REPORTS FROM THE SCIENTIFIC EXPEDITION TO THE NORTH-WESTERN PROVINCES OF CHINA UNDER THE LEADERSHIP OF DR. SVEN HEDIN

— THE SINO-SWEDISH EXPEDITION —

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III. Geology

7

GEOLOGICAL EXPLORATIONS IN WESTERN TIBET

BY

ERIK NORIN

APPENDICES

BY

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PREFACE

There are few regions on our globe comparable in size with the Tibetan "Plateau" (Chang-thang), which are still geologically a *terra incognita* to the same extent as this huge, desolate desert highland. During the second half of the last century the von SCHLAGINTWEIT brothers, LYDEKKER, members of the FORSYTH Expeditions, and DREW gave the first accurate information on those parts adjoining the Karakoram trade routes, and revealed the great development of marine Mesozoic formations within the area. The southern border of the plateau was touched by HAYDEN's reconnaissance survey of southern Tibet in 1903 and 1922, and its northern border by the Russian Tibet Expedition under the leadership of PEVTSOV 1889—90. But our knowledge about the geology of the rest and by far the greater part of the Chang-thang is largely the result of one man's work. During his expeditions in the years 1894—97, 1899—1902, and 1906—08, HEDIN collected systematically specimens of the rocks encountered along his routes, carefully recording their exact position and visible extension. Only a part of this extremely interesting and valuable material has been described and classified by ASKLUND (1922), BÄCKSTRÖM (1900, 1907), HENNIG (1916), and JOHANSSON (1907). The author's study of HEDIN's collections and field diaries in connexion with the preparation of this report has convinced him that much additional information about the geology of this vast region is still to be gained by HEDIN's material in the light of recent researches in the border areas.

A new Era in the exploration of this region began with the reconnaissances of the Karakoram and the western Chang-thang by the trained geologists of the Italian expeditions under the leadership of DE FILIPPI in 1913—14 and 1930, the Dutch expeditions under P. VISSER in 1922, 1925, 1929—30, and 1935, the German expeditions under E. TRINKLER 1927—28 and DE TERRA 1932, and the British expedition under E. SHIPTON in 1937.

Partly because of the difficulty of obtaining permission to enter Tibetan territory, the field of these expeditions has been, with few exceptions, the region adjoining the Indian—Tibetan frontier, a great drawback because of the extremely intense tectonic disturbances to which the strata have been subjected here at the western out-wedging end of the plateau.

When, in 1932, Dr. AMBOLT and the author started a geodetical och geological reconnaissance of western Tibet and the adjoining parts of the K'un-lun, the experience gained during five years of fieldwork in T'ien-shan and the Tarim Basin enabled us to carry out our extensive scientific program in a way hardly possible otherwise in this most inhospitable region devoid of almost everything necessary for the maintenance of a caravan. Although some 70 % of our beasts of burden carried their own fodder, this quantity barely lasted for the first two months in spite of great economy; then the animals began to succumb at a rapid rate.

A full account of our itineraries and methods of survey will be given in "History of the Expedition in Asia 1927—35", Part V. Our routes and camps in westernmost Chang-thang are shown on the geological map Plate A. The caravan started from Yarkand on March 23rd 1932 and arrived at Aq-tagh (4,656 m.) north of the Karakoram Pass 17 days later. Here a permanent meteorological station was established under the supervision of P. K. VOROTNIKOV. From here we travelled in two separate groups along more or less parallel routes eastwards in order to make the reconnaissance as effective as possible, joining on some occasions to discuss the results and the continued work. During April, May, June, and July, the author surveyed the basins of Aq-sai-chin, Lake Lighten, Yeshil-köl, and the hilly region between Lake Markham and the Surghak-tagh, the most northerly of the K'un-lun ranges. An attempt to replenish our transport and supplies at the village of Qarasai resulted in capture by Chinese soldiers on July 25th and transportation to Khotan. From here we were ushered under military escort to the Karakoram Pass, which we crossed on September 17th.

Again free we turned eastward and reconnoitred during the following months the basins of Sarigh-yilganing-köl, Tsaggar-tso and Horpa-tso. When our supplies were nearly exhausted we turned south crossing the great range of Mawang-kangri in the hope of meeting Tibetan nomads to buy yaks and sheeps. A large encampment was encountered on November 1st at our camp N 723. Here our freedom of movement again ended. A dozen armed Tibetans conducted us to the nearest point on the British frontier which we crossed on November 11th over the pass of Domjor-la on the watershed of the valley of Chang-chen-mo. Ten days later we arrived at Pobrang, the first settlement on British territory.

In order to give a clearer view of the orography we have included in the general topographic map, Plate C, also the upper Shayok region (surveyed by DE FILIPPI's and VISSER's expedition) outside our area of reconnaissance, as well as parts of the K'un-lun according to the survey of STEIN, and western Lingzhi-thang according to Sheet 52 N (1928) of the Great Trigonometrical Survey of India.

The areas explored by the author have been mapped in part to the scale of 1 : 100,000, in part 1 : 200,000 by means of plane-table. The topography of the northern parts of the Khushku-maidan, the central Lingzhi-thang, and the northern border of the basin of Tsaggar-tso has been sketched from route-lines and photographic panoramas made by AMBOLT. In order to avoid cumulative errors in the triangulations, new bases were measured frequently, by AMBOLT at almost every camp. Some 400 photographic panoramas taken by AMBOLT from fixed stations, cover almost the whole region surveyed; it is hoped that means may be found to make this valuable material available to geographers. We have also utilized HEDIN's excellent route survey of 1906 and 1908 from the pass of Chang-lung-yogma along the southern border of the Lingzhi-thang, across the Loqzung Mountains to Aq-sai-chin, and farther east through the Eastern Loqzung Mountains to the eastern end of the Tsaggar-tso. Thanks to HEDIN's panoramas, and azimuths usually taken to a large number of prominent peaks from his camping places, the position of these stations could be fixed accurately in many cases.

Because of the total absence of inhabitants in those parts of the Chang-thang visited by us north of the Mawang-kangri, we had no possibility of obtaining eventually existing native names of many regions, lakes etc. To places specially memorable to us, a name was often applied by the servants, and in a few cases we have entered it on the map when it concisely characterizes the locality (Tagda-koram-davan = the pass with polished boulders; Aq-qum-davan = the pass with white sand). The large salt basin in the western Aq-sai-chin called Aq-sai-chin by the Qaraqash kirgises, we used to call the Mangrik Basin to distinguish it from the geographically rather different eastern parts.

The author's geological reconnaissance was much hampered by the contemporaneous work on the indispensable topographical fundament, which often necessitated a route at considerable distance from the mountains in order to obtain the necessary range of view. Thanks to the lucky find of some exceptionally good and only slightly disturbed sections through the greater part of the very thick Late Paleozoic and Upper Cretaceous sequences, a fairly good picture of the geological development during these periods could be obtained. Very fragmentary are, on the other hand, the records of the Triassic and Jurassic periods. Additional valuable data for the understanding of the geological structure of the region may be expected when AMBOLT's gravimetric sections from the high plateau, across the K'un-lun and the Tarim Basin become available. In the geological map, Plate A, have been embodied also the geological observations made by DE TERRA, DAINELLI and HEDIN. We are greatly indebted to Prof. F. HERITSCH, Graz, for describing some corals from the Permian series of the western Chang-thang and southern T'ien-shan (Appendix A). Dr. K. METZ, Leoben, kindly undertook the study of our collection of Permian bryozoa (Appendix B); the foraminifer faunas of the same deposits are being investigated by Dr. F. KAHLER, Klagenfurth; the final results of Dr. KAHLER's study are, however, not yet available because of his long continued military service. Dr. F. BROTZEN, Stockholm, has examined the foraminifer faunas of the Cretaceous limestones and thus succeeded to fix the age of the main divisions of this very thick sequence of strata. Prof. T. G. HALLE, Stockholm, has determined provi-

sionally the Jurassic plant fossils collected in the K'un-lun and the Aghil Zones; Prof. CHR. POULSEN and Prof. H. FREBOLD, Copenhagen, have investigated minor finds of Ordovician, Triassic and Jurassic fossils. To all these scientists, to which largely is due what additions to the knowledge of the stratigraphy of these regions this paper contains, the author conveys the most hearty thanks.

I must once more record my ever increasing indebtedness to the leader of the expedition, Dr. SVEN HEDIN, who has throughout 19 years in the field and at home facilitated my work in every conceivable way. We have often followed his trails in Tibet as well as in Turkistan, and we have had ample opportunity to confirm the opinion expressed by STEIN (1912, II, p. 389) and MARGERIE (1930) of the great accuracy of his pioneer work at the beginning of this century.

To my collaborators and brave companions on the desolate Tibetan Plateau is due the highest honour and credit for the successful accomplishment of the undertaking. I mention in the first place my old friend, Dr. NILS AMBOLT, geodesist, whose work constitutes a valuable complement to my own; together we carefully planned the journey, discussed the problems and selected the routes in a way to solve them. His enthusiasm for our common goal, his genial nature and the fine comradeship displayed, are precious reminiscences of this wonderful journey.

Special acknowledgement is due to Mr. P. K. VOROTNIKOV, our meteorological assistant, who alone faced the isolation and the hardships of the Aq-tagh plateau in a frail tent during two months, making hourly meteorological observations in order to secure to us the necessary base for our hypsometrically determined altitudes.

No less is my obligation to my old servant WANG SHU-YUAN, a faithful companion and friend during six years of travel in Central Asia, who never lost his serene courage in any awkward situation. To Dr. LIU CH'ENG-NGO, botanist of the Haardt-Citroën trans-asiatic Expedition 1931—32, I owe a dept of gratitude for his cooperation as a travel companion; Dr. LIU also made some collections of fossils which, unfortunately, could not be utilized in this paper because of the difficulties of communications raised by the great war.

I am further greatly indebted to Prof. A. HADDING, Director of the Geological Department of the University of Lund, who has facilitated in many ways the laboratory work carried out in his institute. Acknowledgement is also due to Prof. H. BACKLUND, Uppsala, for valuable suggestions during our discussions on topics of Asiatic geology; to Miss W. BERNSTRUP, Lund, who has, since 1935, assisted in the construction and calculations for the maps, and to Dr. G. MONTELL, the Editor of this series, for much help on the illustrations and other redactional details.

The Geological Institute,

University of Lund,

July, 1945. ERIK NORIN.

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INTRODUCTION

High Tibet, also known as "the Tibetan Plateau" or by its Tibetan name *Chang-thang, i. e.* the Northern Plains, is a large orographical unit enclosed between two of the Earth's largest mountain systems: in the north the K'un-lun, in the south the Karakoram—Transhimalaya. It is a drainageless highland of immense, longitudinal plains with numerous generally salty lakes which, in the area surveyed by us, nowhere descends below 4,800 m. The plains are separated by disconnected mountain ranges and mountain groups which mostly consist of Mesozoic strata. The width of this land mass amounts to seven degrees of latitude at its broadest part by a length of some fifteen degrees of longitude. Westward, the border ranges approach each other asymptotically and ultimately the plateau wedges out about long. 78° E. Here, the Tibetan Mass has been subjected in an extremely high degree to the violent forces which created the border ranges, and its geological structure has become almost hopelessly entangled.

The Chang-thang occupies in the orographic picture of southern Asia a position similar in many respects to the Cordilleran Intermontane Geanticline between the Coastal Cordilleras and the Rocky Mountains in western North America. Like the coastal Cordilleras, which fringe the western margin of the two Americas from the Behring Strait to Cape Horn and beyond with a length of some 16,000 km., the Himalayas extend uninterrupted along the southern border of the Tibetan Mass as a part of the southern stem of the Mediterranean Alpidic orogene. Like the Rocky Mountains, the Aghil Ranges or the Tethys-Karakoram separates the geanticline from the Angara continental block, and in the same way as the Rocky Mountains the Aghil Ranges dwindle, expand, and finally extinguish southward, resp. eastward.

