the block of cherty limestone with remains of possible *Daonella* or *Halobia*, found 2 km upstream from the Staghar glacier (p. 63), which seems to be very similar to the calcareous-siliceous rocks with *Daonella*, *Halobia* and *Posidonia* from the Ladinian of South-east Pamirs. Facies similar to the Chikchi-ri shales of the Upper Shaksgam valley can be found in Pamirs, while the thick sequence of dolomitic limestones with *Megalodon* belonging to the highest part of the Triassic sequence in the Eastern Karakorum seems to be missing.

Another element in favour of the affinity between the stratigraphy of the northern side of the Shaksgam valley (Aghil range) and the South-east Pamirs can be found in the Jurassic sequence. Even though we know no details on the stratigraphy of the mountainous area located to the north of the high crest of the Aghil range facing the Shaksgam valley, from the place-names and the sparse notes provided by MASON (1928) and AUDEN (1938), it can be deduced that there are extensive outcrops of red sandstone and shales which in three localities yielded remains of pelecypods, brachiopods and even ammonites (*Holcostephanus* and *Perisphinctes*) of Late Jurassic age.

In the south-eastern Aghil range there are various Jurassic formations which are partly coeval. Of immediate interest are only those belonging to the Middle and Late Jurassic since, at present, only these are known in the Shaksgam valley where they overlay with unconformity the Late Permian and Triassic (?) formations. In South-east Pamirs also the Jurassic sequence is mainly unconformable with the Permian or Triassic formations and even there the Middle Jurassic may be absent. At the base the Jurassic series both complete and partial, there are large outcrops of red sandstones and conglomerates with calcareous matrix which closely resemble those of Bdongo-la and, from the little that is known, also the Aghil ones.

Considering also the Jurassic outcrops which are found on the easterly extension of the Shaksgam valley and Aghil range, near the northern front of the Rimu glacier or around the Karakorum pass or again north-west of Polu (Ammonite Valley), the lithologic and palaeontologic affinities are still more striking (see DAINELLI).

Cretaceous beds have not been recognized, as far as we know, in the Shaksgam valley itself, but have been recorded from the watershed of the Baltoro basin (DESIO & ZANETTIN, 1970). Here it is represented by two formations, one arenaceous-conglomeratic (Khalkhal Sandstone), the other calcareous (Savoia Limestone). Another rock outcrop of the same age, but also fossiliferous, was recorded just to the east of the Shaksgam valley, near the front of the Rimu glacier (DAINELLI & MARINELLI, 1934). The facies is rather similar to the one of the above mentioned formations. In South-east Pamirs there are also Cretaceous outcrops but very restricted.

In the Shaksgam valley and in the surrounding areas (as far as can be seen), as well as in South-east Pamirs, the marine stratigraphic sequence ends with the above mentioned Cretaceous formations. The Paleogene, in fact, has not been well ascertained and, in any case, would have continental facies.

After what has been said on the stratigraphic affinities between the Shaksgam valley and South-east Pamirs, there is no point in talking on the formations in Central Pamirs since, even at a summary review, as a whole they are different. It is sufficient to recall that the stratigraphic sequence starts much earlier than in South-east Pamirs because at the base there is a possibly «Proterozoic» metamorphic complex. This is followed by a thick sedimentary sequence, more or less fossiliferous, attributed to the Ordovician, Silurian, Devonian and Carboniferous, while the Permian formations are less extensive and less fossiliferous and in comparison with those of South-east Pamirs have also fewer affinities with the ones of the Shaksgam valley. Little can be said about the Triassic series because of the same reasons that made difficult a comparison with the ones of South-east Pamirs. The Jurassic has mainly a clastic facies inferiorly, and calcareous superiorly; the last contains pelecypod faunas and rare ammonites, while in the Aghil and in the area further to the east, ammonite faunas prevail. Here the Cretaceous is represented more extensively than in South-east Pamirs and is also much thicker. The Paleogene is characterized at the base by limestones and then by coarse clastic formations, prevailingly red-coloured, alternating with volcanic rocks in a rather thick complex of which there is no trace in the Shaksgam valley.

22. Some Considerations on the Stratigraphy of the Shaksgam Valley and the Eastern Karakorum.

22. 1. THE OLDEST FORMATIONS. In one of my recent reports on the geology of Karakorum (DESIO, 1979), I shortly examined the question of the oldest rocks outcropping in the Karakorum area; here I want to add some details on the question regarding the Shaksgam valley and the Eastern Karakorum.

According to R. LYDEKKER (1883) a large area of the Eastern Karakorum is made of the socalled « Central Gneiss » of STOLICZKA assigned to the Archean; however it is in part undistinguishable from the Paleozoic « Metamorphosed Panjals ». There is no point in talking on this obsolete conception of the structure of the Karakorum and I am going to examine only the opinions of the more recent authors concerning the presence of Archean in the area under consideration.

DE TERRA (1932) discussed this problem in his report on about the Kun Lun and Karakorum. On page 113 the author, after saying that there is no certain evidence that Archean rocks are present in the Karakorum, assigned to the « Proterozoic » the augen-gneiss outcropping to the north and north-west of the Pangkong lake and the « Mischgneiss » with associated horneblende-schists. The red slates outcropping in the Nubra valley under the breccia of the volcanic sequence (agglomerate ?) could possibly have the same age. The author, however, does not provide any proof.

DAINELLI (1934), after criticizing the dating of the metamorphic rocks by LYDEKKER, assumes (p. 602) that « the crystalline schists of Baltistan on the right hand side of the Indus river are pre-Silurian (1) with the only exception of those alternating with the calcareous-quartzitic layers. The latter wer assigned by the same author to the Silurian-Devonian. The evidence for a pre-Silurian, and therefore Cambrian and Precambrian age of the Baltistan crystalline schists, substantially depends upon his attribution to the Silurian of the oldest layers of the calcareous-quartzitic complex (compared with the Spiti stratigraphic records) and his tectonic interpretation.

In this connection I want to mention that, after DAINELLI (pp. 578-579), the Silurian calcareous-quartzitic complex would outcrop also on the Teram Kangri range and from here it would extend further on as far as the Shaksgam-Sarpo Laggo confluence. As we have seen (p. 124), this supposition is lacking of any support in the local geology.

It is worth while to emphasize here DAINELLI's assumption that the calcareous-quartzitic complex represents, as a rule, everywhere in the Karakorum the Silurian and possibly also the Devonian, which upset his stratigraphic and tectonic interpretation of a large area of Karakorum.

AUDEN (1938) hints at an old chronostratigraphic horizon in the « Sarpo Laggo Series ». In his geologic map, reproduced at page 27, the « Sarpo Laggo Series » is referred to the Pre-Cambrian and Paleozoic and is correlated with HAYDEN's « Sarikol shales and slates » and with DE TERRA's « Kilian Series » of Silurian and Devonian age; the lowest beds are dubitatively compared with the « Karakasch Series » (see table at page 20).

My opinion — reported at page 34 — is that the « Sarpo Laggo Series » represents the Baltoro Slates Singhié Shales of Late Paleozoic age.

According to the foregoing stratigraphic descriptions of this report the oldest sedimentary formation oucropping in the area investigated is a sequence of

(1) DAINELLI includes the Ordovician in the Silurian.

blacks shales interlayered with dark sandstones and, in the upper part, with black limestones and called Singhié Shales. In the Shaksgam valley only the uppermost part of this formation is exposed for about 2500-3000 m of thickness.

On account of its relationships with the overlaying Shaksgam (fossiliferous) Formation it was referred to the Carboniferous. We do not know whether the above mentioned sequence represents the whole or only part of the Carboniferous.

As already stated in the section concerning the comparison between the Singhié Shales and similar formations of the Eastern Karakorum (p. 81), fossiliferous beds, undoubtedly belonging to the Late and even less to the Early Carboniferous, are not known in these regions. In a report by DAINELLI (1936, p. 571) there is an obscure passage stating that « the Upper Paleozoic, in the extensive area between the Siachen and Aq-sai-chin, is certainly entirely exposed, although the Carboniferous layers could not be distinguished and, even if they are complete, did not show any conglomerates ».

DE TERRA (1932, p. 95) made a brief reference to Early Carboniferous beds, but in an area located much further to the south, that is the Chang-chenmo valley. Here, in a debris of dark schistose limestone he collected: *Chonetes lipakensis* Dien., *Chonetes hardrensis tibetensis* Dav., *Thomasia margaritacea* Phil., *Avania* sp.
which he correlated with the « *Syringothyris* limestone » of Kashmir, unanimously attributed to the Early Carboniferous. The same author (pag. 90) mentions in the neighbourhood of Lukong, to the north-west of the Pangkong lake, one outcrop of dark slates and phyllites, which yielded very damaged remains of *Orthoceras* and *Productus*, possibly representing the Early Carboniferous, but perhaps belonging to the Permian.

In conclusion we lack of valid documents proving the presence of the Carboniferous in the Eastern Karakorum and DE TERRA himself (p. 114) denies the presence of the Middle and Late Carboniferous in the Karakorum.

Now we will see by which arguments DAINELLI tries to prove the presence of the Carboniferous, but also of the Devonian and the Silurian beds, in the Karakorum between the Karakorum and Tibet and also in the area investigated here.

The only paleontologic data available to the author are three and only one concerns the Karakorum, the others the region further to the east. The most important one is the Ordovician fossiliferous locality near the Qizil pass, at 35°10′ Latitude north and 79° Longitude east from Greenwich, that is in the neighbourhood of the head-waters of a tributary of the Qaraqash river, to the south-east of Aq-sai-chin.

I think it is useful to describe here, summarily, the stratigraphic sequence reconstructed on the data provided by DAINELLI (p. 556-569). This sequence (the members correspond only to the succession of outcrops) is, from top to bottom, as follows:

5. «Yellow beds» (member s). Yellow, light bluish marly-glauconitic limestone, light yellow when weathered, filled with speciments of a small *Orthis*. Among the fossils determined by M. GORTANI (1934) the following can be listed (the new species are omitted): *Orthis tibetica* Salt., *Rafinesquina umbrella* Salt., *Strophomena* cf. *antiquata* Sow., *Bucaniella* cf. *obtusangula* Kok., *Raphistoma qualteriatum* Salt., *R.* cf. *aequilaterum* Kok., *R.* cf. *sinense* French, *Orthoceras* cf. *montalense* Kob., *Illaenus dalmani* Holm., *I. spitiensis* Reed etc.

4. «Red beds» members d + g). Wine-red and light coloured hematitic fossiliferous limestone, «very light-coloured and marly when weathered». The prevailing fossils are cephalopods and trilobites. Among the species recognized by GORTANI are the following: *Spaeronis shihtiensis* Reed, *Orthis thakil convexa* Salt., *Triplecia uncata* Salt., *Vaginoceras wahlenbergi* Foord, *Nileus armadillo* Dalm., *Illaenus esmarki* Schloth. etc.

3. (member y). Dark, grey-brownish and slighty arenaceous shale with abundant fossils. Among them GORTANI identified: *Orthis testudinaria himalaica* Reed, *Strophomena chamaerops* Salt. etc.

2. «Brachiopod limestone» (member t). Light coloured, marly and limonitic limestone, grey-yellowish and yellow-ochraceous when weathered. Among the fossils studied by GORTANI are the following: *Lingulella* cf. *bella* Walc., *Orthis calligramma* Dalm., *O. stacheyi* Reed, *O. testudinaria* Dalm., *O. tibetica* Salt., *O.* cf. *flabellum* Sow., *O.* cf. *porcata* M'Coy, *Rafinesquina* cf. *aranea* Salt., *Strophomena* cf. *antiquata* Sow., *Triplecia uncata* Salt., *Asaphus* cf. *chinensis* Well., etc.

1. (member x). Friable slightly marly thin-bedded limestone grey or grey-yellowish when weathered, composed almost entirely of cistoids. Among the fossils GORTANI recognized *Caryocrinus* cf. *turbo* Bath., *Orthis* cf. *testudinaria* Dalm., etc. This fossiliferous sequence was assigned by GORTANI (1934) to the Middle Ordovician.

A few new fossil species which GORTANI assumed to be representative of the Upper Ordovician or of the base of the Silurian were collected also in the immediate neighbourhood of the Qizil pass. Taking into consideration these data, DAINELLI (p. 569) said that: «this supports the hypothesis... that at the Qizil Pass other beds, hidden by talus and interposed between the members and the Upper Paleozoic, could be present; this proves that the complete Qizil sequence continues towards the east where, however, it soon disappears at the base of the mountain ranges under the Upper Paleozoic and the Triassic; and emphasizes that the Silurian (1) certainly and possibly also the Devonian in the area investigated outcrop much more extensively than it would seem in the sporadic and uncertain available informations ».

DAINELLI extends the presence of the Silurian from the Qizil pass to the Karakorum by saying: « I have pointed out, however, that in the area between the upper Shayok valley and the Aq-sai-chin plateau, another rock unit, mostly comprising arenaceous limestones and wine-red sandstones, often underlies this unit (presumed Carboniferous)... and I said also that these outcrops of red sandstones seemed to outline the trend of anticlines the sandstones evidently underlying layers of the Upper Paleozoic. But, at the present stage of our knowledge on the outcrops near the Qizil pass, we may suppose that these sandstones represent anticlinal cores of Silurian age » (p. 569).

On the basis of the previous assertions he points out that near Kataklik, in the Shayok valley, there is « an outcrop of dark, wine-red, occasionally greenish, coarse-grained, arenaceous rock which, upstream from Kataklik, is in contact with a granitic body but downstram from this camping ground is again followed by the same blackish calcareous, arenaceous and clayey shales ». Further on he states: « I formulated the hypothesis that this arenaceous outcrop could form the oldest outcropping core of that anticline... it can be assumed that such a characteristic rock unit represents the Silurian ».

DAINELLI continues assuming that nearly all the red sandstones or marls reported by other authors and close to Permian formations represent the Silurian and form the core of anticlinal folds. In this connection it must be pointed out that DAINELLI almost always describes these rocks as « red sandstones », « red arenaceous rocks », « red arenaceous marls » etc. when referring to Silurian outcrops; but when he describes the Qizil fossiliferous outcrop and in particular the « red beds », he mentions, on the contrary, red limestone.

There is no doubt that red sandstones and marls are exposed at random in the Eastern Karakorum and also in the Shaksgam valley but, as we will see later, they belong to different and younger stratigraphic units which have nothing to do with the Silurian series.

DAINELLI, however, bases his belief about the presence of the Silurian in the Eastern Karakorum and in the area examined here on the fact that multicoloured conglomerate clasts with a very hard matrix were found within the Qizil Lungur conglomerate (see page 118). These clasts have been described by DAINELLI in many sites: we have mentioned them in the section dealing

(1) See note 1 page 138.

with the Urdok Conglomerate, but it is necessary to consider the question again for its importance in the stratigraphic interpretation.

About the old conglomerate, as a conclusion, DAINELLI said (p. 575): « Although the established comparison is partly hypothetical, the red multicoloured conglomerates and the red sandstones, arenaceous and quartzitic shales are undoubtedly a well-recognizable horizon, older than the Upper Palaeozoic and very similar to the formation representing the Lower Ordovician at Spiti. They seem to be confined, also in relation to the general trend of the geologic zones, to the north-eastern part of our region. I have no evidence that they outcrop to the south-west of a line running southeast-northwest between the upper Nubra and Sarpo Laggo valleys; their outcrops must be almost continuous along these valleys and other outcrops, as already seen, are located further to the north each one representing an anticlinal core ».

What has already been said in the section regarding to the Urdok Conglomerate about the stratigraphic position of the same and other similar conglomerates, such as the ones of Bdongo-la and of the Sarpo Laggo glacier front, clearly evidences that such conglomerates, and in particular the Siachen one, cannot be assigned to the Silurian. The same conclusion can be applied to the red sandstones and shales which are occasionally associated with them. The multicoloured conglomerate and red shales exposed just below the Aghil Limestone, in the Shaksgam valley, in the Siachen, Baltoro, etc. are Triassic; those of Bdongo-la probably Jurassic and, finally, those of the Baltoro basin, partly Triassic and partly Cretaceous if not actually Tertiary, as we have proved in a publication concerning that region (DESIO & ZANETTIN, 1970).

The Silurian outcrop with fossiliferous, mostly calcareous, « red beds » of the Qizil pass has nothing to do with the red and green sandstones of Kataklik in the Shayok valley: they have a completely different facies and belong, moreover, to different tectonic zones. The Ordovician outcrop of the Qizil pass is independent from all the other outcrops located in the south-west.

According to my tectonic interpretation of this part of Central Asia (DESIO, 1965 and 1979), the Pamirs-Karakorum Fault passes near the Qizil pass and divides the Hercynian tectonic region of Qaraqash - Aq Sai Chin from those of Pamirs and Karakorum. In this case the Ordovician of the Qizil pass belongs to the Loqzung tectonic zone, which seems to correspond to the one of Central Pamirs where there are fossiliferous Silurian beds not very different from those of the Qizil pass, but completely different from those of Spiti.

Besides what I said on the Silurian in the Qizil pass and Spiti, the presence of this system in our area has been indicated also elsewhere by other authors.

In the first place we should consider the notice given by A. M. VERCHÈRE (1867) since it is reported by some old authors dealing with the geology of Karakorum. According to him the fossiliferous Silurian beds outcrop on the southern side of the Masherbrum peak which rises between the Baltoro and the Hushe valleys.

I have already dealt in detail with this supposed outcrop in a recent publication (DESIO & GIOBBI MANCINI, 1974); therefore here I will only report the conclusions of that work.

No confirmation of the existence of limestones of that kind in this area was found among the 55 rock samples collected in the end moraine of the Masherbrum glacier by D. ALESSANDRI (of the BARBUSCIO expedition to K^6) who had been made aware of the existence of the problem. A single sample of calcareous rock comes from this moraine and is a crystalline limestone (marble) devoid of any organic traces.

Among those who visited the Masherbrum valley since VERCHÈRE's report, W. CAMPBELL SMITH (1917) mentions « fine-grained dolomite » and A. ROCCATI (1915) « white and grey limestone (also crystalline variety with tremolite), dolomite ». Among these rocks it would seem that there are also limestones, with normal or semimetamorphic facies, but we have no proof other than the vague words mentioned above.

LYDEKKER (1883), who seems to have also reached the southern slopes of the Masherbrum (K^1), makes no mention of the existence of limestones in that area but only of metamorphic limestone much further down, near Hushe.