In this comparison the Tibetan Mass has its counterpart in the Jurozephyria of CRICKMAY (1931), which is split off from the continent at about lat. 35°, wedging out towards the north-north-west. At the great syntaxial bend of the Cordilleras in Alaska, the geanticline appears again as the Juroberingia of CRICKMAY, expanding westward between the northern Rocky Mountains and the Aleutian arches. In the same way the Iranian Mass appears in the Mediterranean orogene at the syntaxial bend of the Karakoram—Himalayas, and farther west the Pannonian Mass between the Karpathian and the Dinarian ranges (KOBER 1928, STAUB 1928, DE BÖCKH a. o. 1929). Like other median masses, the orography of the Tibetan Plateau is dominated by germanotypic tectogenesis, and the region is further characterized by young intense volcanism of mediterranean character.

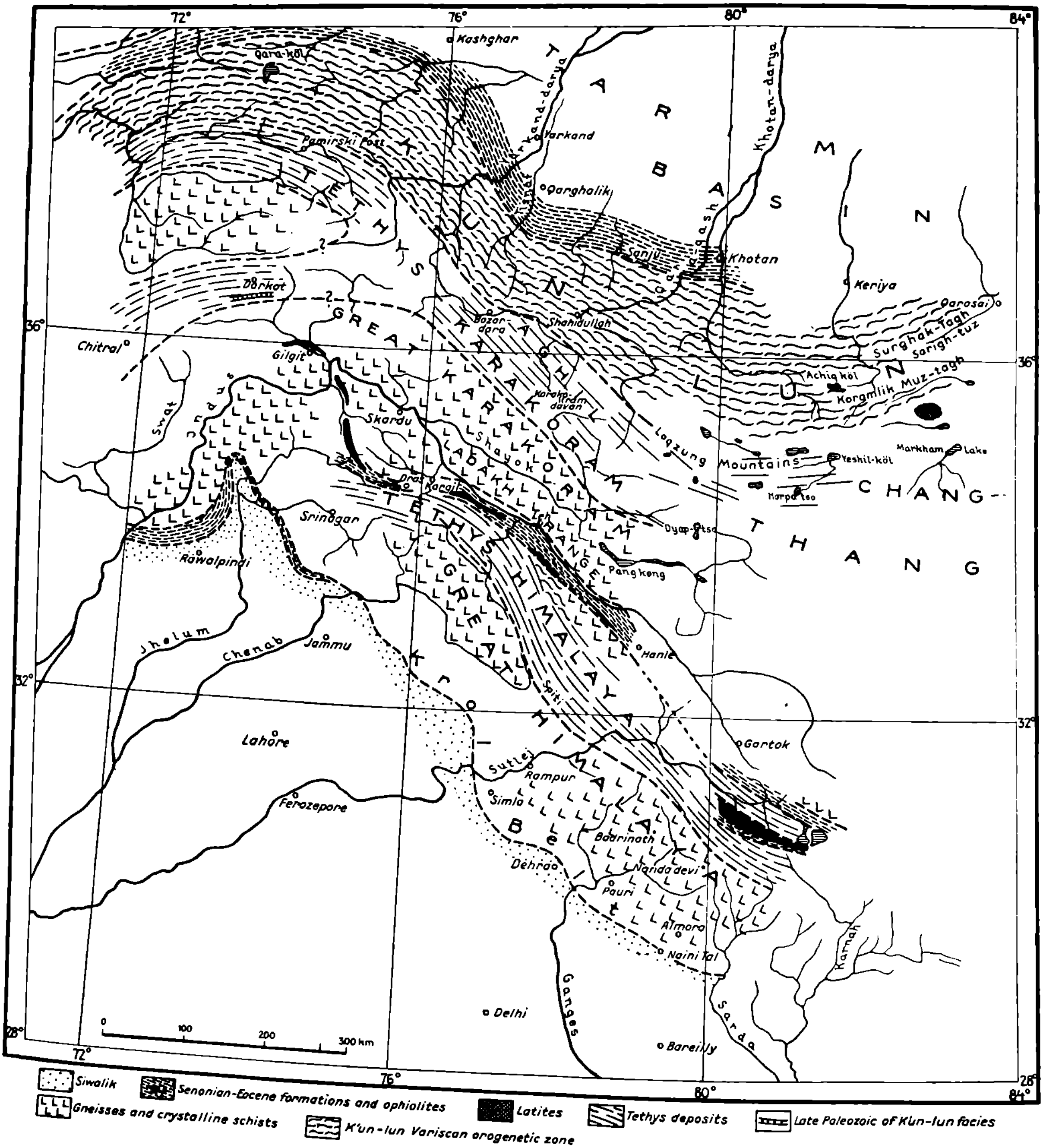


Fig. 1. The principal sedimentary and crystalline zones in the Centralasian Alpidic orogene.

In the west, in Kashmir and Ladakh, where the Tethyan geosynclinal zones are most strongly compressed, the interspace between the Angara Continent and the Indian Gondwana Mass is occupied by crowded mountain ranges which, from the geological point of view, have been grouped into four large mountain systems: the K'un-lun, the Aghil Ranges, the Karakoram, and the Himalayas (Fig. 1).

The Karakoram, inclusive its eastern extension the Transhimalaya, is a broad geanticline of mainly crystalline, largely Paleozoic rocks intruded by granites of various age. This zone appears today as a threshold between the Dinaridic ranges of the Himalayan geosynclines in the south, and the Alpidic ranges *sensu stricto* of the Tethys-Karakoram in the north. It seems, however, not to have existed as an effective barrier during the Late Paleozoic, but may have acted as such temporarily during the Mesozoic and certainly since the beginning of the Tertiary. The crystalline zone of the Karakoram extends uninterrupted into the southern Pamirs and Hindukush, partaking in the syntaxial bend of the Alpidic orogenetic zone around the Gondwana spur of north-western India (WADIA 1931). Its extension eastward into Tibet is not so clearly outlined because of the more shallow Alpidic folding, which has not brought the crystalline fundament to the surface to the same extent as in the west. Although the orographical relation between the Transhimalaya and the Ladakh Range, *i. e.* the most southerly of the Karakoram ranges, is not known, the geological data available hint at a more or less intimate connection. It is known by HEDIN's reconnaissances that granitic and crystalline rocks are also extensively exposed in the Transhimalaya, capped by continental Tertiary formations and large masses of young acid effusives.

South of the Karakoram—Transhimalaya extend the Himalaya Ranges in wide arches convex to the south. They are separated from the former by the longitudinal valley of the upper Indus and the Brahmaputra, some 2,200 km. in length, which follows the trace of a Cretaceous foredeep in front of the Karakoram—Transhimalaya, the folded flysch deposits of which were intruded by large masses of ophiolitic eruptives during the Late Cretaceous and the Early Tertiary. This trough marks the northern boundary of the Himalayan structure with its huge sheets of crystalline schists and Paleozoic and Mesozoic sediments of enormous thickness, overthrust to the south, piled one upon the other in the Himalayas and along the Himalayan frontier, as revealed in the beautiful sections of HEIM and GANSSER (1939).

The Great Himalaya terminates as a prominent topographical feature in the Nanga Parbat (8,125 m.) and is not in evidence as such on the other side of the Indus. "Yet it cannot be regarded as terminating in the Nanga Parbat. Instead, the fold-axes are bent abruptly to the south-west through Kohistan and North-East Hazara, and the Himalaya may be said to terminate as an orographical unit in the hills to the east of Campbellpore" (WADIA 1932, p. 228).

By the crystalline zone of the Great Himalaya Range, in which the oldest rock formations of the orogene are laid bare, the richly fossil-bearing Paleozoic and

Mesozoic geosynclinal deposits of the Zanskar- or Tethys-Himalaya in the north are separated from an equally imposing mainly Paleozoic geosynclinal sequence of strata of entirely different facies almost bare of fossils, which forms an important constituent of the Lesser Himalayas. The total difference in the facies of the deposits on the two sides of the range indicates that the two areas existed as separate sedimentary basins already at the beginning of the Paleozoic (WADIA 1926, p. 85).

In the Tethys-Himalaya there are no certain evidences of any regional Variscan folding although a great disconformity usually separates the Permian—Mesozoic sequence from the older Paleozoic. The transgressive strata generally rest concordantly or nearly so upon their fundament, and when overlap occurs it may be due to broad undulations of epeirogenetic character. In Kashmir, the Tethyan development was introduced by enormous outpourings of basaltic lavas, the Panjal Trap, which began in the Lower Permian, culminated in the Middle Permian, and lasted, locally, into the Triassic.

On the northern side of the Karakoram, the Late Paleozoic and Mesozoic Tethys deposits attain equally great thickness as in the south; the compression did, however, not result in mass movements comparable to the large, flat overthrusts in the Himalayas; minor, generally steep overthrusts with undecided vergence are common. These folded rocks form the Tethys-Karakoram, the western part of which is represented by the Aghil Mountain System. In this mountain system were comprised by VISSER (1935, I, p. 205) the ranges running north-west—south-east between the Karakoram Main Range (as defined in Chapter III) and the K'un-lun. This zone connects in the north-west with the Tethyan formations of the Murgab and Pshart ranges in the southern Pamirs along the northern side of the Karakoram—Hindukush Arch. In the east, on the other hand, about long. 78°, where the ranges begin to assume an easterly trend, the folding becomes less intense, the Mesozoic formations have been extensively removed by denudation, exposing the subjacent Paleozoic fundament. It is therefore hardly possible to draw a boundary between the Aghil System and the Karakoram here.

Like the Autochthonous Central Massifs of the European Alps, the K'un-lun formed the northern border of the Tethys at the beginning of the Mesozoic. It is the most southerly of the Altaidic mountain systems which travers the Angara Continent. But, whereas the Autochthonous Central Massifs in the West were invaded repeatedly by the Mesozoic transgressions and finally became embodied in the Alps by large overthrust masses from the compressed geosynclinal zones in the south, the K'un-lun remained above the level of the sea throughout the Mesozoic Era, and no thrust sheets from the Tethyan geosynclines passed over it. This difference is due to the fact that here in the East, the large overthrust movements principally developed within the Dinaridic zone of the Tethys and were directed towards the south over the Gondwana Land, whereas in the Alps great thrust sheets developed within the Alpidic zone with vergence towards the north. In the west, the

K'un-lun is intimately welded to the Aghil Ranges, but eastward, in the western Chang-thang, the K'un-lun becomes fringed by a broad platform of similar geological structure as the range. This platform forms the K'un-lun Plains.

The K'un-lun borders, in the north, on the Tarim Basin, a part of the Serindian Mass of ARGAND (1924). Along the southern border of this foreland developed, in the Paleocene, the most northerly of the para-geosynclinal depressions of the Alpidic orogene, whereby the epicontinental sea of Russian Turkistan advanced along the K'un-lun slope at least to long. 80°, and lingered until the beginning of the Oligocene. Its sediments are folded with overthrusts with moderate southerly dip along the K'un-lun.

The re-entrant or curvature of the Karakoram ranges towards the east about long. 78° at the western end of the Tibetan Plateau, is a complex phenomenon. In the western Chang-thang, the present orography is largely determined by very young germanotypic tectogenesis, the trend-lines of which usually diverge more or less markedly from the earlier axis of folding. This appears clearly on the geological maps Pl. A and Fig. 8. They show that, in the region between long. 76° and 83° E, the general trend of the axis of Alpidic folding gradually curves from N. W.—S. E. into W. N. W.—E. S. E., whereas at the same time the orographical trend-lines suddenly change into due east or even east-north-east.

CHAPTER I

THE WESTERN K'UN-LUN

Orography.

The huge barrier which K'un-lun forms all along the southern border of the Tarim Basin is a late feature which mainly developed during the Tertiary and the Pleistocene in connection with the general upheaval of the Tethyan orogenetic zone. The K'un-lun begins in the west as the eastern extension of the Transalai Ranges, the most northerly of the Pamir Archs. The Western K'un-lun or the Yarkand Arch extends from there in a south-easterly direction, separated from the intensely folded Tethys deposits of the Aghil Ranges by narrow valleys. We find here the highest elevation in the K'un-lun System in the Muz-tagh-ata which reaches about 7850 m. The slope to the Tarim Basin is deeply dissected with erosion remnants of ancient piedmont plains at various levels and young terrace topography along the base (DE TERRA 1932).