Thus the problem still remains open. However, it should be mentioned that the limestone sample with fossils *Cistideae* was not collected directly by VERCHÈRE but by RYALL, from whom it passed to GODWIN AUSTEN and then to VERCHÈRE, who in turn gave it to DE VERNEUIL to study. We do not feel it is wholly out of place to raise certain doubts on the precise origin of the sample, both on account of the fact that LYDEKKER, who must have known VERCHÈRE's publication, neither found any traces of these limestones nor mentioned them in his reports. Moreover in other occasions GODWIN AUSTEN (1864, 1865) rectified the records of fossils, like, for instance, those collected in the nearby Shigar valley, on account of the confusion that existed in the accompanying labels.

Only DAINELLI (1934) accepted the information as genuine and used it as a basis for an interpretation of the regional stratigraphy and tectonics which, both in the Baltoro valley and in the Shigar valley and elsewhere, has been shown to be mistaken, as has been proved by DESIO (1964) and by ZANETTIN (1964).

In the present state of our knowledge, therefore, the existence of Silurian limestones on the southern slope of the Masherbrum appears highly problematic and, we should like to say, scarcely credible. But unless the southern slope of the mountain is studied more carefully it is not permissible to come to a negative conclusion.

In any case the strip of Silurian limestones — if it exists — would have to be contained in a kind of tectonic splinter enclosed among geologic formations of a more recent period since the metamorphites of that area are largely of a more recent date than was once thought.

There is also other information concerning the presence of the Silurian and, in this case, also of the Devonian beds, in the area investigated. Such information was reported by De Terra and referred to some outcrops one of which is very near the large bend in the upper course of the Shayok river and therefore also to the Karakorum.

The locality described by De Terra (1932, pp. 88-89) is in the neighbourhood of Tankse, in one of the small valleys descending from the peak 19.999′ high, shown on the map published by the Survey of India.

Here, there are outcrops of sandy phyllites and biotite-hornfels with aplite sills, locally giving origin to paragneiss, garnetiferous schists and knotphyllite are also exposed. These paraschists contain also some white-grey and blue-grey, fine-grained thin-bedded layers of marble with ellipsoidal inclusions from 2 to 20 cm in size referred by De Terra to *Stromatopora*, and remains of brachiopods preserved as internal arenaceous moulds, which seem to be *Pentamera*. Another specimen has the shape of a small coral of the *Goniophyllum* type. The marble is slightly bituminous and contains pyrite. The metamorphism of the rocks must be attributed to the injections of the Tankse granite. De Terra concludes that the marble, according to its fossil content, must represent the « Upper Silurian » and that the schistose mantle intruded by the Ladak granite belongs to « Lower Palaeozoic » partly Silurian and partly older.

In the Chang-chen-mo valley, further to the east, De Terra mentions other two localities which yielded Silurian fossils (pp. 93-94). Near Kyam, in dark-grey and greenish shales overlain by tuffs and «porphyrite» he observed worm impressions and a *Phycodes* (Fucoid) very similar to *Phycodes circinatum* Richter, a fossil characteristic of the Ordovician in Germany and southern France. He mentions also the presence in a schistose conglomerate (Kieselschiefer) not far from the previous locality, of orthoceratides and graptolite remains, possibly indicating the Silurian and, further upstream, near Lakarpo, a trilobite-shaped remain.

Unfortunately DE TERRA did not describe or illustrate the above mentioned fossils not even summarily. He, however, did so for other fossils and it is therefore assumed that he identified the above mentioned ones on the spot.

The evidence provided by DE TERRA on the presence of the Silurian and/or the Ordovician in this area is objectively inconclusive. Neither the brachiopods and corals poorly preserved as internal moulds in sandstone, nor such problematic fossils as *Phycoides* can be attributed to the Silurian, nor even to the Paleozoic; this applies more so to the trilobite-shaped remain.

The stromatopores and the trilobites are more significant fossils and more easily recognizable in the field, but also these forms can not be fully accepted unless further confirmation is available.

An uncertain correlation proposed by LYDEKKER (1883, p. 185) and confirmed by DE TERRA, of the white Lukung quartzite with the Devonian Muth Quartzite of Spiti, induced DAINELLI to attribute all the Karakorum metamorphic formations containing marbles and quartzites to the Silurian and the Devonian.

It is not necessary to report the descriptions and the correlations of DAINELLI (1934, pp. 575-591). On the ground of the extrapolation concerning the fossiliferous outcrop of the Qizil pass and the uncertain data mentioned previously, he infers that the Silurian and Devonian formations outcrop in the Karakorum range in bands several hundreds of kilometres long, as shown in the geologic map enclosed in his publication (1934).

It is necessary to record here also his correlation of the Shigar, Basha and Braldo valleys since their study carried out by ZANETTIN and DESIO provided very different conclusions.

DAINELLI's introduction to his lengthy and detailed demonstration of the mistake made by LYDEKKER (1881) in assigning the formations outcropping on the northern side of the Shigar valley to the Triassic, is as follows (p. 579): « However, the established Silurian age of a lithologic complex characterized by the presence of marbles and quartzites, makes interesting to investigate whether that complex is exposed also in Central Baltistan. In fact, it is present there and during my excursion it seemed to me to be the only complex that could be somehow used as a marker in that zone ».

The metamorphic formations of the Shigar valley correlated with those of the eastern side of the Nanga Parbat massif through the Turmik and Middle Indus valley, should be, instead, attributed to the Cretaceous and to the Eocene, it was demonstrated by the petrographic studies carried out by B. ZANETTIN (1964).

Further data showing that DAINELLI assigned a wrong age to the same metamorphic formations to the east of the Shigar valley are recorded in two papers (DESIO, 1965, 1978) dealing mainly with the attribution to the Cretaceous of the semimetamorphic fossiliferous rocks outcropping on the Burji valley, to the south and south-east of Skardu.

The fossils collected by DESIO were studied by C. ROSSI RONCHETTI (1967) who identified the following species:

Oligoptyxis aralensis Pcelinchev
» *cilindrica* Pcelinchev
» *turricula* Pcelinchev
Dalmatea desioi n. sp.
Itruvia canaliculata (d'Orb.)
Pseudomesalia bicarinata Pcelinchev
» *regularis* Pcelinchev
Metacerithium sp. ind.
Pirenella pseudoclathrata (d'Orb.)
Haustator cf. *nodosus* Roemer
Haustator sp. n. ind.
Turritella sp. ind.
Exogyra sp. ind.
Cyprina sp. ind.

The above listed fossils seem to prove adequately the late Cretaceous age of this outcrop and moreover to assign it to the Turonian, since most of the determined forms have a distribution restricted to this stage, or else reach their maximum frequency in it.

The same information suggests that the rock complex, prevailingly composed of quartzite and marble and assigned by DAINELLI to the Early Paleozoic, at least in the Karakorum (see his 1 million scale geologic map of Karakorum) and possibly further to the east, mostly belong to the Cretaceous and probably in part also to the Eocene (see DESIO's W. Karakorum geologic map 1:500,000).

Before concluding this subject I want to add that a vague clue of the existence of an old metamorphic basement (pre-Permian) is supplied by the arkose sample 29KD-560 which was examined by P. SPADEA RODA. Among the clasts of the Late Permian (Pamirian) rock this scholar ascertained the presence of « feldspar grains derived from metamorphic rocks ». These rocks could derive from and old basement underlying the local sedimentary series. Certain gneiss from the Eastern Karakorum, whose age is not yet defined (see DESIO 1978), can perhaps belong to that basement.

In conclusion, the presence of formations older than the Carboniferous in the Shaksgam valley and in the Eastern Karakorum is not yet demonstrated and it is doubtful whether the Early Carboniferous is present in this mountain range. All the other sedimentary formations of Paleozoic age belong to the Permian and frequently they are very fossiliferous.

Metamorphic and plutonic rocks outcrop near the sedimentary formations and, even if they have only a limited extent in the Shaksgam valley, they are much more widespread in the Siachen and neighbouring Baltoro valleys. We will now briefly speak of them.

For a long time these rocks and particularly the various types of gneiss were assumed to represent the oldest core of the Karakorum range. The plutonic and metamorphic formations of the Eastern Karakorum were not investigated by me, but from what I have written in the previous paragraphs, it may be assumed that many of them are younger than previously thought. This observation is true both for the plutonic and for the metamorphic rocks, as it has been demonstrated on the neighbouring territory to the west (DESIO & ZANETTIN, 1970). It is, in fact, known that in the Baltoro basin the Singhié Shales are represented by three different metamorphic facies: the Baltoro Slates, the Falchan Gneiss and the K^2 Gneiss. It is also known that the Shaksgam Formation is represented by some metamorphic sequences: the Doksam sequence and the Mitre and G. P. sequences which may, however, include also some Triassic rocks.

In spite of the previous statements, we cannot exclude — as I said — that rocks older than the Carboniferous are present among the metamorphic rocks of the Eastern Karakorum, but up to now there is no available evidence to support this hypothesis.

22. 2. THE MOST RECENT MARINE FORMATIONS. Small remnants of post-Jurassic marine formations occur on the ridge between the Shaksgam and Baltoro basins. They are the Savoia Limestone and the Khalkhal Sandstone, outcropping in Falchan Kangri and in Baltoro Kangri, and generally they were assigned to the Cretaceous (DESIO & ZANETTIN, 1970). The Savoia Limestone shows a bioclastic facies followed by a clastic facies, occasionally very coarse-grained, which corresponds to the Khalkhal Sandstone; both formations have already been described in the previously-mentioned volume. In the region located further to the west both formations have equivalents, thus making it possible to date them. The Savoia Limestone, equivalent to the fossiliferous beds with *Orbitolina* and rudists of Yasin, probably belongs to the Albian, while the Khalkhal Sandstone is equivalent to the overlying arenaceous-conglomeratic formation also present in the Yasin valley and elsewhere and belongs to the Late Cretaceous.

The region to the east will be also considered. Near the northern front of the Rimu glacier, DAINELLI and MARINELLI (1934) collected a Cretaceous *Exogyra* fauna contained in a hazel, bioclastic limestone grading into a very fine-grained sandstone; the fauna was studied by C. F. PARONA (1928 and 1932).

By studying the samples in the collections of the Geological Institute of the University of Florence I can add further information to the vague lithologic notes of DAINELLI and PARONA. A sample marked « 22 ag. Creta del Rimu N. Senoniano. Fronte N. del Ghiacciaio Rimu » is composed of light hazel tight limestone with chert and quartz small pebbles, quartz sandstone etc. very similar to the sample 54 PZ-63 collected in situ in the Savoia Limestone of the Baltoro glacier. Another sample marked « Rimu settentrionale 29-7-1914. (Creta sup.) » is also made of hazel limestone with fragmentary fossils. Finally, two more samples marked « N. 697. Rimu destra-passi 2150 » consist of light brownish limestone containing small pebbles of a darker limestone. These lithotypes are also present in the Savoia Limestone of Baltoro. It is possible that somewhere in the Shaksgam valley the above mentioned Cretaceous formations outcrop.

Limestones varying from light to dark brown, appearently similar to those from the Rimu, have been found in several places but at least in part they belong to the Shaksgam Formation. It must be added that the presence of Jurassic beds on the Bdongo-la and perhaps on the Marpo-la and the outcrop of Cretaceous beds in contact with the Jurassic ones at the northern front of the Rimu glacier, may suggest the hypothesis that a similar situation exist also in the Shaksgam valley. The question remains open since the field investigations on the Bdongo-la were not exhaustive and furthermore most of the samples from that locality were lost.

Assuming that the strike of the beds in the Rimu glacier outcrop (rather poorly indicated by DAINELLI) is northwest-southeast, their continuation towards the Shaksgam valley would cross the upper part of the valley, just to the west of the Shaksgam pass, near the Jurassic outcrops of the Lungpa Marpo glacier, that is in the Aghil area. Therefore it cannot be directly related to the Bdongo-la outcrop.

V. SUMMARY OF THE PALEOGEOGRAPHIC EVOLUTION OF THE EASTERN KARAKORUM.

The stratigraphy described in the previous sections suggest that the oldest sedimentary formation outcropping in the Shaksgam valley is the Singhié Shales belonging to the Carboniferous and at least partly to the Late Carboniferous. Therefore we cannot say anything on the conditions and on the paleogeographic events of our territory before that age.

The lithofacies of the early part of the Late Paleozoic is represented by black shales containing, inferiorly, arenaceous and locally also conglomeratic intercalations (especially towards the east in the Rimu and Siachen basins and south in the Baltoro one) and, superiorly, calcareous intercalations. These euxinic sediments lead us to suppose that during the Carboniferous in that area existed an oceanic basin situated south of the Eurasiatic continent, basin limited towards the open ocean by a ridge. The quartz and feldspar clasts of the sandstone interlayers indicate an approchment to the source region of those clasts and, according to NORIN (1976), this region was located in the southern area.

In conclusion, taking into account also the relatively great thickness of these deposits, the Singhié black shales together with the sediments of the Shaksgam Formation could represent a distal geosynclinal deposit of flysch type, in a subsiding basin with active sedimentation.

In time the rate of subsidence guadually decreased so much as to cause the progressive infilling of the sedimentary basin, but it is also possible that the movement was reversed, and an uplift of the sea-bottom replaced the subsidence. It is certain that in the Late Permian first a prevalently calcareous-marly facies and then a mainly calcareous facies with fusulines, brachiopods and corals took the place of the black shales. This calcareous facies indicates a warm neritic marine environment near to the continent, but with reefal episodes and characteristic sedimentary features varying both horizontally and vertically.

In the neighbouring regions, proceeding from north to south, the black shale facies becomes more and more prevalent until it represents most of the Permian like in the upper Siachen basin.

We should conclude that in the Permian our territory was located in the marginal part of a geosyncline extending many kilometres in a northwest-south-east direction. In fact, proceeding from south-west to north-east one passes from the prevailingly shaly-arenaceous black shale facies to the marly calcareous facies with arenaceous episodes (pelecypod sandstone) and to biohermal ones, represented by fusulinid and coral limestones.

From the above it can be deduced that during the Late Permian the geosynclinal phase (more developed to the south) ended in the Shaksgam area and the subsidence-movement was reversed becoming the uplift movement of the Hercynian orogeny most active to the north (North Pamirs and Tien Shan) and to the north-east (Kun Lun).

I want to remember here also the evidence of a volcanic activity testified by the sample of Late Permian arkose 29 KD-560, which contains clasts of devitrified lava (see p. 62 and 173).

The sills of volcanic rocks outcropping in the Shaksgam valley belong instead to a more recent volcanic activity.

The Late Permian was undoubtedly characterized by a considerable instability of the examined area as is demonstrated by the rapid changes from clastic formations — occasionally conglomeratic and arenaceous (greywacke type) — to various calcareous formations also of the reefal type.

The organogenic formations of Late Permian are overlain by cherty limestone of probable Triassic age and by a complex of siltites and green, reddish and black shales (Chikchi-ri beds) with volcanic episodes occurring in the basal layers. The upper layers are partly, or also totally, replaced by the Urdok Conglomerate.

The stratigraphic data on the Triassic series are scarce and overall uncertain for the lack of fossils. However considering DAINELLI's data on the eastern part of the studied area we can obtain, as we have mentioned in the stratigraphic part, some less uncertain documents.

The stratigraphic position of the Kyagar cherty limestone is not clearly defined and it is not clear what this limestone represents. According to most recent studies cherty limestones of the Kyagar type may be interpreted as pelagic sediments deposited at a depth of over 200 m (G. C. PAREA, 1970). It seems that at the beginning of the Triassic occurred a phase of rapid subsidence which was followed, however, by a new uplift of the sea-bottom with the spreading of reefs represented by massive, reddish dolomites of Middle Triassic age and perhaps also with partial emergences.

In the Late Triassic the small basins between the reefs and the continent were gradually filled with the clastic sediments of the Chikchi-ri shales till they became lagoons. To the east of the Shaksgam valley these beds include gypsiferous interlayers which confirm this interpretation.

This event occurred during the Carnian, as is indicated by the *Heterastridium* found just to the east of the Shaksgam-la (p. 75).

In the middle Shaksgam valley and especially in the Urdok one the lagoonal formation is partly replaced by a locally very thick calcareous conglomerate (Urdok Conglomerate) which must be interpreted as a deltaic formation, perhaps partly continental, which marks the end of the Carnian age.

The paleogeographic conditions throughout the Middle Triassic and the early part of the Late Triassic are characterized by a great variety of lateral changes in the sedimentary facies. This exactly represents the pattern of a continental shelf environment with scattered lagoons into which large rivers flowed.

At the beginning of the Norian a transgression occurred: a marine regime with clear waters and abundant calcareous dolomitic sedimentation, very analogous both in the lithofacies and in the biofacies to that of the « Hauptdolomit » — which characterizes the Norian of the Southern Alps — was established in the examined area. It is rather peculiar that such a formation should extend for thousands of kilometres keeping the same litho- and biostratigraphic characteristics.

The sea-bottom instability, which characterized the Carnian, swiftly reduced at the beginning of the Norian. The great thickness of the Norian Aghil Limestones is explained by a slow, steady uniform subsidence of the basin. This situation very probably continued throughout the Rhaetian and Liassic, while in the Middle and Late Jurassic the presence of a nearby landmass subjected to active degradation, is indicated by the clastic horizons and by the reddish colour in the rocks.

Up to now deposits of Cretaceous age seem to be missing in the Shaksgam valley, but they occur on the ridges bearing the watershed between this valley and the Baltoro basin.

As it is already known (p. 147) the Cretaceous deposits of Falchan Kangri and Baltoro Kangri show coarse clastic lithofacies indicating a phase of active erosion of a nearby landmass and the beginning of the Alpine orogeny.

There is no point in continuing to deal with this summary paleogeographic review since we would have to refer to stratigraphic documents concerning areas too far away from the one considered here.

VI. TECTONIC OUTLINE.

1. Introduction.

As mentioned in the Introduction to this work, the Shaksgam valley has a general orientation almost parallel to che tectonic axes (fig. 38) and therefore to someone who, like me, rapidly travelled only along its thalweg, it was very difficult to understand its structure.

It can be added that the tectonic elements of the Shaksgam valley are represented mainly by folds and faults, but there are also clues, even if less evident, of rather important overthrusts like near the Aghil pass and in the Skyang Kangri and Falchan Kangri ranges. Other smaller displacements are located at the contact between the plastic and rigid formations which reacted in different ways to the orogenic stress. An example is represented by argillitic rocks (referred to the Late Carboniferous and to the Early Permian and some of them to the Middle Triassic) compared to the calcareous-dolomitic rocks of the Late Triassic and some calcareous horizons of the Late Permian.

The major tectonic disturbances are located in the western part of the studied area, between the zone of the mainly igneous and metamorphic rocks and the zone of the mainly sedimentary rocks.

Such a contact is particularly well exposed near the front of the Sarpo Laggo glacier where an important dislocation called *Sarpo Laggo Fault* crosses the valley in a NNW-SSE direction.

2. Field Observations.

Tectonic data were reported in the descriptive sections of the studied area. Now I will try to summarize and coordinate them as far as possible (see the cross-sections fig. 39-43).

The Sarpo Laggo Fault will be considered first. On account of its direc-

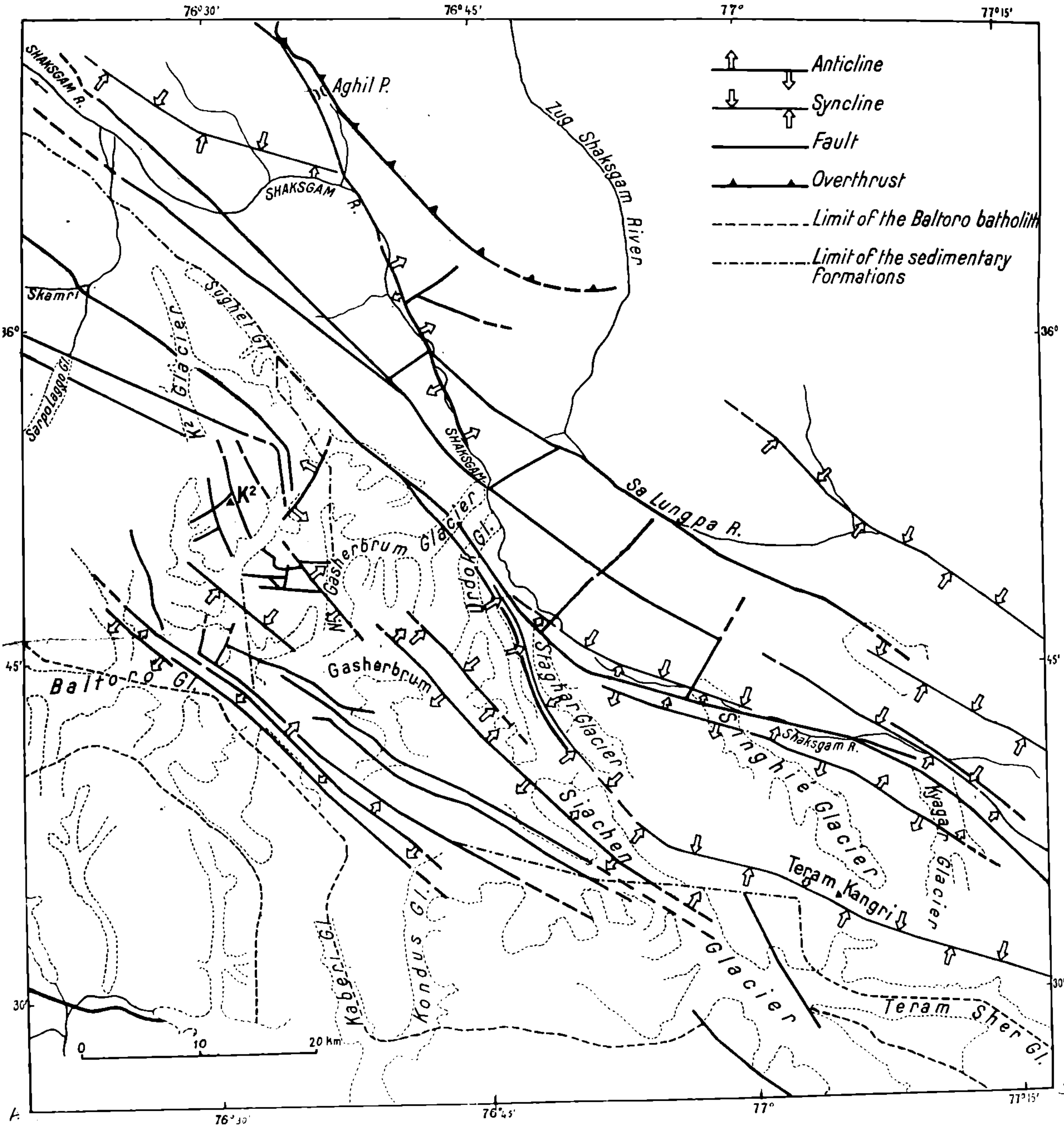

Fig. 38 – *Tectonic sketch-map of the Shaksgam and the surrounding valleys.*

tion it can be assumed that towards the east, probably it crosses the Skyang Kangri ridge to the west of the summit (7544 m); here at least three vertical faults are present. The middle fault is flanked by a layer of red rock, apparently schistose, separating two limestone levels; the lower one is interpreted as Permian limestone of the Shaksgam Formation; the other as Aghil Limestone (DESIO & ZANETTIN, 1970). Near the front of the Sarpo Laggo glacier it seems that there is a similar succession, but instead of the red rock there is a multicoloured conglomerate comparable to the Urdok Conglomerate. This replacement, as we know, is rather common in the stratigraphic sequence of the Shaksgam valley.

To the south-west of the lower limestone outcrop, the ridge heading towards the K^2 is composed of black slates and then of Falchan Gneiss: to the east of the upper limestone outcrop the Falchan Gneiss is also present and is crossed by a vertical fault and by a horizontal thrust (op. cit. fig. 45).

J. B. AUDEN, while examining in 1938 part of the K^2 Glacier valley did not record the Sarpo Laggo Fault: nevertheless, he mentioned that «numerous boulders of limestone-conglomerate, some of them limestone-breccia, were found on the east side of the K^2 glacier, but none was seen *in situ*» (1). Evidently an outcrop of this rock exists upstream from the boulders, that is in the upper K^2 Glacier valley. If we now imagine to connect by a line the conglomerate of the Sarpo Laggo glacier snout with the red rocks of the Skyang Kangri, that line would cross the upper valley of the K^2 glacier. And if we extend this line toward north-west it would meet the conglomerate outcrop of the Skamri glacier valley. This ascertainment seems to confirm a certain continuity of the outcrops of red conglomerate and slates from the Skamri valley to the Skyang Kangri marking the trace of the Sarpo Laggo Fault.

Moreover AUDEN recorded « five wedges of marble interbedded with purple shale » on the western side of the K^2 Glacier valley (2) (fig. 39). One of these wedges stretched in a NW-SE direction seems to reach the northern buttress of K^2 and probably lies on the northern extension of one of the faults crossing the mountain in a north-south direction, but not, however, along the one located just below the top in contact with a wedge of marble. AUDEN did not report the presence of this fault and the others nearby — all of them orientated approximatively north-south (DESIO & ZANETTIN 1970) — in the K^2 glacier valley but this may be explained by the extensive ice cover hiding them. We can suppose that the wedges of marble outcropping on the northern slope of

(1) Drawn from AUDEN's letters.
(1) Drawn from AUDEN's letters.

K² represent mainly slivers of limestone involved in the various faults similar to the one occurring near the top of the peak. It must also be remembered that large blocks of limestone embedded in the K² Gneiss were observed also on the north-western foot of the Falchan Kangri (DESIO & ZANETTIN 1970, fig. 9) where they form a cyclopic fault-breccia.

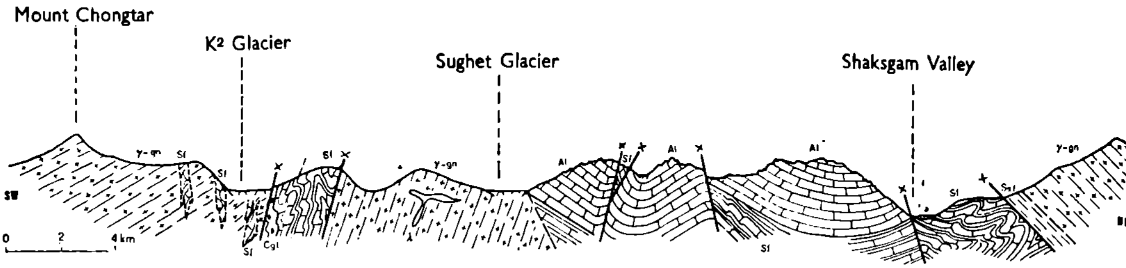

Fig. 39 – *Geologic section across the K² Valley and the lower Shaksgam Valley.* From an original drawing of J. B. AUDEN slightly modified by DESIO.
Al Aghil Limestone; Cgl conglomerate and shales; Sf Shaksgam Formation; γ-gn granite and gneiss; λ lamprophyre; a alluvial deposits; x fault.

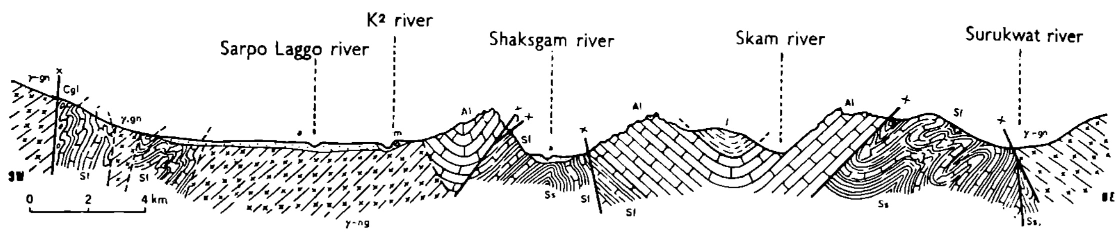

Fig. 40 – *Geologic section across the Shaksgam and the Skam valleys.* From an original drawing of J. B. AUDEN slightly modified by DESIO.
J Bdongo formation; AL Aghil Limestone; Cgl conglomerate; Sf Shaksgam Formation; Ss Sarpo Laggo Slates; γ-gn granite gneiss; m moraines; a alluvial deposits; x fault.

Three main tectonic elements are recognizable near the confluence of the Sarpo Laggo and Shaksgam valleys. One is a fault running along the right hand side of the valley, downstream from the isolated spur of Tek-ri; the other is an anticline following for a short while the Shaksgam thalweg. The fault marks the contact between the thinly-bedded dark limestone, probably of Permian age, and the red slates which seem to be at the base of the Aghil calcareous series (fig. 8). I was not able to follow the fault upstream since it disappears probably under the gravelly bed of the Shaksgam river. The fault strikes NW-SE.

Near the bottom of the valley on the left hand side the beds dip steeply towards south-west while 7 or 8 km upstream they dip in the opposite direction; therefore they seem to outline an anticline which continues for some kilometres upstream. The third important tectonic element is represented by the Bdongo-la faulted syncline which has a Jurassic core (fig. 10). A similar structure marked by red slates is visible in a small saddle above the cairn of Gasherbrum Jilga (fig. 19). This small saddle should correspond to the named Marpo-la (1) on Sheet N°. 51 D map of the Survey of Pakistan.

The affinity of the geologic structure of both these localities might suggest that they are located along the same tectonic line striking NW-SE. We do not have any precise information, however, on the geology of the mountainous region between the two saddles.

These mountains rise to the south of a bend in the Shaksgam valley between Durbin Jangal and the confluence with the Sarpo Laggo.

Proceeding upstream the Shaksgam valley bends towards NE and gets away from the two tectonic lines, whose continuation may be found near the Gasherbrum glacier end.

The valley bend begins about 10 km from the confluence with the Sarpo Laggo. From this point on, for about 12 km, the dip of the beds (Aghil Limestone) becomes more gentle. The low inclination produces the typical Dolomite morphology such as that present in the mountains between the Skam and the Aghil valleys. Between these two valleys the beds form a wide syncline, the northern limb showing in the Skam valley the beds underlying the Aghil Limestones, as shown in figs. 14 and 40.

AUDEN'S geological map supplies more certain tectonic elements on the Skam valley (fig.4). This valley, in fact, transversely cuts the Jurassic core of a wide syncline, the axis of which strikes WNW-ESE and dips towards SE. Further to the east the syncline is crossed by a diagonal fault following the adjacent Aghil valley (*Aghil-la Fault*) and probably continuing along the Shaksgam thalweg. Just east of this fault, according to AUDEN, there is the edge of a mass of « granite » overthrust on the beds of the Shaksgam Formation.

In the upper part of the Skam Lungpa there is an anticline visible from the mouth of the valley, probably running parallel towards SW, to the previously mentioned syncline (fig. 17 B). However, we may assume that here the tectonics is more complex than what would first appear and this could be confirmed by the presence of recumbent folds (figs. 16 and 17 A) further to the east, above Marpo Cholong. The disarrangement of the calcareous-shaly beds between the Skam Lungpa and Bya Lungpa valleys — visible also from the Shaksgam valley — is probably related to the above mentioned overthrust edge.

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(1) Meaning: Red Saddle.

Further upstream as far as the Gasherbrum glacier the Shaksgam valley seems to have developed in the core of an anticline composed of the calcareous shaly beds of the Shaksgam Formation. The limbs of the anticline are made of the Aghil Limestone which forms all the high ridges flanking the valley.

However, although the tectonic features of this part of the valley seem to be relatively simple, the detailed structure is very complicated. For instance, near the mouth of the Bya Lungma a fault plane cuts the Aghil Limestone beds, trends transversely to the fold axes (fig. 18) and produces the lowering of the Aghil Limestone block in comparison with the beds of the Shaksgam Formation. A similar transverse tectonic displacement occurs also near the front of the Gasherbrum glacier on the right hand slope of the Shaksgam valley, where a mass of Aghil Limestone abutts against the Shaksgam Formation beds.

The major tectonic complications of this part of the Shaksgam valley occur, however, in the area between the Karakorum ridge, from K^2 to Gasherbrum I, and the Shaksgam river, that is the western side of the valley. On this slope there is the contact between the Baltoro metamorphic suite and the Aghil sedimentary sequence (fig. 41).

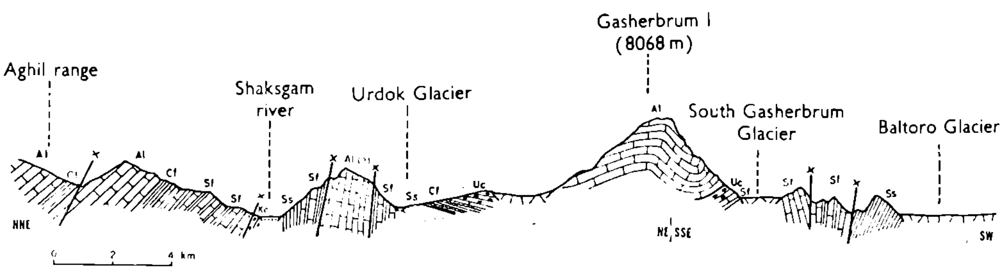

Fig. 41 – *Geologic section across the middle Shaksgam Valley from the Aghil range as far as the upper Baltoro Glacier.*

AL Aghil Limestone; Uc Urdok cônglomerate; Cf Chikchi-ri formation(?); Sf Shaksgam Formation; Ss Singhié Shales; x fault.

It is very difficult to coordinate the poor geologic data collected at random without any detailed geologic mapping and, above all, without a good topographic base in an area covered by an exceptionally extensive ice blanket (1).

The structure of the Karakorum range between K^2 and Gasherbrum I which has already been described by DESIO in the Baltoro valley (DESIO & ZANETTIN 1970), is very complex and shows clear overthrusts mainly in the

(1) I like to mention here that the first topographic map of this part of the valley was surveyed by myself at the same time of the geologic investigation.

Falchan Kangri group (idem figs. 12, 17, 45). Between the K^2 and Falchan Kangri-Gasherbrum ridges there is a torsion of the tectonic axes the direction of which change from N-S on K^2 and Skyang Kangri, to NW-SE. The hinge line occurs in the Falchan Kangri group.

The eastern structures of the Baltoro area are the anticline of Gasherbrum I running parallel to the structures in the upper Gasherbrum and Urdok valleys and the anticline in the upper valley of the Godwin Austen glacier. The latter strikes, however, NNE-SSW and therefore is not to be found in the Shaksgam valley.

The Gasherbrum I anticline, together with the one crossing the eastern slopes of the Falchan Kangri, both with a NW-SE axial trend, are instead part of the Shaksgam valley folded system even though marginally.

The Gasherbrum I anticline continues towards south-east and probably reaches the valley of the Siachen glacier near the Indira-la; then it disappears under the ice body. The syncline which follows towards north-east crosses in a NW-SE direction the upper part of the Gasherbrum and Urdok valleys.

Between this syncline and the Shaksgam river there is an isoclinal structure with incomplete folds accompanied by faults which affect mainly the beds of the Shaksgam Formation, but also those overlying ones. From a short distance it seems that this is the structure of the ridges dividing the middle and lower valleys of the Gasherbrum and Urdok glaciers (figs. 25 and 28).

The southern continuation of this bundle of incomplete folds and faults trending NW-SE, affects also, but longitudinally, the high ridge separating the Urdok and Shaksgam valleys. Very little is known on the structure and composition (prevalently calcareous) of this ridge. It is not known whether these calcareous masses, apparently belonging to the Aghil Limestone, near the Indira-la or Turkestan-la, join the large calcareous masses of the high mountain range culminating in the Teram Kangri and rising between the Shaksgam and the Siachen valleys, or whether they form an indipendent tectonic unit.

In this connection we must take into account that the high ridge of Singhié Kangri-Teram Kangri-Apsarasas range is composed mainly of a very wide syncline (fig. 43) having its axis orientated WNW-ESE, while the ridge separating the Urdok and Shaksgam valleys consists of almost vertical calcareous beds trending NW-SE and faulted on both sides. Beyond the faults outcrop the beds of the Shaksgam Formation (fig. 28).

Assuming that there is a similarity in the geologic composition of the opposite sides of the range dividing the Urdok and the Shaksgam valleys the structure of the range could be interpreted as a syncline.

This syncline is tightly folded and is located on the north-western extension of the syncline forming the Singhié Kangri-Teram Kangri-Apsarasas range. In this case near Indira-la there must be a slight torsion of the tectonic axes which change their direction from NW-SE to WNW-ESE (fig. 38).

To the east of the Staghar glacier the tectonics is more stretched. The bottom of the valley coincides with the faulted core of a syncline flanking the anticline with Carboniferous core (Singhié Shales) running on the southern side of the valley. The high calcareous ridge of the Singhié Kangri-Teram Kangri-Apsarasas range forms the southern limb of this anticline and the northern limb of the successive syncline (figs. 42-43).