About long. 78° E., the ranges curve to the east-south-east, the Suget Range is split off by the longitudinal course of the Qara-qash Valley to end in the region of Aq-sai-chin. The main range continues with easterly trend reaching altitudes between 6,000 and 7,000 m. The K'un-lun is here divided into two main ranges by the longitudinal course of the narrow and inaccessible Yurung-qash Valley. East of Khotan, the outer zone of the K'un-lun ends abruptly in the Tikelik-tagh, the frontier recedes a considerable distance to the south and is formed, further east, by the snowy Ulugh-tagh and its extension, the Surghak-tagh or Shemallik-Muz-tagh. At the same time, the main ranges diverge and give place to a wide plain with several lakes, the largest of which is the Achiq-köl at about 4,450 m.

The northern border range, the Surghak-tagh, takes here an east-north-easterly direction and steadily decreases in size eastward. At Qara-sai, where it is pierced by the Sarigh-tuz River, it forms a narrow ridge only, and behind to the south towers the Usu-tagh, which is the steep escarpment of the slightly warped margin of the drainageless Tibetan Plateau. It merges westward into the plain of Achiq-köl.

The southern border range of the Achiq-köl depression likewise curves to the east-north-east about long. 82°. Its western part is known on the maps as the Chong-Muz-tagh and reaches above 6,900 m. in the Keriya River head region according to Deasy (1901). We traced it to long. 83° 1/2 where it gradually decreases in magnitude. In the east, where we crossed it, the range is only five kilometres broad; it rises 700 to 1,000 m. above the adjoining hilly country, but is divided by low passes into a string of hills which gradually become lower eastward. Our caravan people from Qara-sai called this part of the range Koramlik-Muz-tagh.

Thus, seen from the south, the mighty Western K'un-lun almost disappears as a connected barrier eastward; only the frontier range, the Surghak-tagh and, far to the south, the not very imposing Koramlik-Muz-tagh remain here of the large mountain system. Farther east, however, it again increases in magnitude to form the Middle K'un-lun. But for the great upheaval during the Tertiary and later, we would have had here a broad gap in the range, as is often the case elsewhere in the strongly degraded Variscan mountain systems.

The Crystalline Rocks.

Where it has been studied from the Muz-tagh-ata to the Qaranghu-tagh south of Khotan, the main range of the Western K'un-lun consists of gneisses and crystalline schists intruded by Pre-Jurassic granites and metamorphosed gabbroic rocks. But further east, this elevated crystalline zone disappears, and about long. 83° E. crystalline schists are entirely absent from lat. 35° N. northwards to the Sarigh-tuz-yilga. Within this broad zone dominates a moderately strongly folded complex of Paleozoic mostly fine-grained, dark graywackes, quartzitic sandstones, and slates with a few beds of dark crinoid-bearing limestone. Crystalline schists, gneisses, and strongly deformed granite form, however, the frontier range, the Surghak-tagh, between the Sarigh-tuz-yilga and the Tarim Basin.

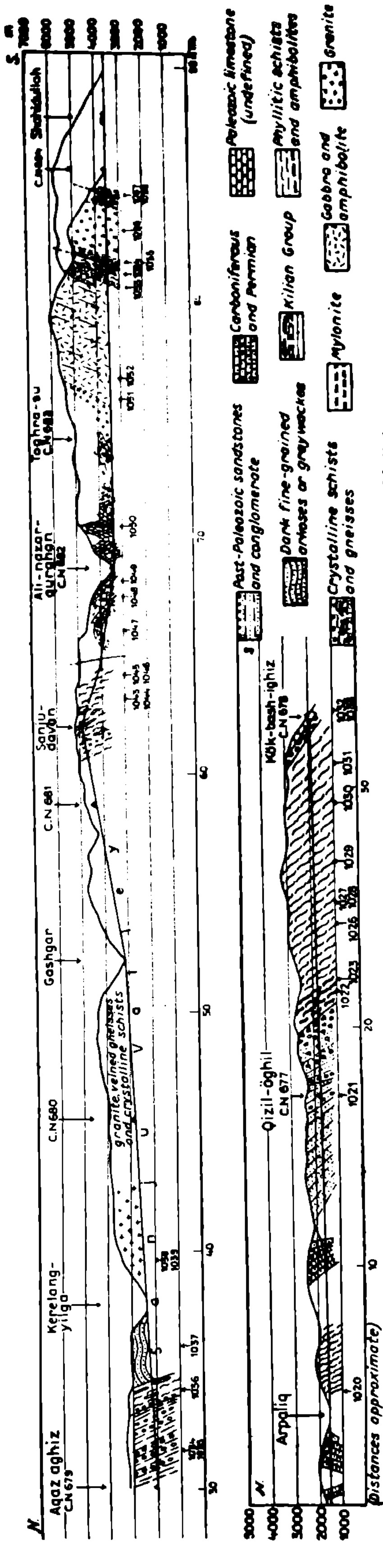


Fig. 2. Section across the Middle K'un-lun between Sanju and Shahidullah.

The oldest formations of the Western K'un-lun are found amongst the rocks in the crystalline zone of the main range and in overthrust or horst-like masses along the northern slope. In a section along the main trade route via Sanju-davan, the crystalline zone of the main range attains a width of 65 km. The zone of maximal upheaval, which reaches about 6,300 m. and which is enclosed in the hairpin bend of the Qara-qash River at Shahidullah, contains here a huge intrusion of medium-grained plagioclase-amphibolite, several kilometres broad and with steep northerly dip. It borders along the southern side with thrust contact on strongly microfolded calc-schists and granite-mylonite-schist which cap a large sheet of granodiorite. The thrust is directed towards the south (Fig. 2).

At the upper contact, the amphibolite borders on similar granodiorite over a syntectic zone. This granodiorite appears as concordant intrusions in a very thick series of massive quartzites, quartzitic schists, garnet-muscovite-schists, calc-schists, and large masses of veined marble and darker crystalline limestone, which are cut by dikes of dolerite (?) and mafic alkaline rocks (1050). These schists which constitute the supposedly Pre-Cambrian Karakash Group of De Terra (1932), form the southern slope of the Sanju Range above Ali-nazar-qurghan with predominatingly east-south-easterly strike.

Similar highly crystalline schists form also the northern slope of the range as far as Ghasgha (Gezge). Here, granitic rocks appear again in large masses and dominate, intimately intermixed with schists and veined gneisses, down to the entrance of the Kerelang-yilga. At this place, a fault which has strongly brecciated the granite, separates it from a zone, 1—2 km. broad, of dark violet gray, very fine-grained quartzitic arkoses with remarkably youthful appearance, and deformed into broad, shallow folds. Another fault near the village of Tam-karaul, forms the boundary between these rocks of the main range and the less strongly metamorphosed formations of the outer K'un-lun.

This important tectonic boundary passes nearly due west intersecting the Kilian Valley south of Lamlung-mazar with foliated granite at the boundary (De Terra 1932, p. 36), and further along the middle course of the Tisnaf Valley at Khalastan. Here, a great complex of Middle Paleozoic porphyrites, keratophyres, and pyroclastics appear at the boundary, bordering to the south on a broad zone of coarse-grained, lavendar gray microcline-biotite-granite, the quartz of which shows only very faint traces of strain shadows. The granite grades into granite-porphyry at the contact, where the porphyritic lavas have been transformed into amphibolites and chloritic schists impregnated with quartz veins.

Higher up the Tisnaf Valley, the crystalline schists of the main range emerge from below the granite six kilometres north of Kude-mazar, dipping 20° towards W. N. W. It is a complex of biotite-quartzite- and biotite-muscovite-schists with rare beds of bluish quartzite and marble, locally interwoven with granitic and pegmatitic veins and minor granitic intrusions; it extends 30 km. up the valley. The strike fluctuates between N. 55° W. and N. 35° E. with persistent westerly dip penduling between only 20 and 50°. The strike of this complex intersects obliquely the trend of the ranges and the strike of the formations of the outer K'un-lun.

These rocks terminate at Qara-aqin at a large body of coarse-grained, porphyritic microcline-granite, and then follows a new stratigraphic unit in which the valley is deeply incised a distance of 8 km. It is a monotonous sequence of dark brownish and violet, mostly fine-grained quartzitic arkoses with subordinate beds of varied coloured slates and limy horizons, the whole strongly folded with dips about 70°, the strike fluctuating between N. 50° E. and N. 65° W. The series resembles strikingly the quartzitic arkoses at Tam-karaul in the Sanju Valley, but the chlorite of the latter is replaced by hornfelsic biotite and the feldspar is largely granulated. The series is cut by dikes of porphyrite and granite-porphyry and, at Tora-öghil, by a broad intrusion of quartz-diorite, dipping 60° towards S. 10° W. at the southern contact with the arkose.

Three kilometres above Tora-öghil, the arkosic series terminates at another large body, 3 km. broad, of coarse-grained, pink, porphyritic, microcline-biotite-granite without any traces of deformation. It grades into a flesh red, fine-grained variety towards overlying crystalline schists. These form, however, only a thin cover and above follows, just below the Yangi-davan, the coal-bearing division of the Mesozoic Yarkand Group with a thick basal formation of light gray gravelly sandstone.

We return to the Sanju section, Fig. 2. North of the great disturbance at Tam-karaul, follows a new great rock complex, the Kilian Group of De Terra (1932) with persistent steep (50—80°) southerly dip. Its northern (lower?) part is a very thick and monotonous series of coarse, largely gravelly, phyllitic graywackes of generally grayish and greenish colour with well water-worn conglomerates. The pebbles, which not seldom attain a size of some 30 cm., consist of white quartz, various mostly fine-grained arkoses, black, carbonaceous siliceous slates and siltstones. Fresh perthitic potash feldspar enters abundantly in the sandy groundmass. The material of the graywackes differs from the conglomerates only by the smaller size of the fragments. Nearer Tam-karaul these rocks border on a strongly deformed monomict limestone conglomerate of great thickness, with small pebbles of light and dark gray crystalline limestone, and then follow phyllitic slates with beds of white crystalline limestone or marble. Isoclinal folding is here locally discernable.

Three kilometres above Aqaz-aghiz, the graywacke series borders apparently conformably on much more strongly metamorphosed phyllitic schists which, judging by Wyss' description (1940) of rock specimens collected by him, extend down to Kiwaz near the mouth of the valley. We followed the schists in the direction of the strike (N. 80° E.) from Aqaz-aghiz to the pass of Chu-chu-davan on the eastern side of the Sanju Valley. At the pass, the schists are overlain unconformably by a coarse conglomerate with well waterworn boulders mostly 10—20 cm. in size but some nearer half a metre. They consist of various crystalline schists derived from the fundament, gray and reddish quartzites, quartz, and gray crystalline limestone. The thickness amounts to some forty metres inclusive interstratified layers of gravelly graywackes.

Above follow black, carbonaceous siliceous slates and black, massive siltstone in which occasionally solitary, small rounded gravels of milky quartz occur; then follows bluish black, carbonaceous limestone with fragments of undefined fossils. In a smooth outcrop on the western side of the pass, a large broom of corals was seen but could not be extracted. At the pass, the beds are dipping 60° towards S. 10° W., but the dip decreases eastwards to 30° at Kök-bash-ighiz. The thickness of this marine series is not known because the superimposed strata were not visible in the rugged topography.

It should be noted that black siliceous slate and siltstone, very similar to these, occur abundantly in the detritus of the conglomeratic graywacke series in the Sanju Valley, and is one of its most characteristic constituents. Pebbles of the black fossiliferous limestone have, however, not been found and no trace of it is seen in the coarse detritus of the graywackes.

The further extension of the section passes from the Chu-chu-davan along the Arpaliq or Puski Valley down to the Tarim Basin. We pass here for a distance of some 13 km. a huge complex of very monotonous crystalline schists with persistent southerly dip penduling about 45°. These schists are, contrary to those of the Kilian Group, completely recrystallized and strongly foliated; all primary sedimentary features are effaced. Amongst the rocks represented in our collections may be mentioned dark green chlorite-albite-schists, greenish gray calcareous epidote-chlorite-albite-schists rich in ore, quartzose chlorite-biotite-, and chlorite-muscovite-schists sometimes with porphyroblastic biotite, sometimes rich in albite, and microcline-muscovite-schists with porphyroblastic microcline. All the rocks are rather fine-grained and rich in titanite.