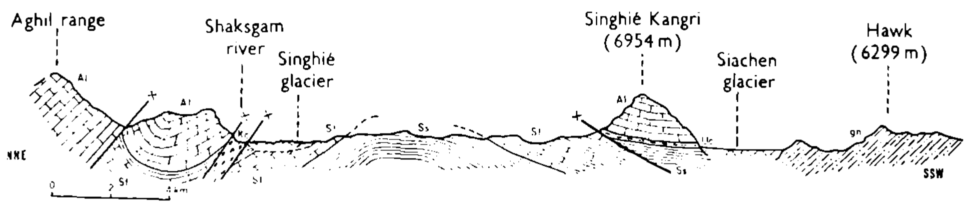

Fig. 42 – *Geologic section across the upper Shaksgam and the upper Siachen valleys.*
Al Aghil Limestone; Uc Urdok conglomerate; Kc Kyagar cherty limestone; Sf Shaksgam Formation; Ss Singhié Shales; gn gneiss; γ granite; x fault.

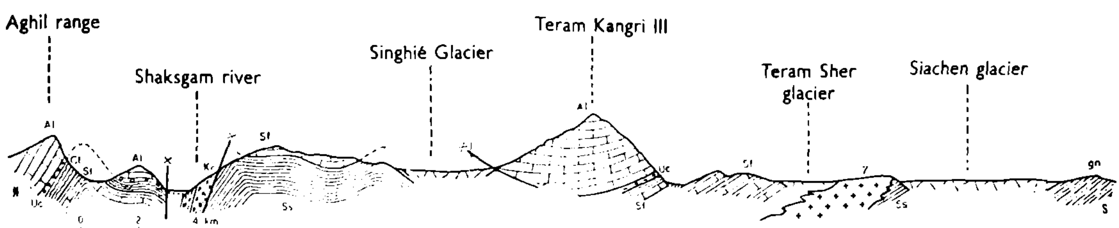

Fig. 43 – *Geologic section across the upper Shaksgam Valley, the Teram Sher, and the middle Siachen glacier valleys.*
AL Aghil Limestone; Cf Chikchi-ri Shales; Cg conglomerate; Kc Kyagar cherty limestone; Sf Shaksgam Formation; Ss Singhié Shales; gn gneiss; γ granite; x fault.

On the opposite side of the Shaksgam valley, that is on the southern slope of the Aghil range, towards north, a sequence of monoclinal beds follows the Triassic core of the fold. These beds underlying the Aghil Limestone are partly Permian and perhaps in larger part Triassic. It is not clear whether these beds represent a continuous sequence or beds repeated by folds and faults. The second interpretation appears to be the more suitable (fig. 41).

With these longitudinal structures there are also transverse faults similar to what occur further downstream. One of these faults cuts the Permian beds near the Staghar glacier front where they are in contact laterally with the Aghil Limestone. A similar situation occurs near the Singhié glacier front.

These transverse faults seem to limit rather rigid blocks of Aghil Limestone, which, overlying relatively plastic rocks such as the Chikchi-ri and Shaksgam formations, were fractured, detached from the underlying beds and displaced in an abnormal position during the orogenic movements.

The principal tectonic elements recognized in the Shaksgam valley are shown in fig. 38 and in the cross-sections figs. 38-43. It must be emphazised, however, that the tectonic structure of the Shaksgam valley could be more complex than what may result from the few data reported here.

3. Relationship between the Tectonics of the Shaksgam Valley and the one of the Eastern Neighbouring Region.

At this point it may be useful to try and find some relationships between the tectonic units described for the Shaksgam valley and those of the area to the east, that is upstream from the Kyagar glacier and in the Rimu basin. Our knowledge of this area is no better than the one on the Shaksgam, nevertheless I will try to coordinate the known data with those collected by me, since this may be useful also for a check of the deductions concerning both areas.

This attempt cannot be extended to the area located in the opposite direction, that is to the north-west, because we have even less geologic data on it.

According to DAINELLI's observations (1934, p. 429) near the northern front of the Rimu glacier there is a faulted syncline trending NW-SE with a core of Jurassic-Cretaceous rocks.

Supposing that such a fault continues towards north-west, it would enter the upper Shaksgam valley about 3 km to the south of the Shaksgam-la, then it would pass under the front of the Kyagar glacier and finally enter the small Marpo-chu valley, separating the Chikchi-ri and Marpo Rgyang ridges. Red rock, probably representing the same Jurassic horizon of the North Rimu glacier front, outcrop in that small valley.

If we climb this glacier following DAINELLI's stratigraphy, first we find a sequence of cherty limestone beds, then an outcrop of Permian marly rocks and then Triassic limestones which may correspond to the Aghil Limestone. It seems, therefore, that this is an anticline with a Permian core. A similar sequence was noted in the Shaksgam valley near the Kyagar glacier snout

(p. 70). Here, too, in fact we observed an anticline with a Singhié Shales core, a northern limb composed of faulted Triassic cherty limestones with a southern one formed by Aghil Limestone of the Apsarasas range.

According to DAINELLI's description (1933, p. 429), proceeding further to the south along the North Rimu glacier there is an outcrop of the Shaksgam Formation (Permian) which should represent the core of another anticline. One of the limbs of it may be made of the Triassic limestones extending to the south in the ridge dividing the North Rimu and Central Rimu glacier. This ridge seems to join the Aghil Limestone of the Apsarasas which should represent the continuation of the syncline of that mountain. In this case the broad anticline with a Carboniferous core of the lower Kyagar and Singhié glacier valleys includes the two anticlines plunging northwards in the upper North Rimu glacier (figs. 38 and. 43).

These interpretations agree with the small scale maps by DAINELLI (1934) and NORIN (1946).

The bundle of folds following one another to the north of the syncline with a Cretaceous core at the front of the North Rimu glacier (upper valley of the Yarkand river) includes anticlinal folds with Permian cores trending SE-NW or ESE-WNW. This folds lie outside the Shaksgam valley: supposing to extend these folds towards west, they would enter the Aghil region to the north of the ridges overlooking the Shaksgam valley, as illustrated in fig. 38.

4. Some Comments on the Regional Tectonics.

The scarce available data on the tectonics of the Shaksgam valley and the lack of geologic information on the adjacent regions, above all the areas to the north and to the west, do not allow us to reach a suitable synthesis. Only some comments and summary conclusions will be made here.

The tectonics of the Shaksgam valley is characterised by a bundle of folds partly faulted, locally overthrust, and generally trending NW-SE, with some small deviations. This fold-bundle becomes progressively wider towards south-east and north-east that is both along the strike of the tectonic axes (upper Shayok valley and Depsang Plateau) and towards the north (Aghil Plateau). In the opposite direction the folds become progressively squeezed and faulted evidencing that in that direction the compressional tectonic stresses were greater; along the same trend there is a rapid passage to metamorphic facies (DESIO & ZANETTIN, 1970). In fact, in the eastern part of the Baltoro basin the formation of the Shaksgam valley, such as the Singhié Shales and the limestones and shales of the Shaksgam Formation, become black slates or even gneiss (Falchan Gneiss, K^2 Gneiss) while the limestone becomes marble sometimes with recognizable fossil remains (1).

In this connection it should be added that, along the same trend, the Karakorum axial batholith outcrops more extensively affecting the tectonic structure of the region.

Apart from the local tectonic disruptions depending on the different competence of the formations, there are clues of overthrusts, the magnitude and importance of which in the structural setting of the region is, however, difficult to evaluate. Three examples can be given here: one mentioned by AUDEN in the neighbourhood of Aghil pass, another on the Skyang Kangri and a third in the Falchan Kangri group. The latter two were recognized only on the Baltoro side (DESIO & ZANETTIN, 1970).

In the Aghil range, according to AUDEN, there is the edge of a « granite » nappe over the unmetamorphosed sedimentary Permian formations along a line which, near the Aghil pass, trends NW-SE and therefore is approximately parallel to the tectonic axes of the Shaksgam valley (2). The extent of this overthrust is unknown, but probably it is not very long at least towards the east, since no traces are known in the upper Yarkand valley and along the trail crossing the Karakorum pass which is better known geologically (STOLICZKA, DE TERRA, DAINELLI, NORIN, etc.).

The limited extent of the overthrust towards south-east is possibly related to the presence there of a rigid basement outlier represented by the granite gneiss massif of K^2, which either represented an obstacle to the advance of the thrust sheet from the north, or belonged to a plate of the earth crust, which, moving towards north, produced the same effect.

Other two overthrusts occur in Skyang Kangri and Falchan Kangri. Both are, however, difficult to interpret since the first is located close to the hinge point of the tectonic axes and the other just on it. These axes, which on K^2 trend north-south, becomes NW-SE oriented and this torsion could have been an important factor in the tectonic setting of that area.

But, bearing in mind that in the Falchan Kangri — where the overthrust

(1) About the origin of the metamorphic facies see DESIO & ZANETTIN (1970).

(2) More precisely AUDEN writes: « I was under the impression that the granite may have been thrust over the sedimentaries in a partially solidified state ».

is better exposed (DESIO & ZANETTIN 1970 pags. 22 and following) — a thick complex of sedimentary rocks, underlain by a calcareous horizon of the Shaksgam formation, covers the layers of coeval metamorphic rocks (Falchan Gneiss), we infer that the beds of the sedimentary rocks probably come from the Aghil zone where these rocks are spread. The presence within that complex of more recent sedimentary formations, like the Cretaceous Savoia Limestone and the Khalkhal Sandstone, could confirm this hypothesis, for in the Aghil area Cretaceous beds presumably initially covered the Jurassic beds before being destroyed by the erosion. However I should not be surprised if in the western Aghil, perhaps to the north of the better known area, there should be Cretaceous beds, analogously to the eastern area (North Rimu glacier front). Furthermore their presence in the Falchan Kangri, where also Jurassic beds are present (DESIO & ZANETTIN 1970, p. 51), can be explained by the great altitude of this mountain group.

With reference to what I said on the effect of the torsion of the tectonic axes, I want to add that the torsion seems to be posterior to the overthrust and also to the main tectonic setting.

The emplacement of the Karakorum axial batholith strongly modified the pre-existing structures (DESIO & ZANETTIN 1970). If we examine, in fact, the tectonic sections crossing the whole Karakorum range, as far as the Hindu Kush (DESIO 1979), it may be easily remarked that the vergence of the beds have opposite directions on the two sides of the axial batholith. This demonstrates the influence that the emplacement of the batholith exerted over the regional tectonics (DESIO & MARUSSI 1960).

The first tectonic phase, which involved the Aghil range and the Shaksgam area is connected with the drift of the Pamirs block (Desio 1979). This block was shifted towards north of at least 100 km along the Pamir-Karakorum transcurrent fault and the Aghil tectonic zone endowed with close stratigraphic affinities both with the South-east and with the Central Pamirs, were separated and displaced one from the other by the interruption of the original continuity of their rock bodies (Desio 1976).

I will not enlarge further this comment on account of the small extent of the Shaksgam area which represents only one part of the Aghil and Muztagh tectonic zones. In order to obtain more information on Central Asia tectonics the above quoted works may be consulted.

VII. TRACES OF PLEISTOCENE GLACIATIONS IN THE SHAKSGAM VALLEY

As already known (MASON 1926 and 1935, DESIO 1930 and 1936) the Shaksgam valley is dammed, but not always completely, by five glacier tongues descending from the upper ridges of the Eastern Karakorum. As a result of this exceptional situation the valley, besides being subjected to the normal fluvial erosion due to the melting water of the glaciers, is also occasionally subjected to terribly strong floods caused by the rapid emptying of the temporary lakes forming upstream from the ice dams. Thus the valley is completely cleaned by the waters which tend to wash away the previous fluvio-glacial deposits and the ones about to form. All the alluvial fans have cut off fringes and most of them are reduced to fragments abutting against the valley slopes (pl. X). In spite of this unfavourable situation remnants of old moraines and polished rocks are occasionally preserved along the bottom and on the slopes of the valley.

Glacial deposits form terraces on both sides of the lower Sarpo Laggo valley, about 160 m above the thalweg, and are to be correlated to the high terrace prolonging the confluence spur of the Sarpo Laggo and Skamri valleys.

The isolated Tek-ri hillok rising 160 m above that confluence is strewn with glacial drift extending almost to the top (3730 m a. s.l.) where some erratics can be found (pl. IX fig. 2). The « roches moutonnées » on the calcareous slopes of this glacial threshold evidence that once the hill was completely covered by ice.

Another glacial deposit is heaped on the confluence spur Shaksgam-Sarpo Laggo. It seems that originally the two deposits formed a single barrier between the Tek-ri hillok and the confluence. Such a barrier would have obliged the river to turn northwards and cut a channel in the right side of the valley.

We may assume that the first emplacement of the channel remount to the time when the Shaksgam valley was dammed by a huge ice stream fed by four glaciers, that is the Skamri and Sarpo Laggo glaciers on the left hand side, and the K² and Sughet glaciers on the right hand side. The left moraine of these glaciers was part of the right lateral moraine of the Skamri and Sarpo Laggo glaciers. At that stage the Shaksgam valley upstream from the Tek-ri probably had no ice since the first large glacier now lying upstream, that is the Gasherbrum glacier, is almost 50 km distant from the above mentioned moraine, while the Skamri and Sarpo Laggo glaciers are about 19 km away. Instead of ice the valley was filled for a certain time with the waters of a lake having its outflow over the moraine between the Tek-ri hillock and the left slope of the valley. The outflow excavated its channel into the moraine and when it reached the botton hollowed its channel into the bedrock.

The remnants of thick gravel deposits, rich in silt, which are spread at the foot of the walls along the gorge, seem rather to represent an old deltaic deposit than a simple alluvial fan. The recent alluvial fans are often intrenched into the channels excavated by the lateral streams in the old deltaic fans.

However, if at this stage the thickness of the ice near the Shaksgam-Sarpo Laggo confluence reached and probably exceeded 156 m, during a previous stage the glacial surface should have been much higher.

The rocky pyramid overlooking the Bdongo-la towards the Shaksgam-Sarpo Laggo confluence has been intensely smoothed and rounded by the glaciers (fig. 9), and therefore we may assume that the glaciers overflowed the Bdongo-la (4359 m). The ice surface was therefore 620 m above the present thalweg and perhaps reached the top of the peak overhanging the Bdongo-la.

The presence of drift or erratics on the Bdongo-la was not particularly investigated, but they very probably exist. The Shaksgam glacier reached this height before the moraines were deposited on the Tek-ri and the change in the river course occurred.

Near Bdongo-la and not far from the K^2 glacier valley mouth there is a large moraine overlooking Sughet Jangal, whose top is 366 m above the valley floor.

It was not possible to establish whether this moraine was deposited during a halt in the joint ice flow of the K^2 and Sughet glaciers or represents a lateral moraine of the Sarpo Laggo glacier which dammed the K^2 glacier valley. It is not clear which hypothesis is more suitable since both basins have similar geologic composition and carried similar till.

However when the Shaksgam glacier overflowed the Bdongo-la, the Sarpo Laggo glacier must have been extended at least 600 m above the valley floor and therefore the moraine damming the K^2 glacier valley must have been formed not only by the material carried by the former glacier, but also by that of the latter one.

At the present stage of our knowledge we may assume that in the area of the Shaksgam-Sarpo Laggo confluence there are traces at least of two different glacier expansions. The first and greatest, during which the ice filled the valley up to 600 m above the present thalweg and the more recent one during which the ice reached only 160 m.

The Shaksgam valley upstream from the confluence with the Sarpo Laggo is narrow and up to the Gasherbrum glacier dam, contains few remnants of glacial deposits. One of them, rich in boulder-clay and striated pebbles, outcrops from the alluvial fan of Marpo Cholong, between Qulan Jilga and Durbin Jangal. This deposit rises up to 150 m above the present thalweg.

Another similar deposit reaching about 100 m above the thalweg occur near Durbin Jangal. Probably similar deposits exist also downstream under the old alluvial and deltaic fans deeply eroded by the river.

All the large rocks emerging from the river bed, both upstream and downstream from the Gasherbrum glacier, show obvious signs of powerful glacial erosion and up against these, there are occasional remnants of old till like near the Urdok glacier front (pl. XXIV).

On the Gasherbrum-Urdok saddle (4715 m) I found numerous erratics and also small till deposits. Evidently the saddle between the Gasherbrum and Urdok valleys was overflowed by the old glacier. The overhanging peak shows the summit (4883 m) smoothed by ice and the long ridge dividing the glacier tongues shows signs of glacial erosion. In this area evident glacial forms are to see up to 5000 m a.s.l., that is not less than 500 m above the glacier snout.

Upstream from the Gasherbrum glacier only the above mentioned glacial deposits were observed, but it cannot be discarded that there are others.

The sand and lacustrine deposits spread upstream from the Singhié and Kyagar glacier snouts, as mentioned in the Introduction (p. 12) testify that the lakes produced by the damming glaciers persisted for a relatively long time.

It is not possible to date the above mentioned glacial deposits. It is certain that during the major Quaternary glaciations the whole Upper Shaksgam valley was filled by a large glacier fed by its five major tributaries descending from higest ridges of the Karakorum range.

But the valley must have been filled by ice also further downstream from the Sarpo Laggo confluence. The question which may arise is how far the end of the ice flow was.

I never visited the Shaksgam valley downstream from that confluence and I do not know any work dealing with Quaternary glaciers in that section of the valley. In this connection I will only refer to an assumption of H. von Wissmann

(1960), who writes (p. 1350): « Probably during the last glaciation the Shaksgam glacier advanced as far as the bend of Sokh Bulag (2944 m) and therefore it was 220 km in length. In this case during the last glaciation the Shaksgam glacier was certainly the longest and the greatest glacier of high Asia (1) ». I do not know on what elements WISSMANN established the position of the Shaksgam glacier end; probably it was based on speculative extrapolations, because as far as I know there are no data about the presence of end moraines at Sokh Bulaq. If we accept WISSMANN's views, however, we must assume that when the glacier reached such an extension the height of the ice at the confluence of the Sarpo Laggo glacier was at least 600 m above the valley floor, as the height of 160 m really appears too low for an ice stream still 76 km far from its end. In the first case the average slope ratio of the ice surface downstream from the Sarpo Laggo confluence should have been 8 ‰, while in the first case only 2 ‰, that is too little for a so long ice stream.

If, in agreement with WISSMANN's assumption, the maximum extension of the glacier is referred to the last glaciation (Würm in the Alps) the reduced glacier extension, that is when the ice surface at the Sarpo Laggo confluence was only 160 m above the thalweg, should be referable to one of the Postglacial stages.

But another interpretation can be advanced. The maximum expansion may be referred to the penultimate glaciation (Riss in the Alps) and the smaller one to the last glaciation. For verifying which of the two hypotheses is the more suitable it is necessary to determine the altitude of the snow line corresponding to the two situations, and to compare them with the present snow line.

The question is a difficult one for, if it is relatively easy to calculate the hight of the present snow line, it is not the same for Quaternary glaciers. I calculated the altitude of the present snow line for the southern side, only, of the Shaksgam valley, since the data for the opposite side are lacking. The elevation is 5660 m (DESIO 1936) without accounting for the Sarpo Laggo and Skamri glaciers. These two glaciers being directed west-east are in better conditions for supplying suitable data. The altitude of the snow line determined for the two glaciers is 5366 m.

Now we will calculate the altitude of the snow line for the two Quaternary

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(1) Sokh Bulaq (not Bulag) is a locality placed near the confluence of the Oprang river and its altitude above the sea level must be higher than 2944 m. According to the maps of the Survey of India, the altitude of the confluence of the Shaksgam and the Yarkand rivers near Toquz Bulaq, viz. 40 km downstream, is 3017 m and therefore the elevation of Sokh Bulaq must be higher. The total length of the glacier was not 220 km, but approximatively 205.

glaciers. If we try to apply the H. von Hofer method (1) assuming the elevation of 3000 m at the end of the Shaksgam glacier and 6700 m as the average altitude of the catchment area ridges, we obtain an altitude of 4850 m, that is 500 m lower than the present one.

In the Alps this value is assigned to the Postglacial stages and not to the main glaciations, but the climatic, orographic and also orogenic situation of the Alps is different from that of Karakorum. If the Shaksgam glacier flowed down as far as Sokh Bulaq, that happened during the greatest glaciation. It is a debatable question whether the glaciation was the last or the preceding one.

I faced a similar problem in a still unpublished report on the Quaternary Indus glacier. In the Indus valley the greatest expansion of the Quaternary glaciers do not coincide with the last (4th) glaciation, but with the 3rd or perhaps the 2nd one. Since the glacier variations are caused by climatic oscillations, the variations ascertained in the Indus glacier can be extended to the Shaksgam glacier.

(1) See: A. Desio, *The Glaciers of the Ortles-Cevedale Mountain Group, Central Alps*. Consiglio Nazionale delle Ricerche-Commissione incaricata di coordinare la partecipazione italiana al Decennio Idrologico Internazionale. Pubbl. n. 6, Roma 1973, p. 44.

VIII. DESCRIPTION OF THE ROCK SPECIMENS

1. Volcanic Rocks

29 KD-V 40 – *Propylitised dacite*; Saddle Shaksgam-Sarpo Laggo (= Bdon-go-la), 6.7.29.

The rock is green-grey in colour and has a porphyritic texture: the phenocrysts, sialic and femic, are about 1 mm in size.

Despite the considerable degree of weathering and the almost complete substitution of the original minerals with others of secondary origin, the rock-texture is still easily recognizable. Phenocrysts are common and consist mainly of plagioclase, completely or almost completely altered to light-coloured mica. The original feldspar, belonging to the oligoclase-andesine type, is present as remnants within some of the crystals: it has more frequently been replaced by very clear neogenic albite. Rare, corroded quartz phenocrysts are also present. The femic phenocrists are uncommon and are so severely altered that they cannot often be recognized even from their morphology; remnants of monoclinic pyroxene and hornblende are rare and most frequently the femic phenocrysts consist of aggregates of different proportions of chlorite, epidote and calcite.

The very fine-grained groundmass is holocrystalline and contains abundant chlorite, diffused as laths, together with epidote and calcite. The latter is microcrystalline or sparry and its irregular distribution creates a certain inhomogeneous composition. Where the groundmass is more strongly recrystallized, its sialic components are represented by quartz and feldspar.

Accessory minerals are: ilmenite, apatite and zircon.

29 KD-195. – *Basic, altered dacite*; left hand side moraine of the Gasherbrum Glacier (Shaksgam Valley), 3.7.29. (Pl. XXXV fig. 1).

(1) By P. Spadea Roda.

The rock is spotted and brown-reddish to green in colour; despite the severity of alteration it still retains a porphyritic texture. The commonest phenocrysts are plagioclase of varied size, not exceeding 1 mm which have been completely altered to light-coloured micas. They generally occur associated with quartz and chlorite. Femic phenocrysts are also present in subordinate numbers; most are severely altered but among them some laths of biotite can still be recognized. The most abundant crystals consist of a skeleton of hematite filled with quartz, calcite and, occasionally, some rutile needles. Their shape suggests that they derived from a pyroxene, some typical basal sections of which are still visible. Quartz phenocrysts are the rarest and appear to be deeply corroded; occasionally they include small prisms of plagioclase or show authigenic rims at the edges of phenocrysts of the same mineral.

The groundmass is very fine-grained, and consists mainly of quartz-feldspar-sericite with numerous finely scattered grains of carbonate and iron oxides.

Accessory minerals are: magnetite, partly altered to hematite, ilmenite, apatite and zircon.

I want to add to the rocks mentioned above some rocks summarily described by P. COMUCCI (1938) who examined the samples collected by DESIO in 1929. I translate literally in English the original names given to the rocks by the author.

29 KD-195′. – *Quartz porphyry* [= rhyolite]: Left floating moraine of the Gasherbrum glacier.

29 KD-70. – *Weathered quartz porphyrite* [= porphyritic dacite]: Oprang-Sarpo Laggo saddle (= Bdongo-la)

2. Parametamorphic Rocks

29 KD-231. – *Epidosite.* Few kilometres downstream from the Kyagar glacier front.

29PD-506. *Amphibolic arenaceous carbonaceous fossiliferous calcschist. Light metamorphic rock wiht briozoa of the genus Fenestella.* Floating moraine coming from the south foot of the Skamri range near the junction of the Drenmang glacier (Panmah Valley). (Pl. XXXV fig. 4).

The rock is grey-black coloured with feebly evident schistosity to the naked eye. Under the microscope it shows a schistose irregular structure of ondulated type. This structure is mostly produced by the distribution of the carbonaceous material which forms sub-parallel twisted or thinly puckered streaks and bands.

The groundmass is made up of cryptocrystalline calcite in the bands richest in carbonaceous material, of microcrystalline calcite in the poorest ones. In particular some thin streaks deprived of carbonaceous pigment show the well crystallized calcite under the shape of rather deformed granoblasts, often crossed by fine-grained calcite alignments or surrounded by them.

Moderate quantity of amfibole, microcline, pyrite and little quartz are present with the calcite. The first two minerals, although spread everywhere, are particularly abundant in the bands poor of carbonaceous material.

The amphibole is of neoformation: it forms lengthened granules irregularly shaped without a particular orientation except in few of them. It is a colourless amphibole of tremolite type. It shows rather well developed poikiloblasts, but only in the darkest patches. The poikiloblasts are so filled with inclusions lengthened in direction of the schistosity, that it is difficult to distinguish them from the groundmass.

The microcline recognizable for its relief and the peculiar sieve gemination, is represented by fairly well developed granules. These are almost limpid and roundly or polygonally shaped. It is difficult to ascertain if they are detrital granules: nevertheless the limpidity and the shape of the individuals seem to exclude this hypothesis. On the contrary one can note a remarkable similarity with authogenic feldspar of certain sedimentary rocks.

The quartz make up small patches intimately associated with the calcite.

The pyrite granules with brown-reddish rims coloured by iron oxides — evidently produced by weathered sulphides — are numerous. The ochraceous pigment is spread also in the shape of small bodies and thin veils.

Small granules of a mineral with high relief and anomalous interference colours are present in irregular pattern: perhaps it deals with clinozoisite.

3. Sedimentary Rocks.

29 **KD-560.** – *Protoquartzitic, biocalcarenitic sandstone with calcite cement*; immediately upstream from the Staghar glacier, left-hand slope of the Shaksgam Valley, 1.7.29. (Pl. XXXV fig. 2).

This rock is brown; quartz grains, fossil fragments and casts of pelecypod shells are visible with the naked eye.

The granulometric composition is rather uniform and the quartz grains are very well rounded; the fossil fragments consist of pelecypod shells which are arranged parallel to the bedding.

The quartz grains are the most abundant detritals and occasionally exhibit a mosaic structure indicating a derivation from metamorphic rocks; the feldspar grains are less abundant (albite, often altered), as are chert and feldspathic quartzite; some of the detritals appear to be highly altered, devitrified acid lavas. The calcite cements is very finely cristalline, but easily visible, and has a yellow-brownish colour as a result of limonitic impurities; alternatively it occurs as thick, small colourless prisms which are perpendicular to the detrital grain margins.

Accessory minerals are very scarce and include tourmaline, zircon (mostly metamictic), ilmenite and rutile.

The fossil fragments consist of pelecypod shells and echinoid plates.

29 KD – *Fossiliferous protoquartzite with calcite cement; Shaksgam Valley, Staghar Glacier front*, 1.7.29.

Dark-grey, medium- to fine-grained sandstone containing abundant fossil fragments.

The detrital components are subangular and are contained in an abundant, well crystallized calcite cement which partly corrodes the detritals, especially the feldspar. The grain size varies from 1 to 0,06 mm.; the most abundant mineral is quartz, with minor feldspar (plagioclase, which is cloudy due to alteration into sericite, and clear albite), light-coloured mica and chlorite. Accessory minerals are biotite, zircon, green tourmaline, apatite, magnetite and rutile. Some grains of chert are also present.

The organic content is sparse and consists of shell fragments, spines of Productidae, probable bryozoa, rare Lagenidae and probable Archaeodiscidae.

29 KD-412. – *Fine-grained arkose*; immediately upstream from the Staghar Glacier, left-hand slope of the Shaksgam Valley, 1.7.29.

Fine-grained, light-brown-reddish sandstone containing small pelecypod casts. The detritals have a rather uniform grain size (from 0,25 to 0,1 mm) and consist of quartz with minor feldspar (plagioclase). The matrix of quartz-sericite is extremely scarce and in many places is totally missing. More common are interstitial aggregates of limonite, often associated with carbonates, which represent chemically precipitated cement, the carbonate part of which has been affected by oxidation and leaching.

The quartz grains are subangular and are often welded together to form a quartzitic texture. The feldspar grains are generally altered to sericite and calcite. Some grains contain drop-shaped inclusions of quartz and sericite as orientated microlites which suggest that the feldspar was derived from metamorphic rocks; some of the quartz grains also show pseudoschistose structure due to the metamorphic character of the rocks from which they originate.

Accessory minerals are: zircon, tourmaline and apatite.

29 KD-V 20. – *Fine-grained arkose*; left-hand slope of the Shaksgam Valley, immediately upstream from the Singhiè Glacier, 29.6.29.

Very fine-grained, light-brown-reddish rock; thin flakes of light-coloured mica are visible with the naked eye. The detritals have an irregular shape and are rather uniform in size (about 0,1 mm); the most abundant minerals are, in decreasing abundance, quartz, feldspar (sericitized plagioclase, and subordinate potassic feldspar, generally perthitic) and light-coloured mica. Accessory minerals are: mostly chloritized biotite, apatite, zircon and tourmaline.

The matrix is very scarce and consists of thin flakes of sericite developed for short distances between the detrital grains.

Irregular aggregates of limonite, which partly replace the detrital minerals, particularly the mica, are frequent.

This sample differs from sample 29 PD-412 in having a finer grain size and a greater abundance of feldspars and mica.

29 KD-V 19/410. – *Biosparite*; left slope of the Shaksgam Valley, in the limestone with crinoids and corals, between the Kyagar and Singhiè Glaciers. 29.6.29.

Grey-black, fossiliferous rock containing bryozoa, pelecypod casts and fragments of crinoid plates and ossicles, which are visible to the naked eye.

The matrix consists predominantly of clear, microcrystalline calcite; the size of the grains is in close relationship with the degree of recrystallization.

Fossils are varied and numerous: besides those mentioned above, there are numerous spines of Productida and tests of foraminifera belonging to the genera *Lasiodiscus*, *Glomospira*, *Nodosaria* and probably *Endothyra*. Some fossil remnants which are difficult to recognize, could belong to Ostracoda and Algae (*Solenopora* group).

29 KD-V 7/504. – *Arenaceous biomicrite with algae*; Shaksgam Valley, left-hand slope, about 4 km downstream from the Kyagar Glacier, 27.6.29.

More than one third of the rock-volume is formed by remnants of algae, clearly visible to the naked eye, which are cup-shaped and have a size of few millimetres. The rock is grey in colour and has a micritic matrix which varies from very fine-grained to occasionally coarser-grained due to recrystallization, and in which detrital quartz grains and, to a lesser extent, chert and feldspar are abundantly and randomly distributed. The detrital grains are particularly abundant in the material within the algal cavities; some grains of zircon are also present.

Besides algae, crinoid plates and ossicles, and pelecypod shell-fragments also occur.

The morphology of the algae indicates that they belong to the *Dasycladaceae* group: a more precise determination is impossible due to the complete recrystallization of the thalus.

29 KD-V 35/498. – *Fossiliferous microsparite*: Signal camp of Gasherbrum Jilga (Shaksgam Valley), 3.7.29.

Blackish rock containing some remnants of bryozoa. The calcite is formed of very small, uniform grains about 10 microns in size, associated with a small quantity of very fine authigenic feldspar crystals. The feldspar consists of very clear albite, rarely with polysynthetic twinning: the crystals are idiomorphic and occasionally they have an irregularly shaped nucleus around which feldspar having the same composition as the nucleus has grown.

The rock also contains some hematite, mostly as small, irregularly scattered patches.

Fossils are very varied but relatively uncommon. They are represented by bryozoa, echinoid fragments, *Productus* spines and foraminifera (Archaeodiscidae, Ammodiscidae, Globivalvulinidae, and Tuberitinae).

29 KD-503. – *Fossiliferous pseudosparite*; immediately downstream from the Staghar Glacier, left slope of the Shaksgam Valley, 1.7.29.

Dark-grey rock, uniform and very fine-grained, showing thin veins of white calcite with occasional hematite. The matrix consists principally of carbonate grains with an average size of 15 microns (the size varies from 10 to 40 microns).

Fossils are scarce and are represented by crinoid ossicles and indeterminate shell-fragments.

29 KD-431 – *Fossiliferous, slightly marly pseudosparite*; Shaksgam Valley river-bed, immediately upstream from the Staghar Glacier (not in situ), 1.7.29.

Dark-grey rock with incipient structure of irregular laths which differ slightly in their clay content and with abundant fossil fragments. The rock is made up of an idiomorphic mosaic of fine, rhombohedral calcite crystals, which are in part interlocking and in part separated by a little argillaceous matrix. Rare, splintery quartz grains are also present. The rock texture is clearly a result of the recrystallization of an original micrite containing argillaceous impurities.

Pyrite is present as an accessory mineral and is clearly diagenetic since it often impregnates the remnants of organisms.

The fossils are very poorly preserved, and consist mostly of bryozoa and spines of Productida. Moreover, remnants of small shells, possibly ostracoda, are visible.

29 KD-V 17/255. – *Fossiliferous oointrasparite with superficial oölites*; a few km downstream from the camp near the front of the Kyagar Glacier, right bank of the Shaksgam River, 29.6.29.

The rock is medium-grained and light brown in colour. The intraclasts are both spherical and oval in shape and have a size of about 1 mm; the cement is sparse and consists of very clear sparry calcite. The larger intraclasts are generally oval in shape and consist mostly of micrite containing frequent fossil remnants with lesser quantities of oömicrite composed of oölites identical to those occurring individually within the rock, and minor amounts of coarse skeletal fragments and chert. All these clastics show a thin concretionary edge, occasionally partly eroded and with a zoned-concentric structure, formed by brownish or reddish, often fibrous, calcareous material. The smallest intraclasts consist of skeletal fragments of oölites, most of which have an organic nucleus.

Fossils are numerous: fragments of bryozoa and echinoidea are most common, but remnants of small, completely recrystallized shells of gastropoda, and some foraminifera with a microgranular shell are recognizable; the latter are indeterminate due to their poor preservation.

29 KD-V 15. – *Brecciated, fossiliferous intrasparite*; above the Kyagar Glacier camp, 28.6.29.

The rock appears to be a coarse breccia formed of grey limestone and cemented by thick veins of pink, sparry calcite.

The overall colour of the rock is reddish due partly to the presence of very small crystals of haematite deposited along the fractures and partly to dispersed limonite. The fragments of calcareous rock are usually crossed by a network of crystalline calcite veins, older than the thicker veins of sparry calcite. The rock texture is poorly preserved due to the widespread recrystallization; remnants of intraclast embedded in a matrix of sparry calcite are, however, still recognizable. Moreover, numerous fossil fragments are also recognizable; among them crinoid ossicles and probable remnants of foraminifera and ostracoda are still visible.

In some parts of the rock the calcite is associated with chert which forms replacement aggregates and irregular laths, often fractured and recemented by calcite. Rare grains of authigenic feldspar are also present.

29 KD-V 15′. – *Conglomerate formed of cherts and limestones and with a calcite cement*; above the Kyagar Glacier camp. 28.6.29.

This rock is formed predominantly of breccia-like fragments of brown or light-brown chert (which have an irregular shape with rounded edges); limestone pebbles, ranging in size from a few millimetres to about 0,5 cm, are subordinate, and rare calcareous pebbles also occur, which have a diameter of 1-2 cm. The rock has a scarse calcareous cement.

29 KD-V 16. – *Polymictic conglomerate consisting of chert and limestone with calcareous-limonitic cement*; above the Kyagar Glacier camp. 28.6.29. (Pl. XXXV fig. 3).

The pebbles, mostly flat and poorly rounded, consist principally of reddish or brownish chert with minor amounts of very fine-grained, grey light brown limestones. Some limestone pebbles reach a size of 2 cm, but the average pebble size is about 0,5 cm. The matrix is widespread and, together with the cement, forms about 2/3 of the rock-volume; its colour is yellow-reddish. It is formed of sand-grains of very variable diameter consisting, like the pebbles, of chert and limestones embedded in abundant, very fine-grained calcareous-haematitic cement. The margins of the calcareous grains are transitional with the cement which partly replaces them. The well crystallized calcite forms numerous veins ramifying into the rock and they often widen to forme irregularly shaped aggregates.

The chert pebbles often contain scattered, very small grains of carbonate; the calcareous pebbles are formed of microsparite with rare organic remnants (echinoid spines) and occasionally quartz grains and small aggregates of chert.