This great complex of mainly quartzose schists probably largely represents arenaceous and calcareous sediments of graywacke character, which have obtained their present features by regional metamorphism. Apart from the difference in metamorphic facies the complex differs from the crystalline schists of the main range by the absence of pure quartzites and pure calcareous sediments.

One kilometre and a half above the hamlet of Qizil-öghil (Camp N 677), the crystalline complex borders with a thrust plane dipping 50° S. on a thick series of Post-Paleozoic sandstones and conglomerates. The overthrust is marked by a large breccia of angular and subangular fragments and blocks of gray, Carboniferous limestone. The beds are beautifully exposed in an unbroken section along the valley which cuts them nearly perpendicularly to the strike (N. 85° E.) for a distance of several kilometres, the dip gradually decreasing to 30° S.

A short distance above the village of Arpaliq, the sandstone series borders with a fault on gray, semi-crystalline limestone of great thickness and with moderate to steep southerly dip. Another fault separates this latter from a broad zone of microfolded, quartzose biotite-chlorite- and chlorite-sericite-schists identical with those above the sandstone series. North of Arpaliq, in the outermost of the foothills, the massive limestones appear again and border on the strongly dislocated Tertiary of the Basin with a strongly brecciated contact zone.

Some 15 kilometres to the west, below the village of Kiwaz in the Sanju Valley, Stoliczka (Blanford 1878, p. 22) describes a section very similar to ours; it is reproduced as Fig. 3 below. He found in the massive limestone, a *Spirifer*, possibly *Sp. striatus*, and two species of *Fenestella*, indicating Late Paleozoic, probably Carboniferous. Later, Wyss (1940) collected a rich Upper Uralian fauna at the same place, probably from younger beds associated with the massive limestones.

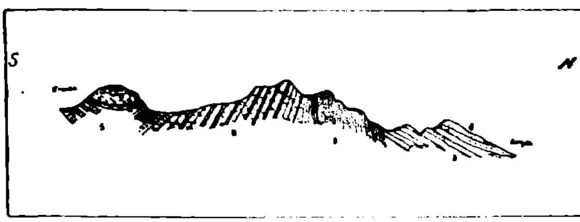


Fig. 3. Section at Kiwaz, Sanju Valley, according to Stoliczka (Blanford 1878, p. 22).
1. Chloritic schists.
2. Late Paleozoic limestone.
3. Red sandstone.
4. Sandstones and marls with *Gryphæa vesiculosa*.
5. Conglomerate with reddish clay (Distance about 2 miles).

On the general geological map of De Terra (1932), the graywacke series and the quartzitic schist series in the Sanju Valley, have been included in the Kilian Group. The observations recorded above show, however, that a distinction must be made between them, the schists series having been subjected to much more intense regional metamorphism than the graywacke series and associated formations.

In the Kilian Valley, the next larger valley to the west, the succession of formations and the tectonics seem to be rather similar to those found in the Sanju Valley as suggested by De Terra's sections and description. The rocks of the Kilian Group, which here includes also older members of the sequence, occupy a zone 15 km. broad, between the crystallines of the main range and Aq-shor-talak, compressed into isoclinal folds with predominatingly steep southerly dip. At Aq-Shor-talak follow phyllitic and quartzitic schists in similar position which, above the village of Kilian, border on an anticline of Late Paleozoic limestone and this, in turn, on the Tertiary formations of the Basin.

Also still further west, south of Kök-yar, the formations of the Kilian Group are developed with very great thickness, occupying a zone 15 km. broad, and also here with generally steep dip. They are separated from the crystalline rocks of the main range by a broad zone of Paleozoic lavas, and are intruded by quartz-diorite near the border.

De Terra arrived at the following stratigraphic subdivision of the Kilian Group in ascending order:

1) a basal formation of coarse conglomerates (about 200 m.) with pebbles of quartz and crystalline schists;
2) dark gray quartz-phyllites, in part gravelly and conglomeratic, associated with graptolite-bearing, carbonaceous slates and cherty beds, with an aggregate thickness exceeding 1,000 m.;
3) mostly dark, quartzitic graywackes of variable coarseness and very great thickness;
4) a great complex of crystalline limestones associated with crystalline schists. Fragmentary fossils have been found occasionally in the limestones; this subdivision is probably of Silurian age.

The conglomeratic graywacke series of the Sanju Valley probably represents — in part — divisions 1 and 2, the calcareous complex below Tam-karaul probably division 4.

A similar position as the Kilian formations occupies in the Transalai and the Alai Ranges a complex thousands of metres thick of dark slates, chloritic, calcareous, and arenaceous schists, quartzitic sandstones, graywacke rocks, compact pudding stones, and interbeds of dark limestones. In the latter, Ordovician fossils have been found at some places. South-west of Osch, beds with Cambrian brachiopods are associated with the complex, which therefore is supposed to represent mainly the Cambro-Ordovician (Mushketov 1928, Nalivkin 1932, Nöth 1932). It is succeeded by fossiliferous Silurian limestones and shales of great thickness.

The map, Pl. A, shows that the zone occupied by the formations of the Kilian Group rapidly becomes more narrow eastwards, the width decreasing from 15 km. in the Kilian Valley to 3—4 km. in the Sanju Valley. South of Khotan, the Kilian formations are not represented. Here, the structure of the K'un-lun slope differs strikingly from that of the more westerly regions. Thus, at the sharp bend of the Qara-qash River above Langhru, the Tertiary of the Basin borders immediately on crystalline schists, which form the steep frontier of the K'un-lun, rising abruptly about 700 m. above the foreland (Pl. I, Fig. 1). The boundary is a fault with steep to moderate southerly or south-easterly dip.

We have here a huge complex of very monotonous, mostly quartzose crystalline schists which, alone, occupy a zone more than 50 km. broad of the K'un-lun slope. The sketch map, Fig. 4, shows the remarkably flat position of the schists, which extend southward like an only slightly deformed sheet over a large part of the area to the watershed between the Mitaz and the Nissa drainage systems, an architecture similar to the one found in the upper Tisnaf area.

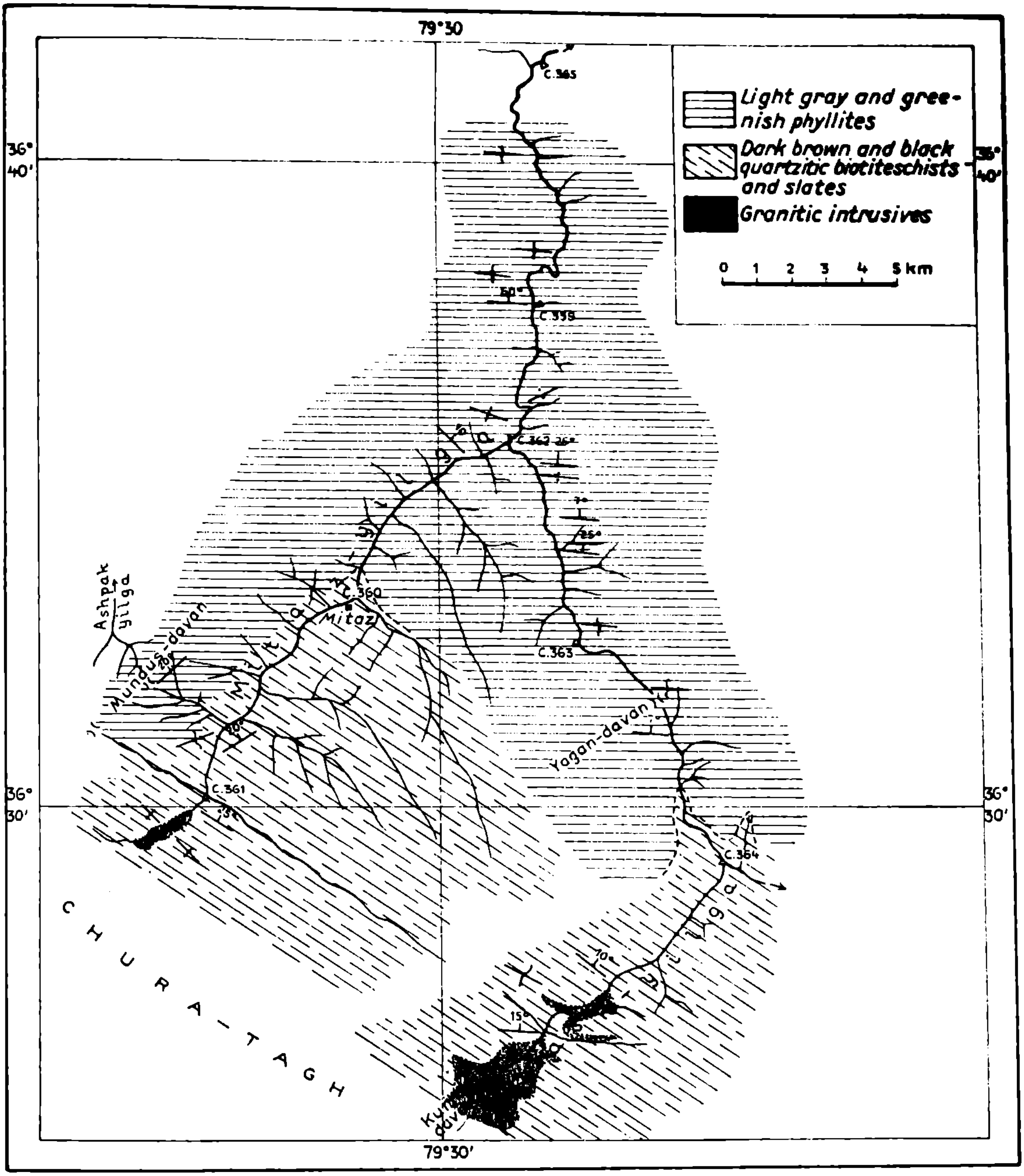


Fig. 4. Sketch map of the Mitaz Hills south of Khotan.

In this complex, two main divisions are distinguished. The upper consists of mainly light grayish and greenish, fine-grained, more or less quartzose epidote-muscovite-feldspar-schists with porphyroblastic greenish biotite, biotite-feldspar-schists with porphyroblastic microcline, calcareous biotite-chlorite-schists with or without epidote, and muscovite-chlorite-feldspar-schists with porphyroblastic ore minerals. Tourmaline occurs occasionally. The lower division, which crops out only farthest to the south, consists of mainly dark brownish gray, fine-grained, banded or laminated quartzose biotite-zoisite-schists in part rather massive, more or less calcareous biotite-feldspar-schists, and bluish gray calc-schists. Nearer the subjacent granite, the rocks may acquire the appearance of veined gneiss by impregnations of quartz and feldspar. The metamorphism gradually decreases upwards. Between both divisions, the transition is gradual.

A very fine section through this complex of schists and its fundament is obtained in the range of Yaghan-davan between the upper Chach Valley and Yaghan-aghiz. The schists have here predominatingly low northerly dip which locally becomes undulating (cfr Fig. 4). The upper division of mostly greenish phyllites forms all the northern slope and the watershed. Below it follows, on the southern side of the Yaghan-davan, the dark schists rich in biotite of the lower division, which here attains great thickness. Then follows, in the Chach Valley, several beds of light gray, medium-grained, granulitic gneiss resembling coarse marble, intruded into the schists and dipping conformably to these 10—15° towards north-east. The uppermost granitic bed has the following mineral composition: quartz (only slightly deformed), nearly pure albite (An_{04}), microcline, much muscovite, and pale violet garnet; the rock is recrystallized and the feldspars largely *eingeregelt.*

Near the head of the valley appears as the lowest of these intrusions a large body of quartz-mica-diorite which builds up the slopes of the valley as far as Kurme-davan with an exposed thickness of at least 500 m. In the adjoining high mountains, the eruptive is capped by the schists in nearly horizontal position. It is a medium-grained white rock stained with black biotite-scales and consisting of rather strongly deformed quartz, zonary built oligoclase-andesine (An_{45}—An_{20}), potash feldspar very sparsely in the interstices, biotite, muscovite, clinozoisite, and apatite. The rock represents a slightly younger intrusion than the granulitic gneiss, and has caused its metamorphism.