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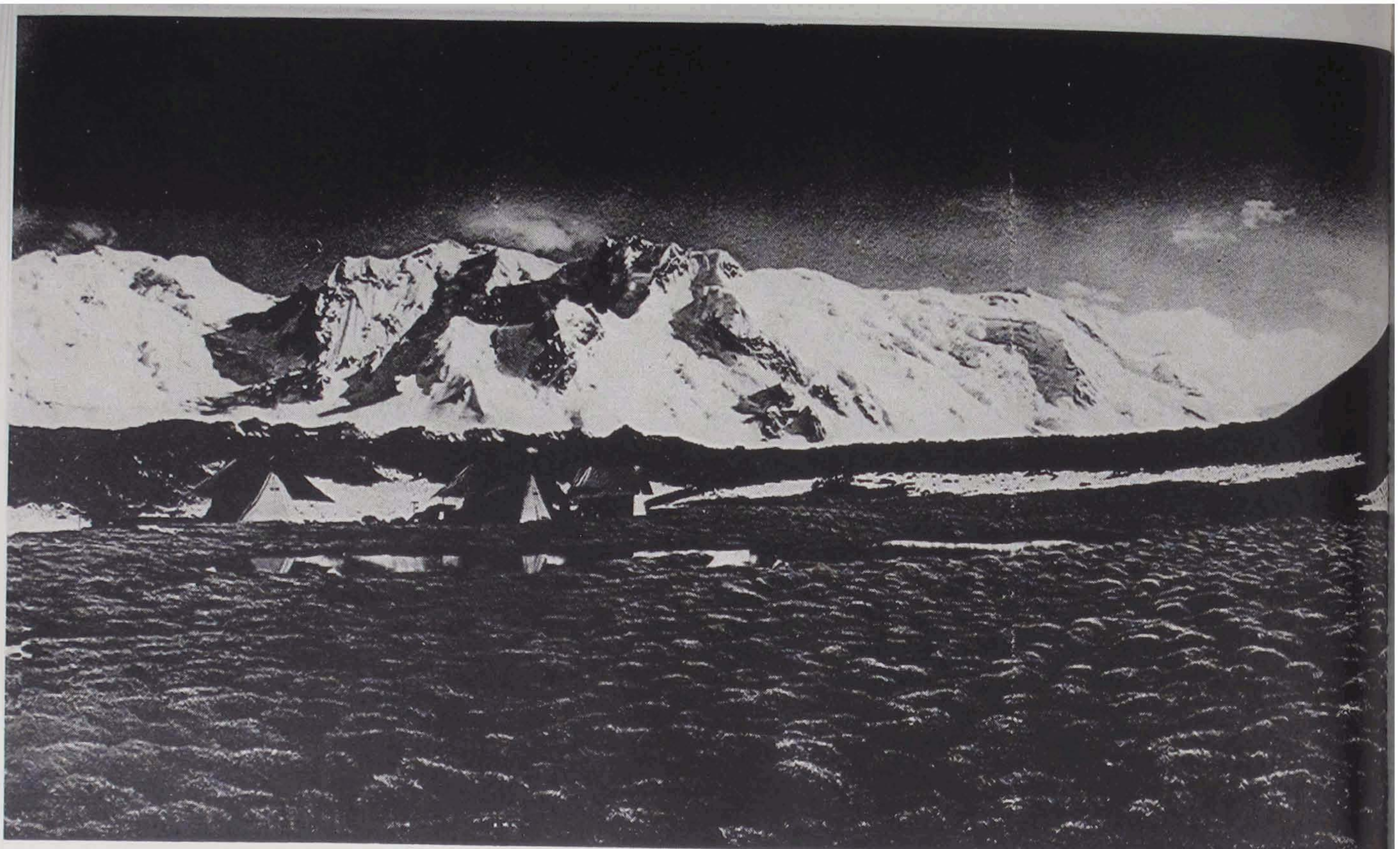
PLATES



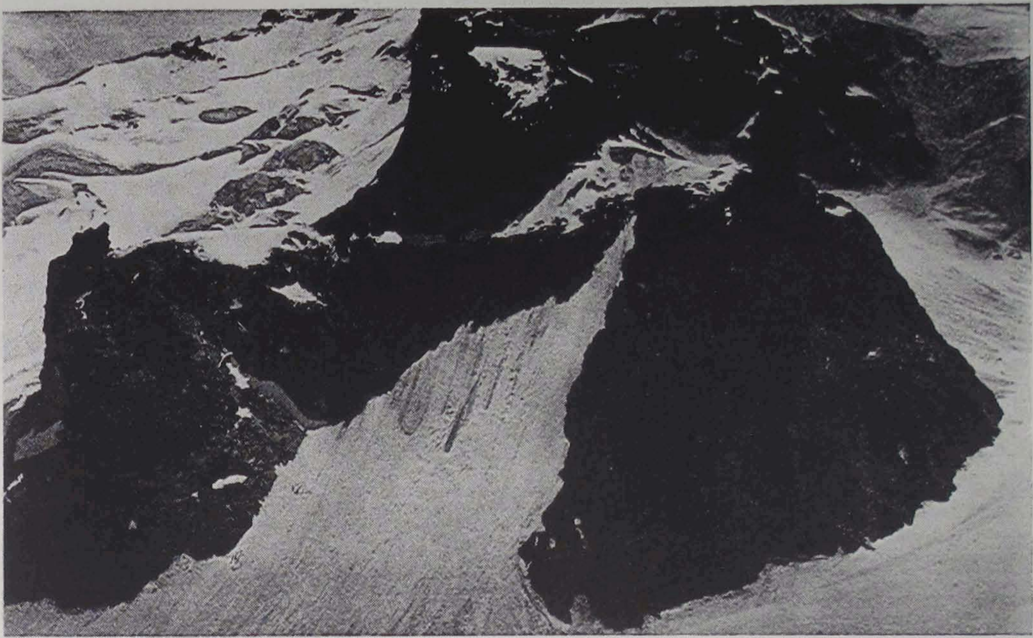


Fig. 1. *A spur near the outlet of the Karphogang Glacier valley on the right hand flank of the upper Sarpo Laggo Valley*. Granitic dykes in the peribatholithic gneiss.

Fig. 2. *Outcrop of granite gneiss in the Karphogang Glacier Valley.*

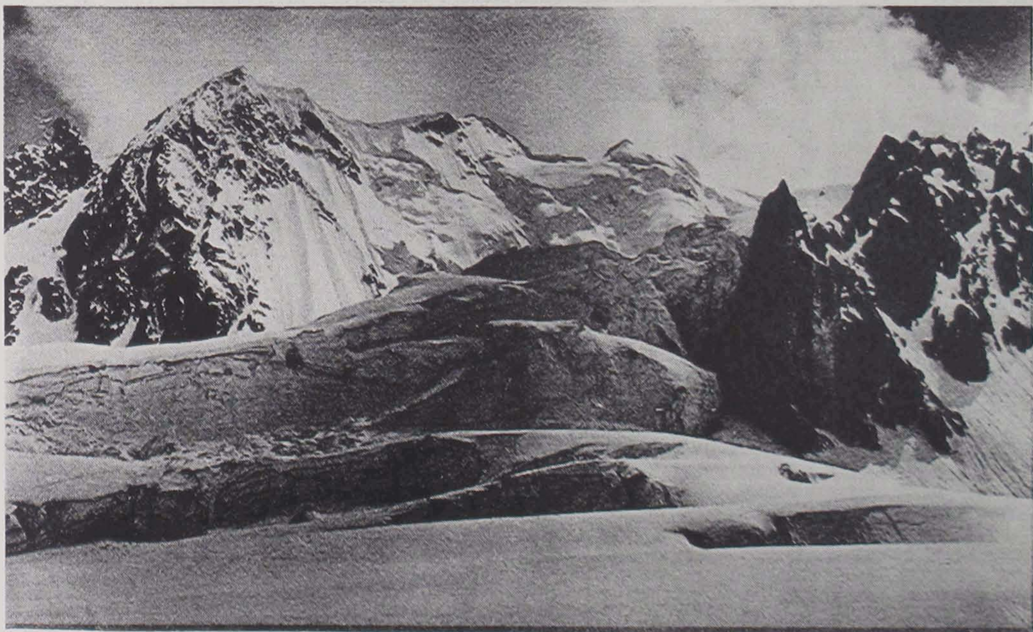


Plate II

Fig. 1. *The granite gneiss crest of the right hand side of the upper Sarpo Laggo Valley*. The gentle slopes on the right are compos
of black slates. In the foreground a hummock field (thufur).

Fig. 2. *The surroundings of Chang Tok in the Sarpo Laggo Valley*. Note the contrast in the morphology between the area of black
(in the foreground) and the area of the granite gneiss (on the right side of the background).


Fig. 1. *The lower Sarpo Laggo Glacier valley (foreground), the Chang Tok group (background) and, in the middle toward the left, the Moni Glacier.* View from the left hand moraine of the Sarpo Laggo.

Fig. 2. *View of the right hand side of the Sarpo Laggo Valley from the left hand moraine of the glacier.* In the background the K^2 pyramid.

Plate IV

Fig. 1. *Left hand flank of the Sarpo Laggo Valley near Moni Bransa.* The slopes are made of black slates. In the foreground the end of the interrupted tongue of a lateral glacier.

Fig. 2. *The right hand flank of the lower Sarpo Laggo Valley with small tributary glaciers downstream from the Moni Glacier.* The slopes are made of gneiss.

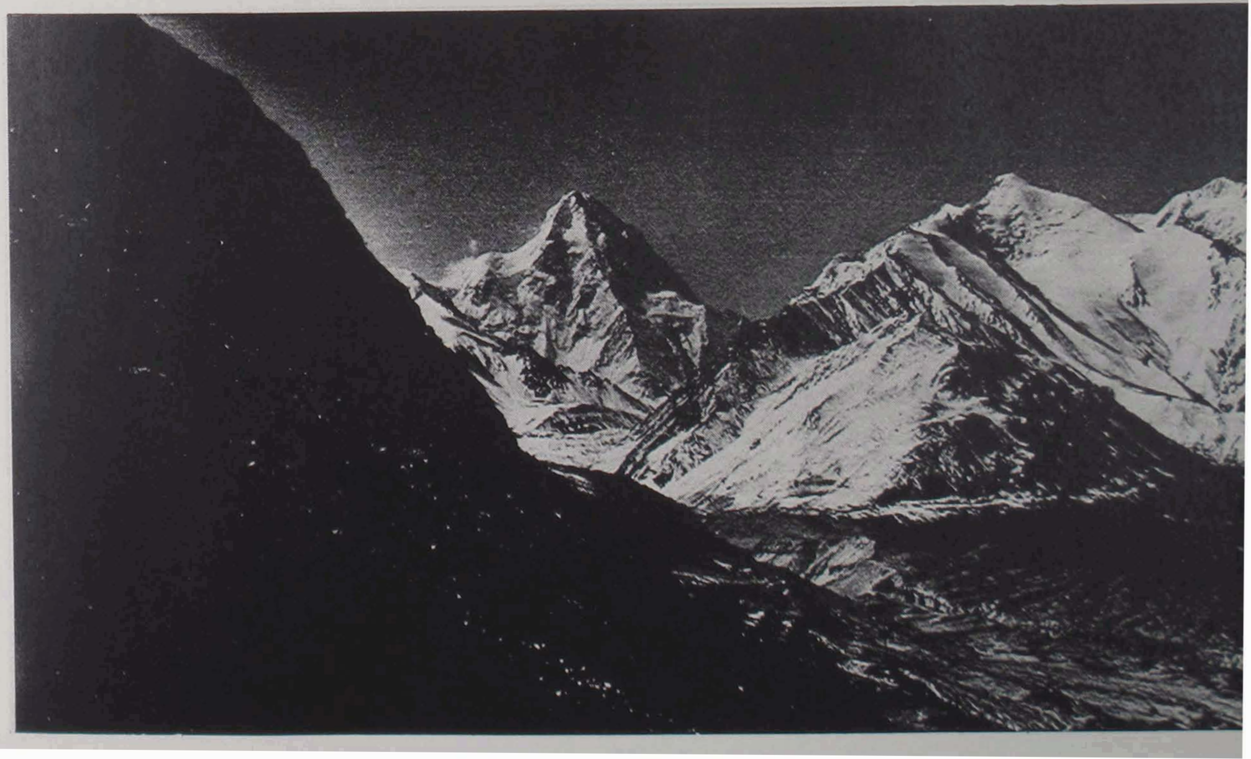
Fig. 1. *View of the Sarpo Laggo Valley from the Tek-ri hillock.*

PLATE VI

Fig. 2. *The snout of the Sarpo Laggo Glacier (July 8, 1929).*

Fig. 1. *The lower Skamri Valley and the end of the glacier (June 13, 1929).*

Fig. 2. *View of the K² Glacier valley from the Tek-ri hillock.*



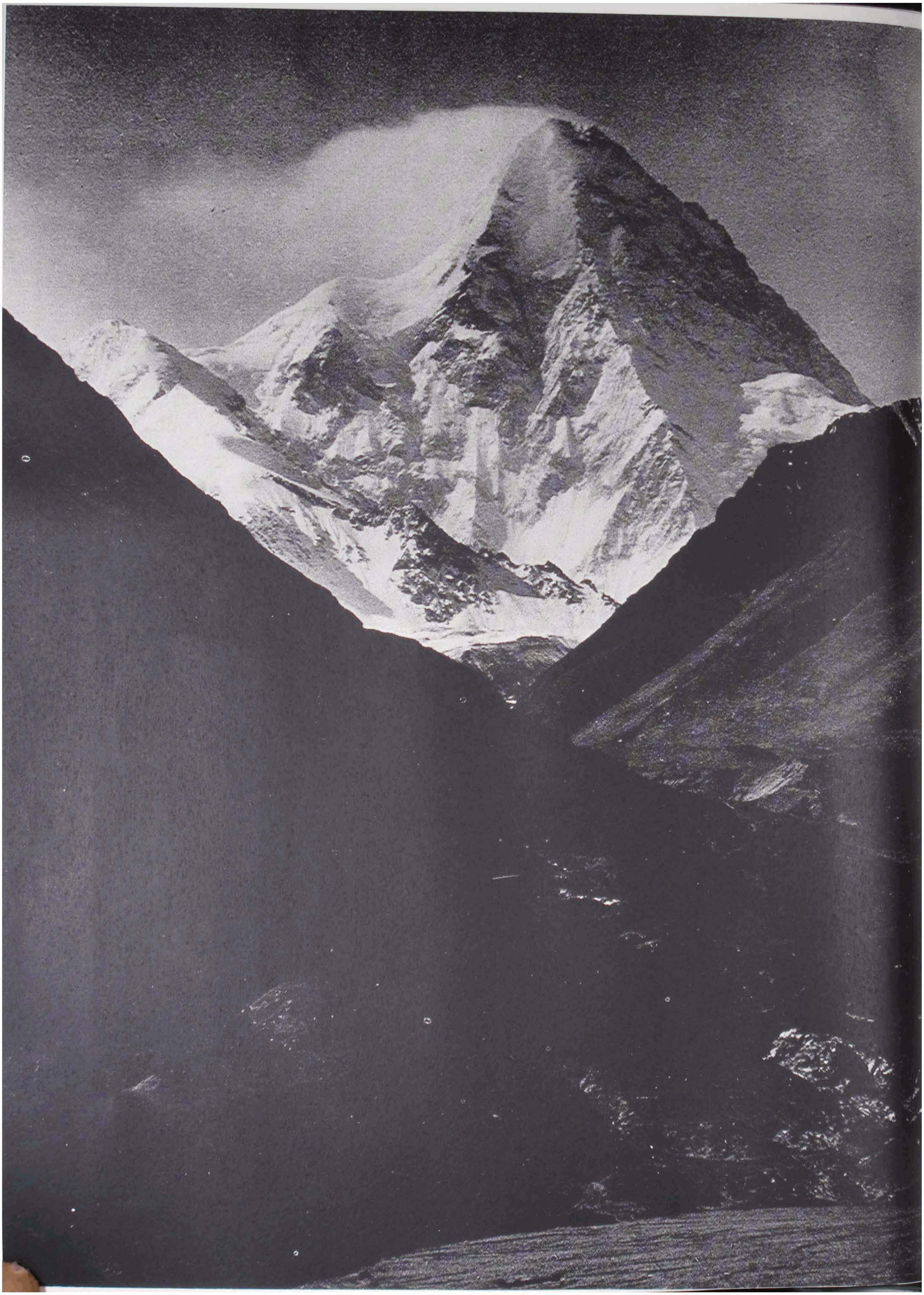


Fig. 1. *View from the Tek-ri hillock toward the lower Shaksgam Valley*. See the geology in the fig. 8 of the text.

Fig. 2. *The Shaksgam Valley and the Tek-ri hillock from upstream.*

Plate VIII

The northern wall of K^2 from the Tek-ri hillock.

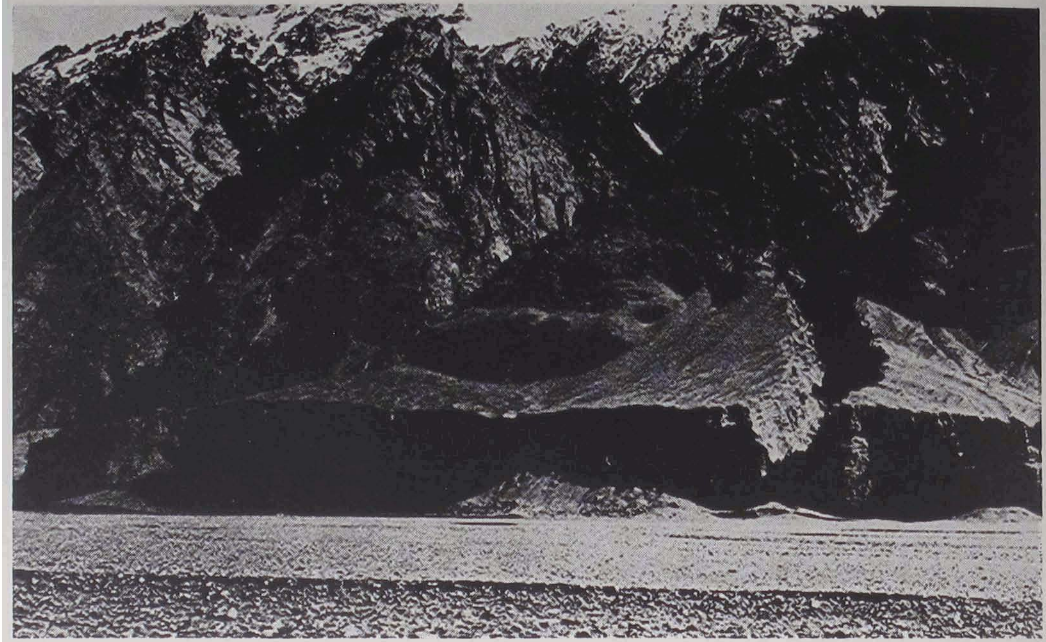


Fig. 1. *Old alluvial fan downstream from Durbin Jangal, Shaksgam valley.* In the background the limestone wall of the Khorkum Ridge.

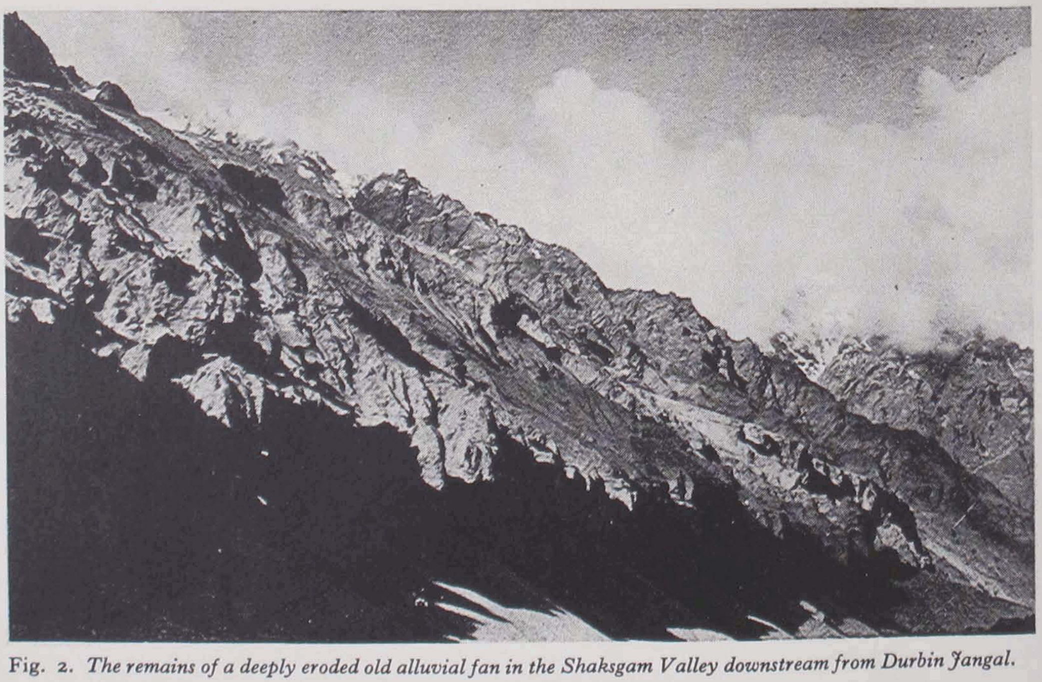


Fig. 2. *The remains of a deeply eroded old alluvial fan in the Shaksgam Valley downstream from Durbin Jangal.*

Plate XI

The Shaksgam Valley upstream from the Tek-ri hillock.

Fig. 1. *The SE end of the Khorkun ridge, made of Aghil Limestone.*

PLATE XII

Fig. 2. *The "Shaksgam Dolomites"* (*Khorkun ridge*).

Fig. 1. *The outlet of Bya Lungma.*

Fig. 2. *The outlet of the Skyang Valley.*
In the background the K^2 group.

⇦ Plate XIII

Fig. 1. *The outlet of the Aghil Valley.* In the background the gneissic ridge of the Aghil range.

Fig. 2. *The outlet of the Sham Valley.* On the right the western end of the Choto-so calcareous ridge. See fig. 11 in the text.

Fig. 1. *The end of the Gasherbrum Glacier*. The Aghil range in background.

Fig. 2. *The wall of Aghil Limestone at the front of the Gasherbrum Glacier.*

Fig. 1. *The Gasherbrum Glacier valley*. The Gasherbrum ridge in the background.

PLATE XVI

Fig. 2. *View of the Urdok Glacier valley*. The Gasherbrum ridge in the background.

Fig. 1. *View of the Urdok Glacier valley from the Gasherbrum-Urdok Saddle.* On the left side the range rising between the Urdok and the Shaksgam valleys.

Pl

Fig. 2. *A characteristic aspect of the Urdok Glacier.* In the background, on the right, Indira-la; on the left a saddle bearing to the Stag

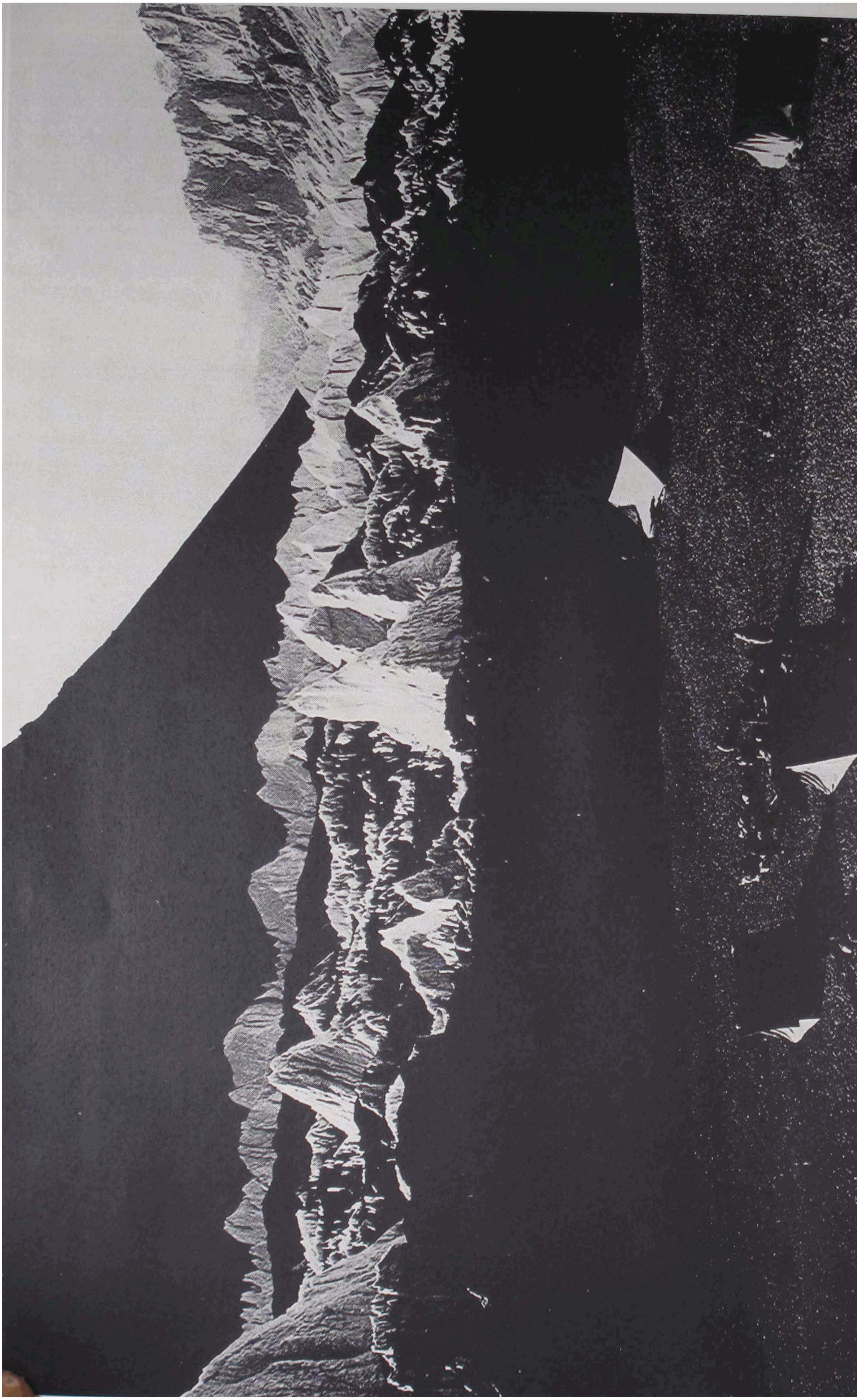


Fig. 1. *The limestone wall of the Aghil range from the moraine rampart of the Gasherbrum Glacier (in the foreground).*

Fig. 2. *The outlet of the Urdok Glacier valley from upstream.* In the background the Aghil range.

Fig. 1. *The upper Urdok Glacier valley ; the Gasherbrum I (8068 m) in the background.*

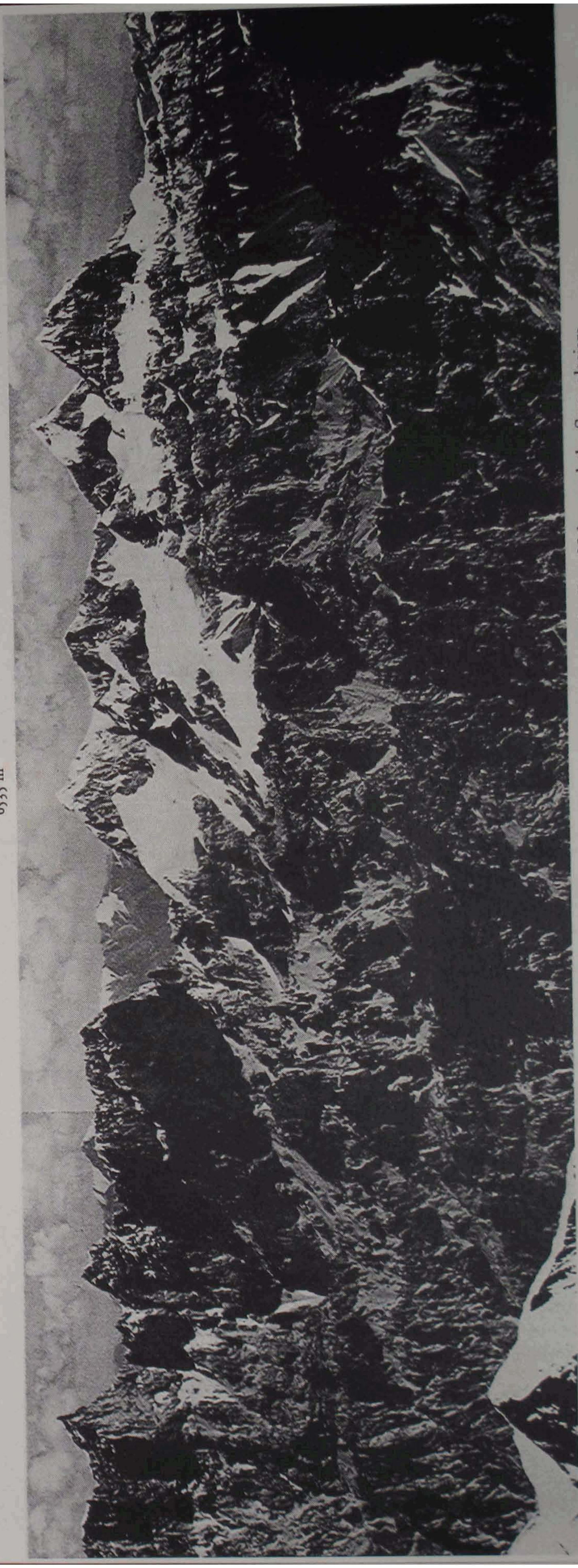
Fig. 2. *The head of the Urdok valley.* See the geology in fig. 27 of the text.

PLATE XXI

PLATE XXII

Fig. 1. *The confluence of the East Nakpo Glacier (in foreground) with the North Gasherbrum Glacier from the Gasherbrum-la.* (Foto F. Maraini). In background the Aghil Range and the Takht-i-Kangri peak (6523 m) (↓).

Fig. 2. *The Shaksgam Valley near the outlet of the North Gasherbrum valley from the Gasherbrum-la.* (Foto F. Maraini). In the background the Aghil Range and the Takht-i-Kangri peak, 6523 m (↓). In the foreground, on the right, the ridge between the East Nakpo and Sgan glaciers; on the left the contact by fault of the Singhié Shales and the limestones of the Shaksgam Formation. The Aghil walls are made of Aghil Limestone.



The Aghil Range from the Gasherbrum-la. (Foto F. Maraini). In the foreground the ridge between the East Nakpo and the Sgan glaciers. In the background, on the right side, the Gatson Kangri group. The wall below the right hand side of the Shaksgam Valley is made of the Aghil Limestone.

Fig. 1. *Huge limestone blocks in the floor of the Shaksgam Valley upstream from the Urdok Glacier.*

PLATE XXIV

Fig. 2. *Hillock smoothered by the glaciers near the Urdok Glacier snout* (*Urdok-zgo*). The contact between the limestone (below) and the black slates can be seen in the middle. On the right the Aghil limestone wall; on the left the slopes by the Singhié Slates.

Fig. 1. *The Staghar Glacier from downstream.* On the left the Permian beds of the Shaksgam Formation. The same composition show the peaks in the background.

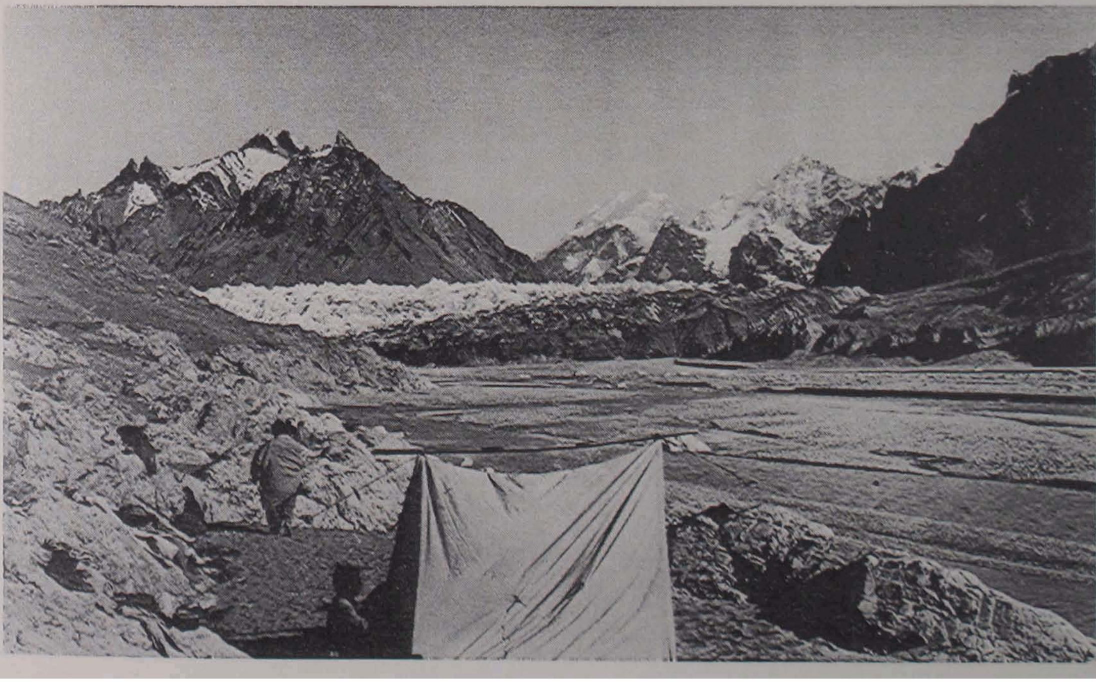


Fig. 2. *Th*
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Fig. 1. *The Permian fossiliferous locality of the Staghar Glacier front.*

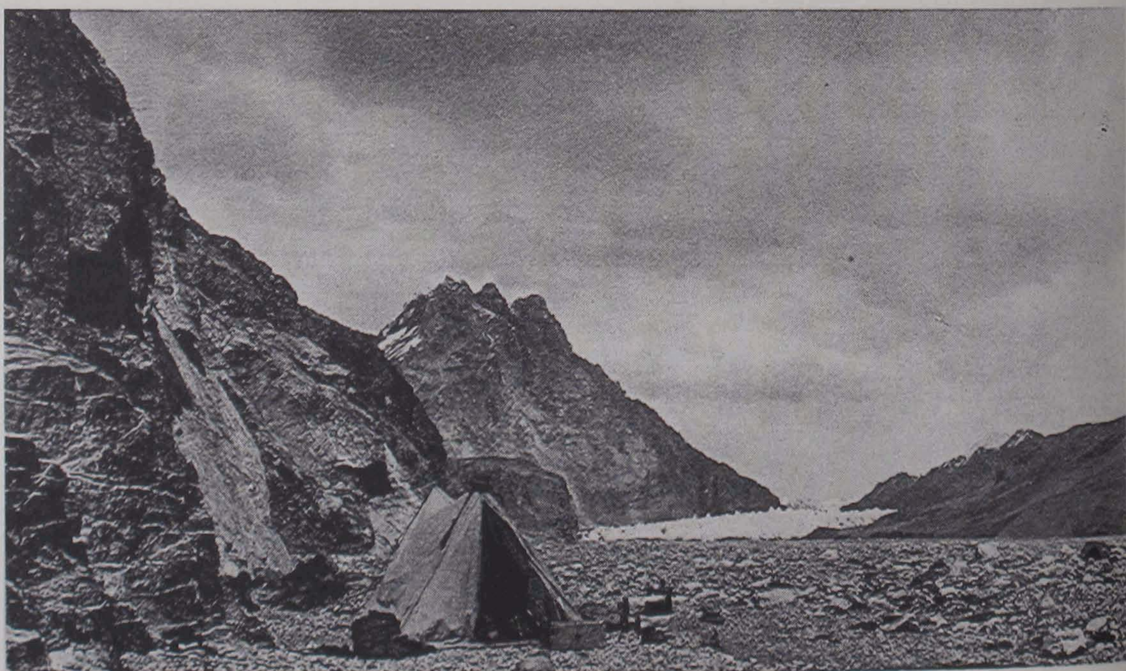

Fig. 2. *The Shaksgam Valley upstream from the Staghar Glacier.* In foreground the Singhié Glacier and the Chikchi-ri ridge (on the left).

ATE XXVII

e ice pinnacles of
Singhié Glacier.
the background
Teram Kangri
68 m).

Fig. 1. *The Singhié Glacier valley hollowed in the black shales.* In the background the Teram Kangri (7468 m) made of Aghil Lime
The spur stretching out from the Teram Kangri divides the Singhié Glacier from the Kyagar Glacier.
It is composed of Singhié Shales overlied by the beds of the Shaksgam Formation.