13 km. to the west-north-west, in the upper Mitaz, the granulitic orthogneiss is exposed to a depth of some 50 m. in a window in the covering schists, which also here are developed as dark brownish, quartzose biotite-zoisite-schists. The mineral composition of the gneiss is the same as in the Chach Valley, the only difference being a slightly higher content of An in the plagioclase (An_{13}—An_{03}). This bed seems therefore to extend over a large area at approximately the same stratigraphic level.

In spite of the usually flat position of the crystalline complex, the strata have been intensely deformed; the present bedding and foliation does not represent the original stratification. At the Mundus-davan in the upper Mitaz, the beds resemble a series of mud flows piled one upon the other with a general dip of 20° towards N. 50° W. This deformation is, however, older than the regional metamorphism.

Besides this bedding there is also a schistosity with fairly constant strike about N. 40—60° E. and steep dip. This becomes more intense northwards and is the only structural feature discernable in the Ulugh-art Massif and along the mountain frontier. To what extent this schistosity here coincides with the bedding is not known.

This complex of crystalline schists probably represents a sequence of fine-grained argillaceous and calcareous, sandy sediments of very great thickness. No trace of gravelly or conglomeratic horizons have been noticed, neither pure quartzites nor considerable formations of limestones. Although more strongly metamorphosed, the upper division resembles strikingly the great complex of crystalline schists in the Arpaliq Valley described above; the rocks are, in hand specimen, hardly to be distinguished. The dark brownish quartzitic biotite-schists, the massive beds of which are the most conspicuous members of the lower division of the Khotan Complex, have not been encountered in the Arpaliq section. They may possibly represent the dark quartzitic arkoses of the upper Tisnaf Valley in a more far advanced stage of metamorphism.

Orders from the governor-general CHIN-SHU-JEN to return to Urumchi, prevented the author from carrying out the planned reconnaissance of the regions of Nissa and Qaranghu-tagh nearer the K'un-lun watershed, where extremely interesting geological conditions could be expected according to BOGDANOVICH's explorations in 1889 (1892). According to the general section of BOGDANOVICH between Khotan and Qaranghu-tagh, the large massif of Tikelik-tagh which rises east of the lower Yurung-qash between the plain and the Buya Valley, consists of crystalline schists bordering on granite along the southern side. This is evidently the eastern extension of the crystalline complex of the Chach and the Mitaz valleys with its fundament of quartz-diorite. This crystalline zone terminates abruptly in the Tikelik-tagh, the K'un-lun frontier recedes far to the south and is formed further east by the steep slope of the main range in which again crystalline rocks appear.

The interspace between this southern crystalline zone and the Tikelik-tagh is occupied by a broad syncline of Carboniferous limestones, which enclose multicoloured, marly formations referred to the Angara Group. The limestones are, near Qaranghu-tagh, in part metamorphosed into coarse-grained, white marble in which still the fossils stand out very distinctly.

The Late Paleozoic Formations.

Our knowledge of the development of the Western K'un-lun during the later Paleozoic is due mainly to BOGDANOVICH and DE TERRA. The Devonian formations are intimately associated with the formations of the Kilian Group, and have probably the same distribution. As Devonian have been identified with some certainty only more or less strongly crystalline limestones and shales in which a few fossils of Middle Devonian affinity have been collected by the named explorers. The occurrence of Lower, Middle, and Upper Devonian horizons associated with crystalline schists in the Vanch Range of the northern crystalline zone of the Pamirs, may lead us to expect a similar more full representation of the Devonian also in the eastern extension of this zone in the K'un-lun.

As the youngest division of the Devonian is considered a series of slightly metamorphosed, redeposited tuffaceous material and greenish, sandy shales with indeterminable plant remains. These beds probably represent the base of the next great unit of the Paleozoic sequence, *viz.* a great complex of various porphyrites, keratophyres, tuffaceous beds, and agglomerates, which locally attain a thickness of thousands of metres. They record an epoch of very intense volcanic activity at the end of the Devonian or the beginning of the Carboniferous comparable to the great Franciscan complex in the coastal Cordillera of California.

The stratigraphic position of these beds is fixed by the succeeding Carboniferous complex, which rests upon the folded Devonian unconformably. It begins with the Tisnaf Beds: coarse, detrital masses derived largely from the volcanic series and older formations but containing also pebbles of red granite. It grades in the higher parts into red-violet, gravelly arkosic sandstone. Then follow, conformably, limestones and shales referred by DE TERRA to the Lower and Middle Carboniferous. In an earlier paper, the present author (1941) has shown, that the supposedly Lower Carboniferous marine beds as well as the subjacent red sandstones possibly also are to be included in the Middle Carboniferous. Thus, the folding of the subjacent Lower Paleozoic took place some time during the interval between the Devonian and the late Lower or Middle Carboniferous, *i. e.* the folding corresponds to the Bretonian or to the Sudetan phase of the Variscan orogeny. This was probably the main period of folding in these parts of the K'un-lun, with large overthrusts of alpine type such as represented by the huge sheets of crystalline schists south of Khotan. To this tectonic phase belongs probably also at least the earlier, synorogenetic intrusions of gabbroic, quartz-dioritic, and granodioritic magmas in the crystalline zone of the main range.

It might be expected that such a great revolution as this should have left distinct traces in the Devonian-Carboniferous stratigraphic column of the neighbouring Alai and the basin of Farghana, where all the principal divisions of these systems are represented. Here we find, however, no trace of Bretonian tectogenesis. The youngest Devonian horizons here represent the Famennian; the oldest Carboniferous horizons identified by fossils, represent basal Visean; between them occur very thick unfossiliferous limestones of uniform character exhibited in the section without any trace of break. They speak in favour of a continuity of marine conditions in east Farghana throughout Devonian — Lower Carboniferous time (MUSHKETOV 1928, p. 223). In the Aravan Valley, on the northern side of the Alai near Osch, slightly deformed beds with *Spirifer mosquensis* rest unconformably on steeply dipping older Paleozoic formations, inclusive Visean (BORN 1929). Here, the folding clearly represents the Sudetan phase. In this respect the Alai differs from the Central T'ien-shan where the Bretonian is the main period of folding (GRÖBER 1914, KEIDEL 1906).

In the western K'un-lun a disconformity (DE TERRA) or unconformity (BOGDANOVICH 1892, LEUCHS 1937), which may comprise the greater part of the Upper Carboniferous, separates the Middle Carboniferous from the succeeding Permian formations. These are subdivided by DE TERRA into two main divisions separated by a slight unconformity. The lower, which consists of calcareous shales and limestones with a basal formation of calcareous sandstone, represents Lower Permian of Tien-shan facies; the upper consisting of coarse plant-bearing sandstones with marine interbeds in the higher parts, represents probably the Upper Permian (MERLA 1934). In the Kelpin Region of the western Tarim Basin, similar littoral Late Permian beds rest perfectly conformably on the Permian-Carboniferous sequence.

The Mesozoic Deposits.

At the end of the Paleozoic, the sea receded definitely from Serindia and the adjoining regions subjected to Variscan folding, but for minor confined ingressions at the end of the Mesozoic and the beginning of the Tertiary. The development of the western K'un-lun during the Early Mesozoic is registered in thick deposits of continental sandstones, shales, and conglomerates, the Yarkend Group of DE TERRA, which are the molasse deposits of the rapidly decaying Variscan ranges.

The author has had the opportunity to study these formations at one place only, *viz.* in the valley of Chong-hamasse (Fig. 5), which opens into the Tarim Basin south-east of Ighiz-yar (long. 76° 15′). We have here a monotonous series of mainly very fine-grained, dark gray and greenish, calcareous sandstones, and black and gray shales in rapid alternation, with an exposed thickness of rather more than less than a thousand metres. Gravelly beds are rare. In the lower part of the series occurs a bed of good coal about 0.5 m. thick at the outcrop. The black shale associated with the seam contains plant fossils abundantly (Loc. N 62). The collection which was delivered to the Geological Survey of China for study in 1935 like our other collections of Mesozoic plants, has not yet been described. In 1934, professor T. G. HALLE, Stockholm, identified provisionally the following species:

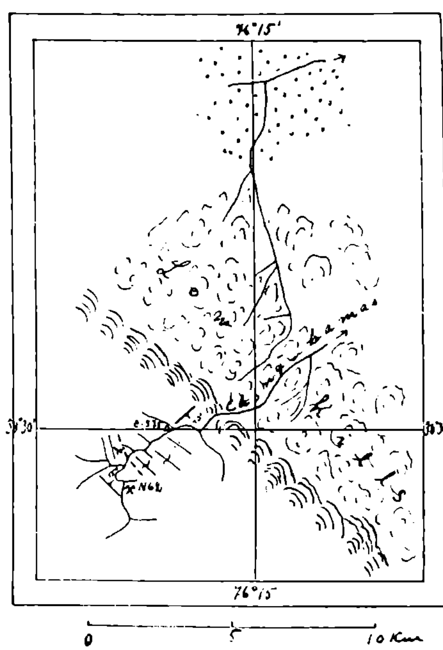


Fig. 5. Situation sketch of the coal pit of Chong-hamas south of Yangi-hissar.

"*Cladophlebis* sp.
Nilssonia cf. *simplex* OISHI (slightly broader than most of OISHI's specimens; cf. however OISHI [Rhaetic Plants from the Nariwa District; 1932] Pl. 45, Fig. 4 on the right).
Nilssonia or *Pterophyllum* sp.
Phoenicopsis speciosa
Pagiophyllum? sp. (Cf. *Elatocladus heterophylla* HALLE)
Problematicum (recalling *Annulariopsis inopinata* ZEILL. from the Rhaetic of Tonkin, but segments united almost to the apex. No commissural furrows but a continuous lamina. May possibly represent some unknown type of pseudo-peltate fernleaf. Cf. *Hausmannia-Clathropteris-"Mazaria"*).

The age of this flora is undoubtedly Mesozoic, most probably Jurassic, but an exact determination will require more careful study, and will be dependent on the age assigned to some other Asiatic floras which are in need of a thorough revision".

Near the contact with the Paleozoic limestone series at the head of the valley, occur numerous large blocks of a coarse conglomerate with boulders as much as 0.3 m. in size composed of various sandstones, white quartzites, and milky quartz. No exposures of the actual contact could be seen because of the thick cover of alluvials along the slopes.

Below Camp N 575, shales become subordinate and stratified, fine-grained, dark gray calcareous sandstones form the upper part of the series. At the foot of the range, the beds are tilted to the vertical and border with fault contact on a low anticline of black shales with thin beds of dark claystone and coaly layers. Then follow in the forehills light gray and reddish sandy shales and very fine-grained, argillaceous, ripple-marked sandstones of considerable thickness, overlain, apparently conformably, by light gray sandstones of rapidly fluctuating coarseness, locally conglomeratic. Fragments of coal occur abundantly in some horizons. Lithologically, these sediments are very similar to the Tertiary Artysh Beds north-east of Kashghar.

A rather different development of the Mesozoic complex is recorded by DE TERRA (op. cit.) in the hills south of Qarghalik. He distinguishes three main divisions which together form the Yarkend Group. The lower division, which rests apparently conformably upon fossiliferous Upper Permian, consists mainly of gray fluviatile and reddish sandstones, in part eolian, interstratified with shales and marls with an exposed thickness of about 440 m. DE TERRA is inclined to place it at the Permo-Triassic boundary but, as no fossils have been found, the age is uncertain.

The middle division of the Yarkend Group is, in the Tisnaf and the Köllqash valleys, composed of fluviatile and lacustrine sediments of generally grayish colour, characterized by frequent alternation of sandy, argillaceous, and conglomeratic beds, and the occurrence of coal seams in the lower part. The exposed thickness amounts here to about 300 m. This series agrees lithologically rather closely with the coal bearing series in the Chong-hamasse although its thickness is much less.

The upper division of the Yarkend Group begins with reddish sandy shales followed by yellow marls with a Lower or Middle Jurassic flora *(Coniopteris hymenophylloides, Taeniopteris vittata, T. de Terrae, Podozamites lanceolatus,* and *Phoenicopsis cf. speciosa).* The exposed thickness amounts to about 180 m.