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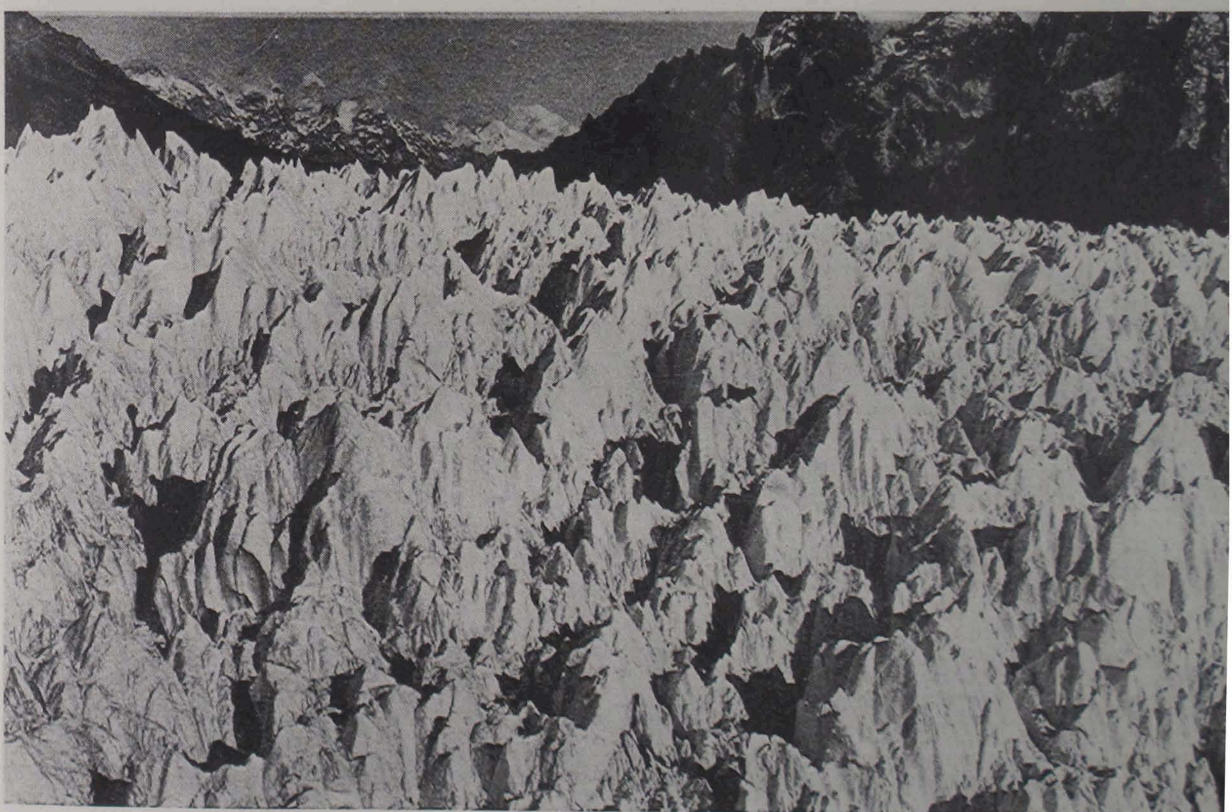
Fig. 2. *View across the Singhié ice pinnacles.*



⇦ PLATE XXVIII

Look on the gully between the ice pyramids in the Singhié Glacier.

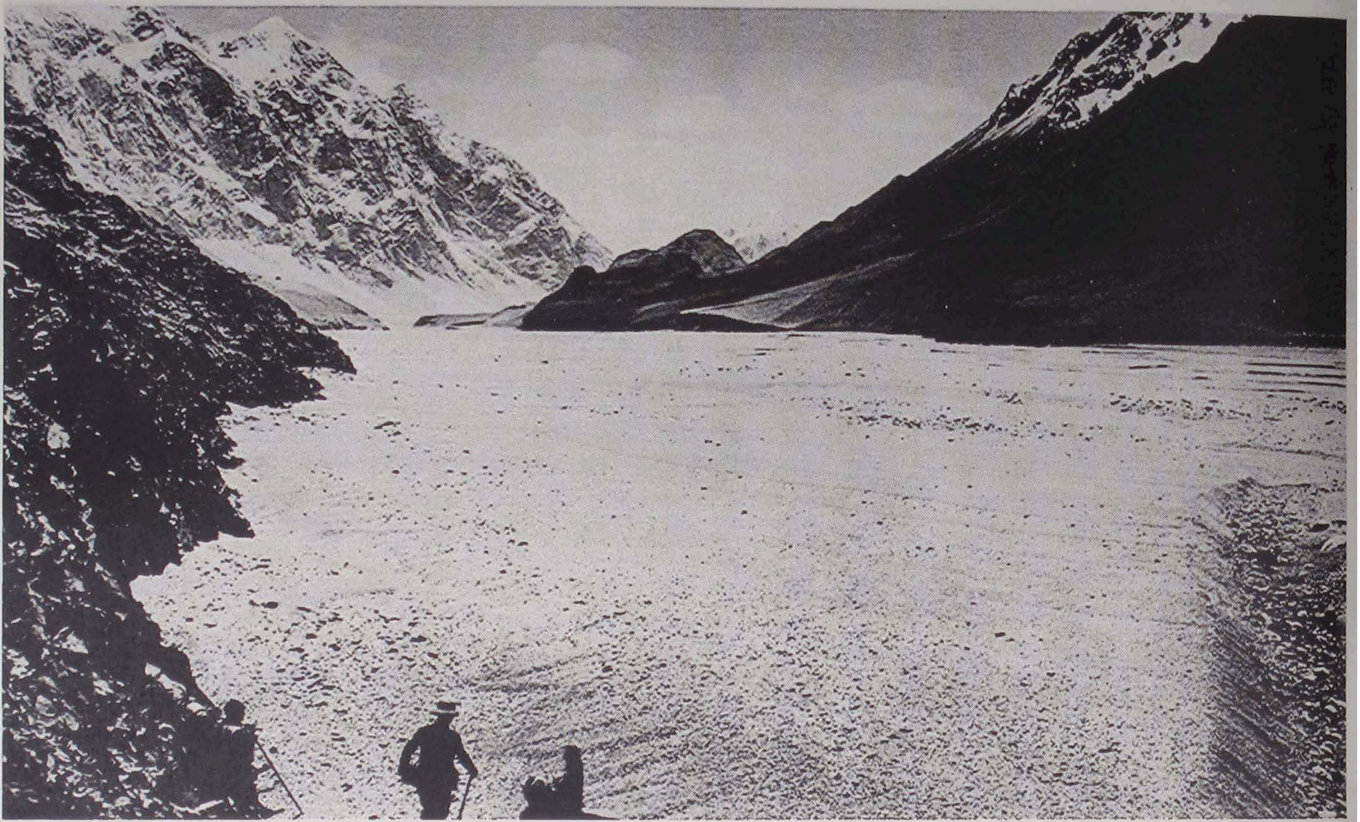


Fig. 1. *The floor of the Shaksgam Valley between the Singhié and the Kyagar glaciers.* In the background, on the left, the Chikchi-ri range made of Aghil Limestone.

Fig. 2. *The Marpo Rgyang range from the cairn above the left hand side of the lower Kyagar Glacier.* The contact between the Aghil Limestone and the Shaksgam Formation is visible. The Singhié Shales outcrop on the left.

Fig. 1. *Sand dunes upstream from the Singhié Glacier*. In the background the 6648 m peak of the Chikchi-ri western crest made of Aghi

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Fig. 2. *The wall of Aghil Limestone downstream from the Kyagar Glacier*. In the foreground see a moraine deeply fractioned by

Fig. 1. *Large outcrop of cherty limestone downstream from the Kyagar Glacier.* In the background the Dragang Peak.

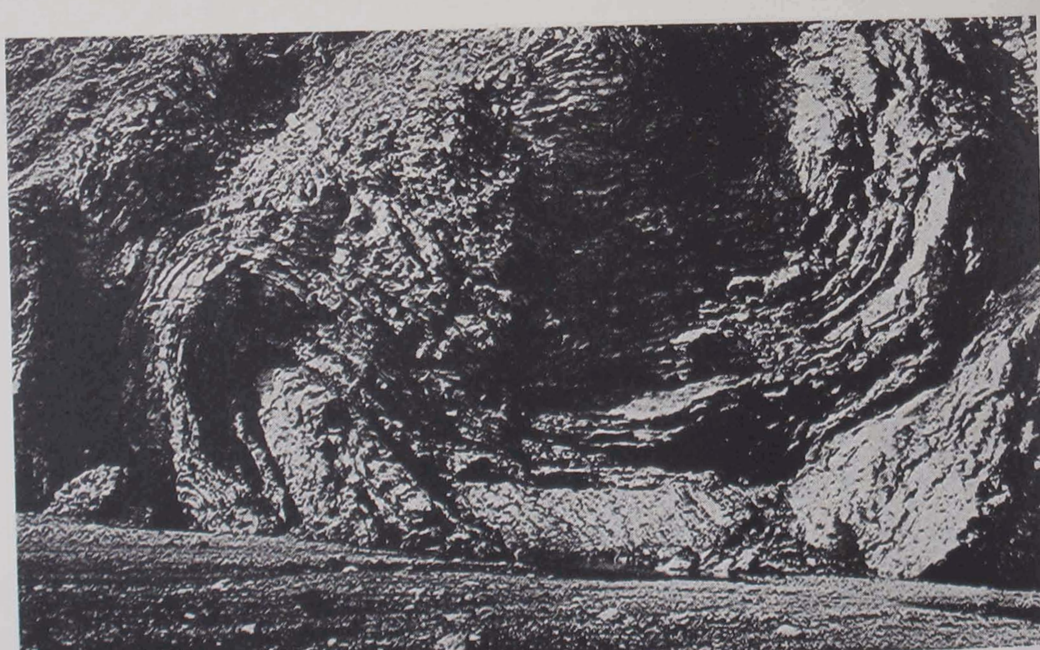


Fig. 2. *Small folds in the cherty limestone downstream from the Kyagar Glacier snout.*

Fig. 1. *The Dragang peak.* The highest part of the mountain is made of the beds of the Shaksgam Formation horizontally la
The hills in the foreground are composed of the Singhié Shales.

Fig. 2. *The sample 29KD-506 with* Fenestella *sp. from the floating moraine at the south foot of the Skamri range near the confluence of the Drenmang and the Nobande Sobande glaciers (Panmah).*

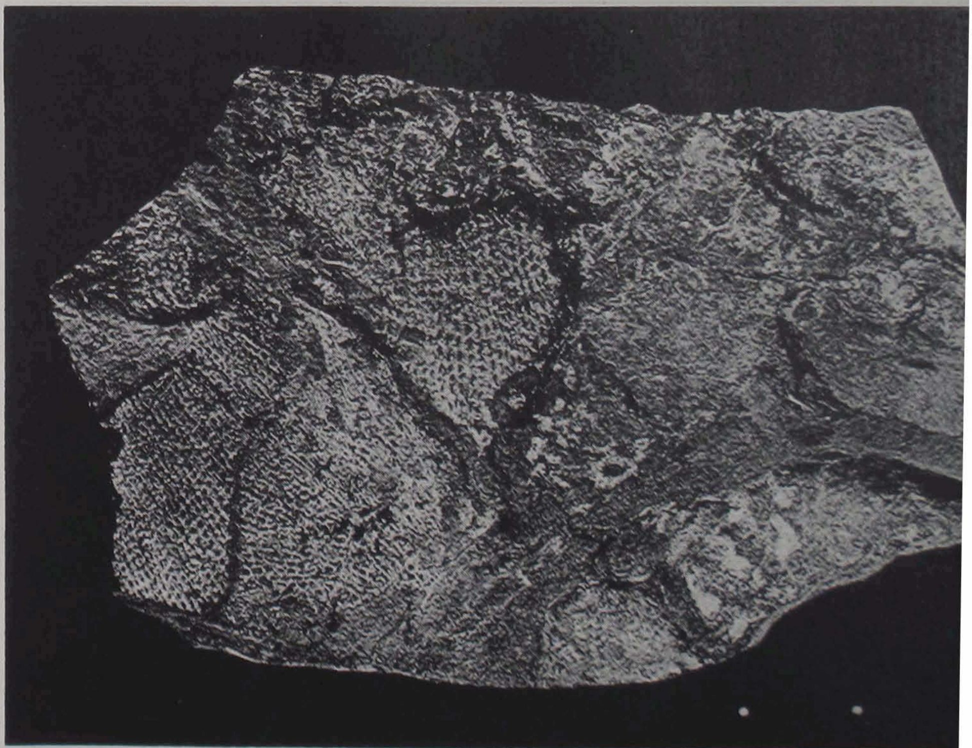
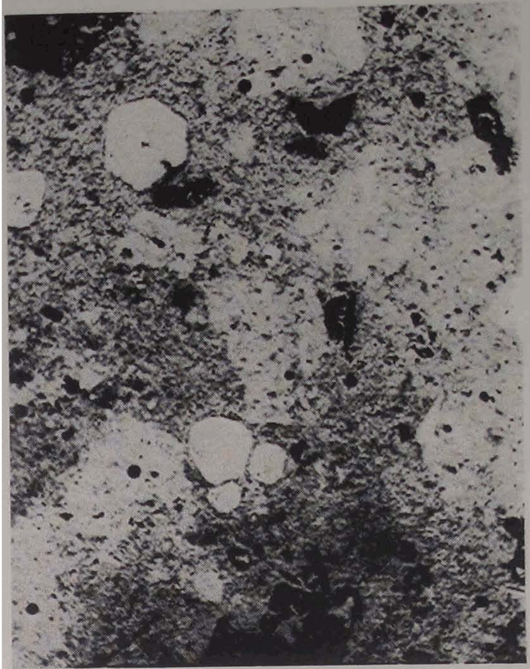


Fig. 1. *The snout of the Kyagar Glacier (Juny 27, 1929).*

PLATE XXXIV

Fig. 2. *The Kyagar Glacier valley hollowed in the Singhié Shales.*



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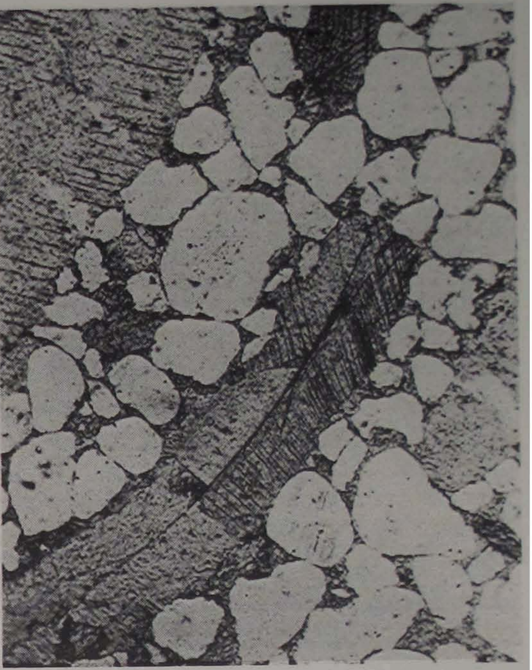

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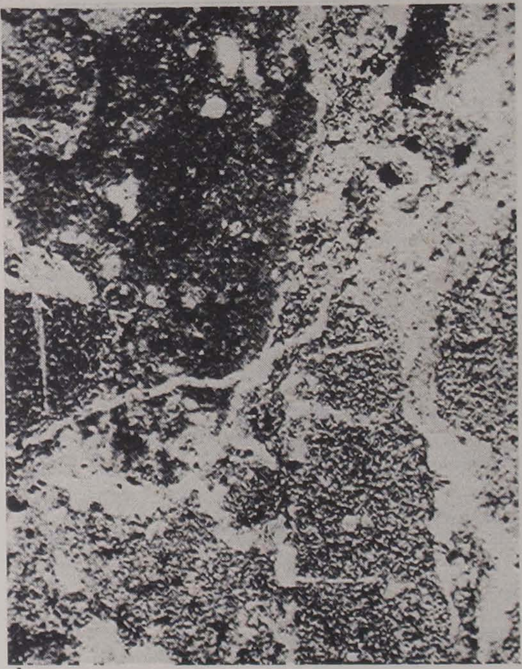

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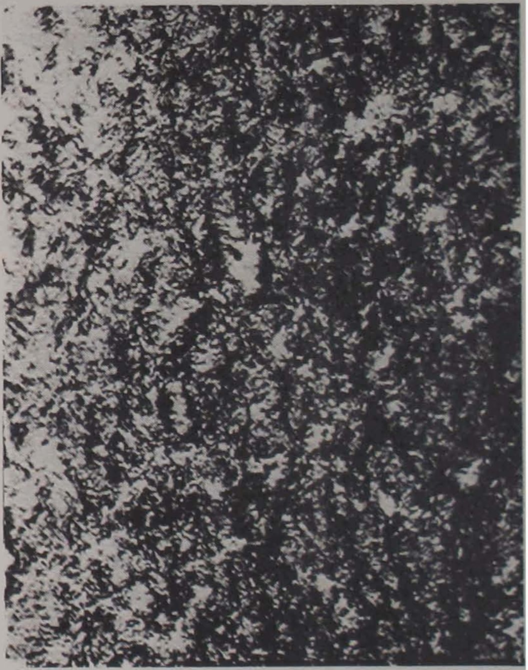

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Fig. 1. *Basic altered dacite.* Left hand side moraine of the South Gasherbrum Glacier (29 KD-195). Common type of the socalled "Porphyrite" from the Shaksgam Valley. Quartz phenocrysts evidently corroded, sericitized plagioclase and femic phenocrysts probably consisting of altered mica and pyroxene. (x 40 parallel nicols).

Fig. 2. *Protoquartzite, biocalcarenitic sandstone with calcite cement.* Immediately upstream from the Staghar Glacier, left hand slope of the Shaksgam Valley (29 KD-560).
Quartz grains mostly very well rounded and prevailing on the feldspar ones. Pelecypods shells parallel to the bedding. (x 40 parallel nicols).

Fig. 3. *Polimictic conglomerate of chert and limestone pebbles with calcareous cement.* Above the Kyagar Glacier camp. (29 KD-16).
The pebbles of the conglomerate, mostly flat and poorly rounded, consist principally of chert. Some limestone clasts are embedded together with the chert ones, into an abundant cement formed of sand grains. (x 40 crossed nicols).

Fig. 4. *Amphibolic arenaceous carbonaceous calcschist with "Fenestella".* Floating moraine coming from the south foot of the Skamri range near the junction of the Drenmang Glacier (Panmah Valley). (29 PD-506). Rock with schistose, irregular ondulated structure, mostly produced by the distribution of the carbonaceous material forming thinly puckered streaks and bands. (x 40 parallel nicols).

INDEX

C

L

M

N

O

P

Q

R

T

U

V

W

Stampato
nelle Officine della
Bolis Poligrafiche s. p. a. Bergamo
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