The coal bearing Mesozoic series appears again with entirely different facies near the top of the K'un-lun main range at the head of the Tisnaf Valley below Yangi-davan. Here, the series begins with gravelly, grayish white sandstone which rests with normal sedimentary contact on folded crystalline schists and granite. Then follows medium- to fine-grained nearly white sandstone with gravelly layers and streaks of coal (about 100 m.) overlain by black, plant bearing shale (Coll. 879) with coal seams and layers of iron-claystone (about 200 m.). At the base, the series dips 20° towards S. 15° E. increasing to about 45° in the upper part. It borders, just below the watershed, on a huge thrust breccia of dark violet quartzite and gray limestone.

If the stratigraphic sequence of the Yarkend Group as recorded by De Terra is true, it follows that here the lower division of arid sediments is missing, and the humide, coal-bearing sediments of the middle division follow directly on the crystalline fundament. This would imply, that a widening of the area of sedimentation took place at the beginning of this stage.

The lithological character of the sediments of the Yarkend Group and the occurrence of coal deposits near the crest of the main range are evidences strongly in favour of the view expressed by De Terra, that the ranges formed by the Variscan orogeny had been reduced by denudation into a region of low relief already at the beginning of the Mesozoic. "Das Flachrelief besass also wohl zu jener Zeit eine Hauptabdachung gegen die heutige Tarimniederung, und seine äussere Gestalt wird mehr einer flachen Landschwelle wie einem starkgegliederten Gebirgsland ähnlich gewesen sein. Ein Bestehen von K'un-lunketten während der mesozoischen Aera, wenigstens soweit deren Schichten uns bekannt sind, möchte ich aus diesen Gründen für unwahrscheinlich halten" (De Terra 1932, p. 60).

The Tertiary Sequence along the northern K'un-lun Frontier.

In the Arpaliq Valley appears between the Late Paleozoic limestones of the foothills and the crystalline zone of the range a series, several hundred metres thick, of mainly fluviogenic sediments of rather youthful appearance, the age of which is not known (Fig. 2). Their actual contact with the Paleozoic beds is not exposed, but the sandstones border with 30—40° southerly dip on the steeply tilted limestones.

The lowest exposed part of the series is a thick formation of reddish, fine-grained sandstones. Up the valley, the sandstones become gravelly, then at Camp N 677 again more fine-grained and of light grayish or pink colour; cross-bedding is common. The dip has here increased to about 60° towards S. 5° E. The sandstones are composed of rather pure quartz sand with fragments of coal, some feldspar, and argillaceous matrix. The gravel consists mainly of gray limestones, some of which are rich in Late Paleozoic foraminifera, but also of brown jasper and sandstones.

Above Camp N 677 stratified gravel and riverine conglomerates become of increasing importance interstratified with sandstones and sandy gray shales with coaly imprints of plants. The dip fluctuates between 30 and 50° S. In the upper part of the series, the conglomerates increase in coarseness and become predominant; the pebbles consist mainly of gray limestones. The sequence terminates with a breccia with subangular pebbles and boulders, as much as half a metre in size, of gray semi-crystalline limestone not unlike the one of the foothills at Arpaliq. Here the dip amounts to about 50° south. This breccia is overlain by the crystalline complex of the upper Arpaliq Valley, beginning with amphibolitic schists with the same dip as the conglomerates. We have here an overthrust of some magnitude.

This sandstone series is not unlike the one, which forms the base of the Tertiary series north of Arpaliq and at Sanju, but it is also remarkably similar to the supposedly Triassic series (Lower Yarkand Beds) described by De Terra in the Tisnaf and the Köllqash valleys.

The base of the Tertiary sequence and its primary contact with the fundament has been observed with some certainty at one place only, *viz.* by Stoliczka near the mouth of the Sanju Valley below Kiwaz (Fig. 3). Here, the Mesozoic Yarkand Beds are not represented, and Permian limestones are overlain by coarse, soft conglomerates interstratified with beds of red sandy silt. The connection between this formation and the main Tertiary sequence south of Sanju (the Sanju Beds) is interrupted by a series of faults.

The lowest observed division of the Sanju Beds is a series of reddish calcareous sandstones in which Trinkler collected *Ostrea bellovacina* var. *trinkleri;* Böhm (1933) places this horizon in the Paleocene or Lower Eocene. Above follow coarse, gray calcareous sandstones and greenish marls locally filled with large species of *Gryphaea* (Stoliczka 1878) and representing Middle Eocene.

Excellent exposures of the Tertiary sequence are found some forty kilometres further east in the Duwa Valley and along the slopes of the Yagme-tagh between the latter and the Qara-qash (Fig. 6). Thus, in the Duwa Valley, 5 km. south of the village of Tash-ariq, Tertiary beds dipping 45° towards S. 30° W. emerge from below overthrust Paleozoic limestone, which here forms the frontier range. From here all the way to Tash-ariq we passed through an apparently connected series of Tertiary strata with a rather constant dip of 15 to 20° towards S. 30—40° W. The

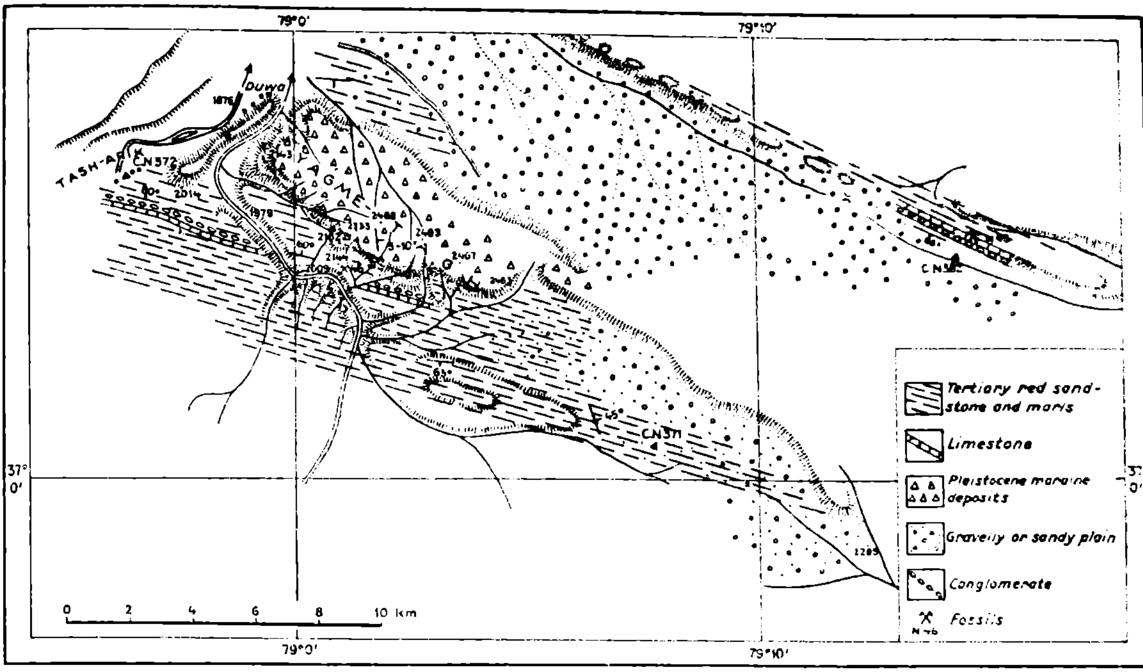


Fig. 6. The Tertiary and Pleistocene beds at Yagme-tagh, W. of Khotan.

uppermost division consists of mainly grayish or greenish calcareous sandstones alternating with red brown silt or marls. About 1 km. downstream, the dominating sediments are red silt or marls, in part gypsiferous, densely interstratified with riverine gravels and reddish, marly sandstones. Then follow, at km. 2.5, yellowish calcareous sandstones alternating with red brown marls and varied coloured silt or shales. Nearer Tash-ariq, outcrops were seen only sporadically.

At the outskirts of Tash-ariq, a fault separates this sequence from another with steep northerly dip. Here, the stratigraphically lowest exposure is a horizon of yellowish gray, dense limestone which becomes sandy in the upper part. Then follows a coarse limestone conglomerate, several metres thick, with well water-worn boulders as much as 15 cm. in diameter, mixed with large Gryphaeas and other shells. Above it comes richly fossil-bearing, coarse, yellowish calcareous sandstone and red, sandy and marly sediments. Near the disturbance the beds are dipping 80° towards N. 10° E. but the dip decreases rapidly northwards.

This very conspicuous conglomerate and associated beds have been traced eastward in the direction of the strike over a distance of 10 km. Along the southern slope of the Yagme-tagh, the yellowish calcareous sandstone, which may have a thickness between 10—20 m, is mixed with quartzy gravel and is richly fossil-bearing. It grades into red brown marl interstratified with fine-grained reddish sandstones. In the lower marly beds, fossils occur in great abundance. The strata are here dipping 60° towards N. 10° E. (Pl. I, Fig. 2).

The fossils of Locality N 46 were collected in the yellow sandstone and the associated red marl at several places along the outcrop mainly by my servants. In the large material thus obtained FREBOLD (1942) has identified the following species: *Ostrea ambolti, Gryphaea (Sokolovia) esterhazyi* var., *Liogryphaea kokanensis, Cardita* sp., *Naticina* sp., and *Conus* sp.

FREBOLD refers *Liogryphaea kokanensis* and *Cardita* sp. to the Upper Eocene; *Gryphaea esterhazyi, Conus* sp., and *Naticina* sp. are referred to the Middle Eocene, and *Ostrea ambolti* to the Paleocene. The coarse, yellowish calcareous sandstone is probably the same horizon as appears at Sanju, and which BÖHM refers to the Middle Eocene. No fossils were obtained in the dense limestone which appears below the conglomerate and may represent a considerably older horizon.

North of Yagme-tagh extends a gravelly desert, about 7 km. broad, with scattered low hills, bounded to the north by a higher ridge which runs in a perfectly straight line in N. 68° W.—S. 68° E. over a distance of 22 km. Here, the marine Eocene beds crop out again dipping 60—70° towards S. 22° W. At Camp N 382 the lowest exposures consist of red gypsiferous marls and reddish marly, fine-grained sandstones of unknown thickness. They are overlain by yellowish or cream-coloured, sandy limestone or marl, about 10 m. thick, crowded with shells (Loc. N 48). Then comes a conglomerate, a few metres thick, composed of well water-worn pebbles of the subjacent limestone, the size of a hen's egg or less, together with fragments of shells embedded in a red silty matrix. Above follow red brown marls, in part gypsiferous, and reddish, fine-grained sandstones in rapid alternation.

But for less thickness and the smaller size of the pebbles, this conglomerate and the subjacent yellow limestone are very similar to the conglomerate and associated beds at Tash-ariq. This correlation is strengthened by the fact, that amongst the fossils collected at Loc. N 48, FREBOLD identified *Ostrea turkestanensis* ROM., an index fossil of the Lower Eocene in Farghana. The horizon of Loc. N 48 should, thus, be older than the beds above the conglomerate at Tash-ariq and Yagme-tagh. This conglomerate indicates a regression of the sea and considerable denudation between the Lower and the Middle Eocene.

In the section at Momuk in the Tisnaf Valley, described by DE TERRA (1932, p. 25, 61), the Lower Eocene is represented by a formation of coarse, yellowish calcareous sandstone (77 m.) with *Ostrea turkestanensis* ROM., overlying a bed of yellowish, hard limestone (3.5 m.). Above the sandstone follow conformably multi-coloured sandy and marly beds with Middle and Upper Eocene fauna. No conglomerate is recorded here.

During his gravimetric survey of a section across the Tarim Basin along the Khotan-darya, AMBOLT discovered a richly fossil-bearing formation in the Tertiary sedimentary sequence at Khotan Mazar-tagh (lat. 38° 30′) in the middle of the desert of Takla-makan. The Mazar-tagh consists of two parallel ridges 100—200 m. high, which extend an unknown distance towards the west-north-west. The southern ridge, which has a red general colour, is called Qara-tagh. It consists according to TRINKLER (1932, p. 103) of red-violet marls and sandstones with 30—40° southerly dip (AMBOLT) and some 100 m. thickness. Above follow a bed of gravel (1 m.) and a thick series of multicoloured sandstones and marls with layers and veins of gypsum.

The northern ridge, which is separated from the former by a gravelly plain, is called Aq-tagh because of its white colour. It consists, according to AMBOLT, of cream-coloured or grayish white, dense limestone interstratified with red marls; deposits of gypsum or alabaster are recorded also. The dip is south-westerly.

In the cream-coloured limestone AMBOLT made a very large collection of fossils (Loc. A 57) amongst which FREBOLD identified the following species: *Ostrea* (several species amongst others *O. ambolti?), Gryphaea* aff. *vesicularis, Modiola* spp., *Pectunculus* spp., *Crassatella* sp., *Lucina* spp., *Cardium* cfr *trifidum, Solen* sp., *Pholadomya norini, Turritella* sp., *Naticina* sp., *Cypraea turkestanensis.*

FREBOLD (1942) states that this fauna, which has very slight affinity to the Eocene faunas encountered elsewhere in the Tarim Basin, cannot represent any Lower, Middle or Upper Eocene horizon but must be either of Paleocene or Lower Oligocene age. Of these alternatives the former is considered the most probable because some forms *(Ostrea* cfr *ambolti, Gryphaea* aff. *vesicularis, Cardium* cfr *trifidum,* and *Pholadomya norini)* are at least closely related to typical Paleocene species. It is therefore assumed that the Aq-tagh limestone belongs to the lowest part of the marine Tertiary sequence, approximately equivalent to the beds with *Ostrea bellovacina* in the Sanju section and *Ostrea ambolti* in the Duwa Valley. It should be noted also that real limestones of considerable thickness are known as yet only below the Tash-ariq conglomerate in the Tertiary sequence.

The total thickness of the Paleocene—Eocene marine series is not known; it probably amounts to a few hundred metres only. Compared with the rest of the huge pile of Tertiary beds as exposed *e. g.* south of Tash-ariq, this thickness is not imposing. There is, however, no distinguishable boundary between the fossil-bearing marine strata and the mostly red, marly, sandy, and silty deposits, which constitute the greater part of the upper division of the sequence, but the common occurrence of gravelly beds and deposits of gypsum indicates that these sediments are largely subaerial or lacustrine, deposited in shallow lakes or swampy plains.

In the Tertiary sequence between Qarghalik and Khotan, the following divisions have, so far, been recognized in descending order:

7. Light-coloured, grayish or greenish, mostly fine-grained sandstones interstratified with red silt and riverine gravel (Langhru, Tash-ariq).
6. Red marls or silt, in part gypsiferous, interstratified with reddish sandstones and riverine gravel (Tash-ariq, Yagme-tagh).

5. Coarse, yellowish calcareous sandstones grading into red marly and sandy beds (Yagme-tagh, Sanju).

4. Conglomerate (Tash-ariq, Camp N 382).

3. Yellowish or cream-coloured limestone or marl (Mazar-tagh, Camp N 382, Tash-ariq, Momuk).

2. Red marly sediments and red calcareous sandstones (Camp N 382, Sanju).

1. Basal conglomerate (Kiwaz).

CHAPTER II

THE K'UN—LUN PLAINS

The great bend of the Western K'un-lun about long. 78° E. coincides with the appearance of a new and important orographical feature, *viz.* the K'un-lun Plains. This name was introduced by Drew (1875) to designate that part of the western Chang-thang which is enclosed between the K'un-lun and the Loqzung Mountains. The plains expand all along this part of the K'un-lun and its eastern extension, the Altyn-tagh, at a mean altitude about 4,900 m. with only insignificant breaks by hilly tracts. About long. 81°½, the Loqzung Mountains are dissolved into isolated hills, and further east there is no sharply defined boundary between the K'un-lun Plains and the more central parts of the Tibetan "Plateau". The flatness of the plains is due to far advanced denudation of the rocky floor, which often is covered with only a thin blanket of riverine detritus and lacustrine deposits, through which the fundament locally protrudes with softly moulded surface forms.

The western parts of the K'un-lun Plains are known as Aq-sai-chin (*i. e.* The white desert of China), a name due to the gravel of white milky quartz which is scattered over the plains like a thin cover of snow especially along the K'un-lun side. The quartz is derived from innumerable veinlets and breccias in the crystalline schists in this tectonically strongly disturbed region.

The southern boundary of the Aq-sai-chin is of a tectonic nature, marked in the east by the steep frontier of the Eastern Loqzung Mountains, which extends smoothly curved from the southern shore of Lake Lighten towards the west-south-west and west over our camp A460, and then towards the north-west to the Qara-qash Valley, opening a broad gap in its eastern slope. This is the most convenient route to enter the Aq-sai-chin from the west, with perfectly level going and no passes worth mentioning.

In the north-west, the Aq-sai-chin is bounded by a large mountain complex enclosed between the K'un-lun and the Loqzung Mountains, a dissected *Rumpfgebirge* with similar morphology and geological structure as the neighbouring parts of the K'un-lun. It is covered with large snow fields especially in its western part, which attains a mean altitude about 6,300 m. The Qara-qash Valley cuts the block, like a huge crack in W.S.W.—E.N.E. between Sumnal and Abdul-Gafur-langar parallel to its north-western frontier, which rises with a steep and straight escarpment above the plains of Khushku-maidan.

The mountain complex descends to the basin of Aq-sai-chin with long spurs separated by broad bays. The principal valleys run N.N.W.—S.S.E. along fractures which extend right across to the Qara-qash gorge. The same system of fissures determines also the north-westerly course of the Qara-qash Valley between Chong-tash and Qizil-yilga, and the very regular system of strike valleys in the Western Loqzung Mountains.

The Mangrik Basin.

The K'un-lun Plains are divided by low rocky thresholds into a number of drainageless depressions, which generally contain residual lakes or salt marshes. Furthest in the north-west is the basin of Mangrik, a broad hollow in the formations of the Kilian Group, which form almost exclusively the oldrock fundament of these parts of the K'un-lun Plains. This basin descends to 4,806 m. and is the lowest depression in the western Chang-thang. But for some patches of scanty *Carex* grass farthest in the north, it is completely devoid of every kind of vegetation.

During the earlier stages of the Ice Age, the basin was occupied by an ice mass, the erosive action of which is in evidence in the valleys along the western border and in the softly moulded shape of the hills in the central parts. These are seldom more than 400 m. high; an exception is the large truncated cone 5533, a prominent landmark which rises 700m. above the salt bed, and which, according to AMBOLT, is due to an intrusion of granite (or porphyry?) in the slates. The basin is separated from the Qara-qash drainage by a broad flat threshold at 4,976m. covered with moraine. Another threshold at 4,934m. separates the basin in the east from the depression of Thaldat.

There can be little doubt that glacial action has been instrumental to a considerable degree in the modelling of many of the large depressions in the western Chang-thang, although conclusive proof in the form of moraines and striated pavement is only rarely to be found. The rarity of such evidences is due to the fact that many of these basins lacked outward drainage also during the later stages of the Ice Age and were occupied by more or less stagnant ice masses. These prevented the accumulation of glacigenous detritus, and the erosive action of the ice was largely confined to the peripheral parts. Thus, at the southern border of the plain of Aq-tagh, on the main trade route, a *roche moutonnée* beautifully polished and with striae running N.15°E. is laid bare of the detritus of the plain. Neighbouring outcrops, which have longer been exposed to the action of the atmospheriles, do not show such striation but the softly moulded shape is the same. Other examples are found in the plain of Sumtsi-ling (see below p. 53).

All along the border of the Mangrik Basin, there extends a series of well preserved beach lines. The uppermost one is sculptured in the solid rock of the hills and spurs, forming a rocky ledge which can be traced for long distances by its conspicuous brown colouring (Pl. II, Fig. 2). Opposite Camp N609 its altitude amounts to 4,893m. or 74m. above the salt bed. During the stage of maximal extension, however, the level of the lake overtopped the pass 4,934[1] at the south-eastern end of the basin, for the pass consists of a reef of shingle formed by the action of the waves. It corresponds to the highest beach line into which it passes laterally. Thus, we have here evidence of late crustal movements and tilting of the basin.

The basin sediments consist of yellowish gray, stratified, lacustrine silt, in part sandy, overlain by brownish gray, porous tufa of calcified vegetable remains a few decimetres thick. The total thickness exposed amounts to 60m. at Camp N610. These sediments were deposited in a lake the extension of which is shown by the highest beach. The absence of incrustations of salt or gypsum as well as the character of the calcareous tufa show that the water of this lake was fresh or only slightly salty during this stage.

A later lacustrine stage is represented by the large salt crust which covers the lake basin inside a terrace sculptured in the lacustrine sediments. This terrace is shown on the general map. At the northern end of the basin, its altitude is 4,893m.; from there it gradually descends southwards to 4,826m. near the southern end. The tilting of the basin has evidently occurred along an axis parallel to the K'un-lun, and probably in connection with the elevation of this range.

The thickness of the salt bed locally exceeds two metres. Its surface is very rugged with deep hollows and furrows. The sections thus exposed consist of white, fine- to medium-grained salts throughout, without any intercalations of silt or sand. The chemical composition of a representative sample is given below.

According to Dr BRIAN MASON, the mineral composition is the following: "*Halite* predominant. *Thenardite,* Na_2SO_4, rather much. Very rare small prismatic crystals of *pinnoite,* $MgB_2O_4 . 3H_2O$ ($\varepsilon = 1{,}573$, $w = 1{,}565$), not inconsistent with the low boron content of the analysis". The absence of magnesium salts is remarkable.

Pools of brine occur at a few places in the second and third basin. A shallow lake of about 3 sq. km., frozen at the time of our visit (May, 1932), occupies a hollow 3 km. south of Camp N609. It is fed by springs with fresh, ferrugineous water at the foot of the terrace on its western side.

The main part of the surface of the northern basin consists of hard silt. A rim of silt, 1/2—1 km. broad, extends also along the eastern border of the salt crust

[1] The pass 4934 is situated 76 m. above the salt crust at Camp N610. The altitude of this camp was fixed relatively to the fixed meteorological stations at Aq-tagh (4,656 m.) and Aq-sai-chin, Camp A 430 (4,918 m.) by contemporaneous barometric observations during 13 hours. Based on the former station the altitude of Camp N610 was found to be 4,847 m., based on the latter 4,869 m.; the mean value 4,858 m. has been used.

Table 1.

Sample (912) of the salt crust at Point 4826 in the Mangrik Basin.

Analyst: S. PALMQVIST.

	%	Normative composition	
SiO_2	Not det.	Na_2CO_3	1.53
Al_2O_3	" "	Na_2SO_4	19.28
Fe_2O_3	" "	Na_2Cl_2	76.32
MgO	Trace	$CaSO_4$	2.08
CaO	0.86		
Na_2O	50.52		
K_2O	Trace		
CO_2	0.53		
SO_3	12.09		
Cl_2	46.29		
B	<0.01		
H_2O	— —		
	110.29		99.21
$-O_2$	10.45		
	99.84		

in the eastern basin, widening to cover entirely its south-eastern part. The silt is here locally covered with white, quartzy gravel. Two kilometres east of Camp N 610, a ravine about 15 m. deep, is incised in the lake bed, the bottom locally covered with ice. It is possible that this ravine is the upper course of a valley which penetrates the threshold south of Point 5028 and opens into the basin of Thaldat.

The Thaldat Basin.

At the time of maximum extension, the Late Quaternary Mangrik Lake was connected by a narrow sound at the pass 4934 with another large lake, which occupied the greater part of the basin of Thaldat. A later lacustrine stage is represented by a terrace sculptured in the old lacustrine deposits. Its beach lines are well preserved on the eastern side of the pass 4934 and on both sides of the long rocky peninsula 5058, where it extends along the foot of the hills far to the west. At Camp N611, the edge of the terrace rises 41 m. above the residual lake. In the neighbourhood of the camping place Yang-pa, on the northern side of the lake, remains of the ancient basin filling of lacustrine cream-coloured, stratified silt occur in the shape of isolated *mesas* about 3m. high. STEIN (1912, II, p. 467) who passed here along the trail to Kitai-davan and the Qara-qash Valley says, "Up to a level of eighty to one hundred feet above the present marsh bed they (the spurs) all showed well-marked old shore lines; in places eight or ten of them could be clearly distinguished."

This is the lowest part of the Thaldat Basin, which here descends to 4,872 m. collecting the seapage of a very large drainage area. It is covered with soft salt and disconnected surfaces of locally nearly fresh water formed by a stream from the Thaldat lakes in the south.

The southern part of the Thaldat Basin is a perfectly smooth, very extensive plain of hard silt, absolutely sterile and covered with fine gravel mainly of quartz. No salt crusts were seen anywhere. The altitude increases imperceptibly to 4,903 m. at Camp N612 near the northernmost of the Thaldat Lakes, a string of long, irregular, shallow fresh water lakes, which obtain their water from numerous springs in the hills 14km. south-west of Camp N612. The lakes are drained by the stream mentioned above which flows east of our route. At Camp N612, it is incised in the silty, lacustrine deposits of the plain to a depth of 6m; its volume amounts to about one cub. m./sec.

The basin is bounded in the east by a semicircle of moderately high, softly moulded hills buried in detritus and fringed by a broad piedmont surface *(sai)* covered with white quartzy gravel. In the west, at Camp A457, enters a fairly large brook, the Thaldat Stream. It originates in the snowy mountains south of Qizil-yilga, traverses the northern plain of Lingzhi-thang, breaks through the Loqzung Mountains and flows north-north-west over a broad valley flat between the offshoots of the Loqzung Mountains; at lat. 35° 22′, it takes a north-easterly and easterly course and emerges in the Thaldat Basin, where its water soon disappears in the stream bed.

The Basin of Aq-sai-chin.

The lake of Aq-sai-chin occupies a hollow in the plain at an altitude of 4,907m. It is separated from the basin of Thaldat by a very flat, imperceptible swelling at 4,930m. Its water is salty (sp. grav. 1.167 at 17.5° according to HEDIN 1922, IV, p. 36), less so, however, in its south-western part, where springs arise on the bottom. Traces of ancient beaches, a few metres above the present level of the lake, were seen along the southern and western shore. TRINKLER (1932, p. 24) states that the highest lacustrine deposits occur 40m. above the lake; they consist of silt filled with peat-like remains of seaweeds which locally form compact beds in the silt. Beach lines corresponding to this lacustrine stage have been found neither here nor in the southern part of the Thaldat Basin, yet, the continuity of the lacustrine deposits from the residual lake at Yang-pa to the lake basin of Aq-sai-chin leave little doubt that the ancient Thaldat Lake extended all over the area of the present plain.

The basin of Aq-sai-chin extends 100km. to the east-south-east, where a broad threshold of coarse fluvial deposits and moraine separates it from the basin of Lake Lighten. Along the Loqzung frontier in the south, longitudinal ridges and forehills of Cretaceous strata protrude through the sterile piedmont plain; in the north rises an undulating, hilly terrain of phyllitic rocks covered with detritus and scanty *Ca-*

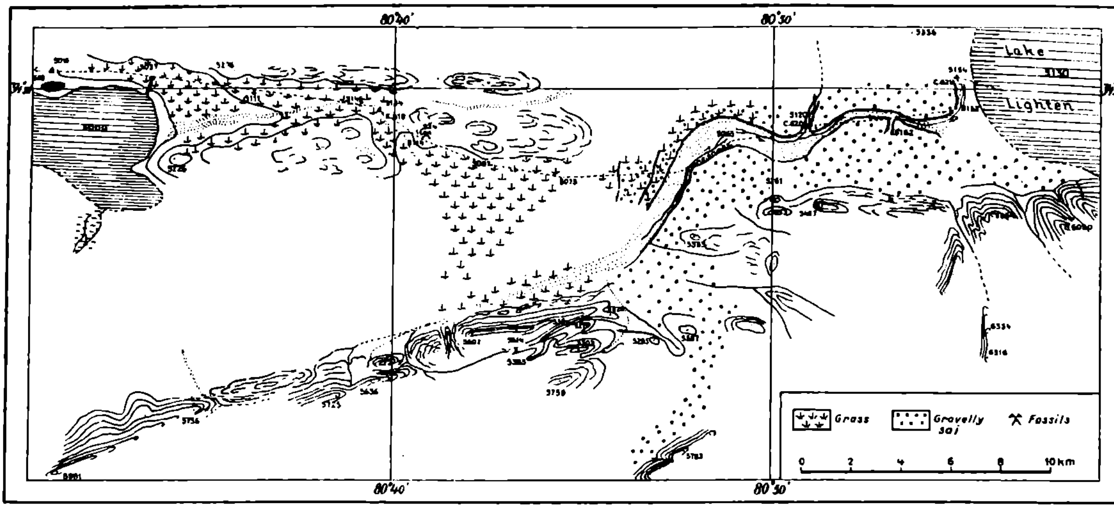


Fig. 7. The eastern part of the basin of Aq-sai-chin.

rex grass. Behind these follow the softly moulded forehills of the K'un-lun and still further to the rear, high snowy ranges.

In the middle of the plain flows the Aq-sai-chin River, the volume of which was estimated at about 2 cub.m./sec. (May, 1932). Only a few insignificant brooks reach it from the large snow fields in the K'un-lun, its main volume coming from the lake at Camp N618, on the southern side of a ridge of Cretaceous strata overlying phyllitic slates. Four kilometres east of the camp and 36m. above the level of the lake emerges a foaming stream of fresh, clear water through a tunnel at the foot of the ridge. The stream is 3m. broad and about 1 m. deep at the point of emergence, the velocity about 1 m./sec.; thus, its volume amounts to 2—3 cub.m./sec.

Further east, the hydrographic conditions are rather peculiar (Fig. 7). The threshold which separates the basin of Aq-sai-chin from the basin of Lake Lighten, is intersected by a broad and deep stream bed, which runs near the frontier of the Loqzung Mountains. Where our route enters it east of Camp N619, the bed is 1 km. broad and is enclosed between terraces 10 m. high. It contains a small brook with fresh water flowing north-east. At the point where the stream bed turns to the east, the brook disappears into the gravel at an altitude of 5,063 m.; only a few hundred metres further it appears again, but now the water flows westward. At Camp N620, a large ravine abuts from the north and from this comes the main part of the volume of this brook. Further east the stream bed slowly ascends and culminates with a very flat watershed at 5,162 m. It is also here sharply incised in the plain to a depth of 15 m. and is 300—500 m. broad. Then the terraces diverge trumpet-like and the stream bed gradually descends to the level of Lake Lighten at 5,130 m. The fine sections exposed in the steep terraces all along the stream bed consist of fluvial conglomerates with pebbles 10—20 cm. in size interstratified with fine gravel. This stream bed, the largest seen within the drainageless regions of the western Chang-thang, no doubt served at one time as the outlet of Lake Lighten into the basin of Aq-sai-chin. The present hypsometrical conditions are proof of very late tectonic movements, whereby the threshold at 5,162 m. was formed.

The Basin of Lake Lighten.

This large lake was discovered by WELLBY and MALCOLM in 1896. They gave it this peculiar name because at this point they had to lighten their caravan, which was much reduced by the hardships of the road. The lake measures 29 km. from west to east with a width of 5—7 km. Soundings taken by HEDIN in 1906 showed a depth exceeding 63.2 m. at several places. Its water is only slightly brackish, a puzzling feature in view of the fact that the lake has no visible outlet.

The author searched in vain for ancient beach lines about the 30-metres level, which might correspond to the threshold at 5,162 m., which forms the watershed of the basin of Aq-sai-chin. A series of low gravelly beaches, the highest 2 m. above the lake, extend close to the southern shore. Along the northern shore, STEIN (1912, II, p. 459) saw "old shore lines and lagoons almost cut off by sandy peninsulas from the main lake". Such are also found at the extreme eastern end but not above the 2-metres level.

The lake is bounded in the north by the easy-graded slope of the K'un-lun, a terrain of softly moulded hills covered with detritus. It has the appearance of a *rundhöcker* landscape moulded by ancient piedmont glaciers, the moraines of which project as peninsulas in the lake (STEIN, *op. cit.).*

The Basin of Yeshil-köl.

A broad, flat, gravelly threshold through which protrude several small massifs and ridges of Cretaceous strata separates the basin of Lake Lighten from the basin of Yeshil-köl. The pass point has an altitude of 5,330 m.

The Yeshil-köl is the terminal lake of a very extensive drainage area. It receives from the south-west the Yeshil-su, a fair-sized stream which flows over a broad, swampy plain and collects the drainage of the Eastern Loqzung Mountains. Here the main road from Rudok passes to Chinese Turkistan over the pass of Baba-Hatim and the Keriya River. Another considerable stream originating at the lake of Horpa-tso (Arport-tso) enters the Yeshil-köl from the south. Between them extends a low, hilly terrain of dark and multicoloured, sandy and argillaceous sediments, only moderately strongly folded, and locally capped by Cretaceous beds.

The lake of Yeshil-köl is bitterly salt and is fringed by a broad zone of salt deposits. The greatest depth recorded by HEDIN (1922, p. 52) amounted to 16.1 m. Its former wider extension is shown by a series of beautiful beaches which encircle the basin, rising one behind the other like the benches in an amphitheatre. The highest, which is sculptured in the rocks on the northern side, is situated 115 m. above the level of the lake. Nearly to this level reach also the ancient lacustrine deposits of cream-coloured, indistinctly stratified silt, which at one time filled the basin, and the remains of which form a fringe of varying width all around it, delimited by a steep terrace edge. At several places near the rim occur doline-like depressions. The largest with a length of 7 km. extends along the north-eastern side of the basin parallel to and near the terrace edge (Map Fig. 8). It has a depth of 60 m. by a width of 2 km. The bottom is covered with a thick deposit of salt.

ZUGMAYER (1908, p. 170; 1909, p. 148) mentions the occurrence of hot springs on the northern shore. He found three active geysirs here, each about 75 cm. in diameter, surrounded by sinter and sulphurus incrustations. Deposits of similar springs were also noticed by the same explorer on the rocky ridge on the western shore.

GEOLOGY OF THE K'UN-LUN PLAINS

Between the Qara-qash-darya below Qizil-yilga in the west and Lake Lighten in the east, the fundament of the K'un-lun Plains is a strongly folded, rather monotonous complex of epizonal, usually fine-grained, grayish and greenish quartzitic graywackes, light gray or white quartzitic sandstones, phyllitic and calcareous slates, and, more rarely, crystalline limestones as well as effusive and hypabyssic greenstones (Fig. 9). DE TERRA (1932), who studied this complex along his route between the lake Aq-sai-chin and Shahidullah, refers it to the Kilian Group and considers it as the continuation of the similar deposits in the K'un-lun. A noteworthy difference is, however, the very rare occurrence of gravelly or conglomeratic horizons, which are a prominent feature of the group in the latter region.

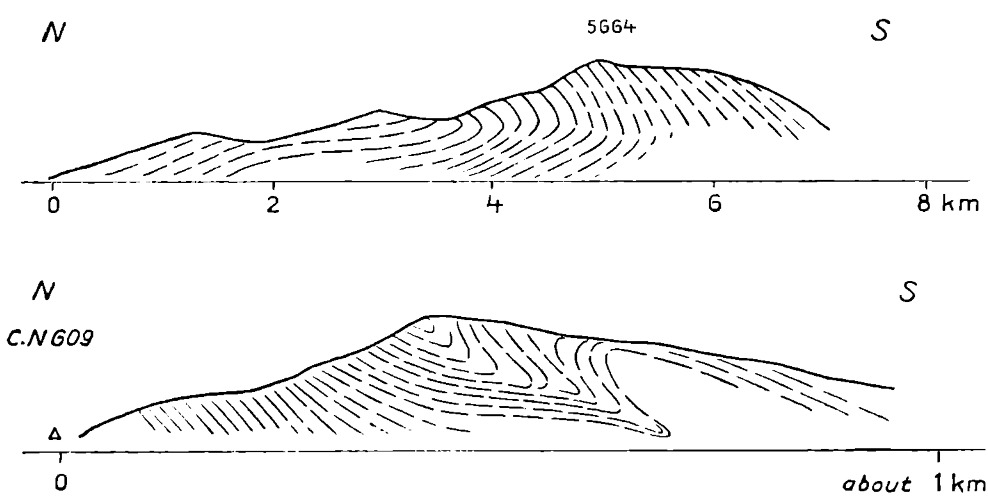
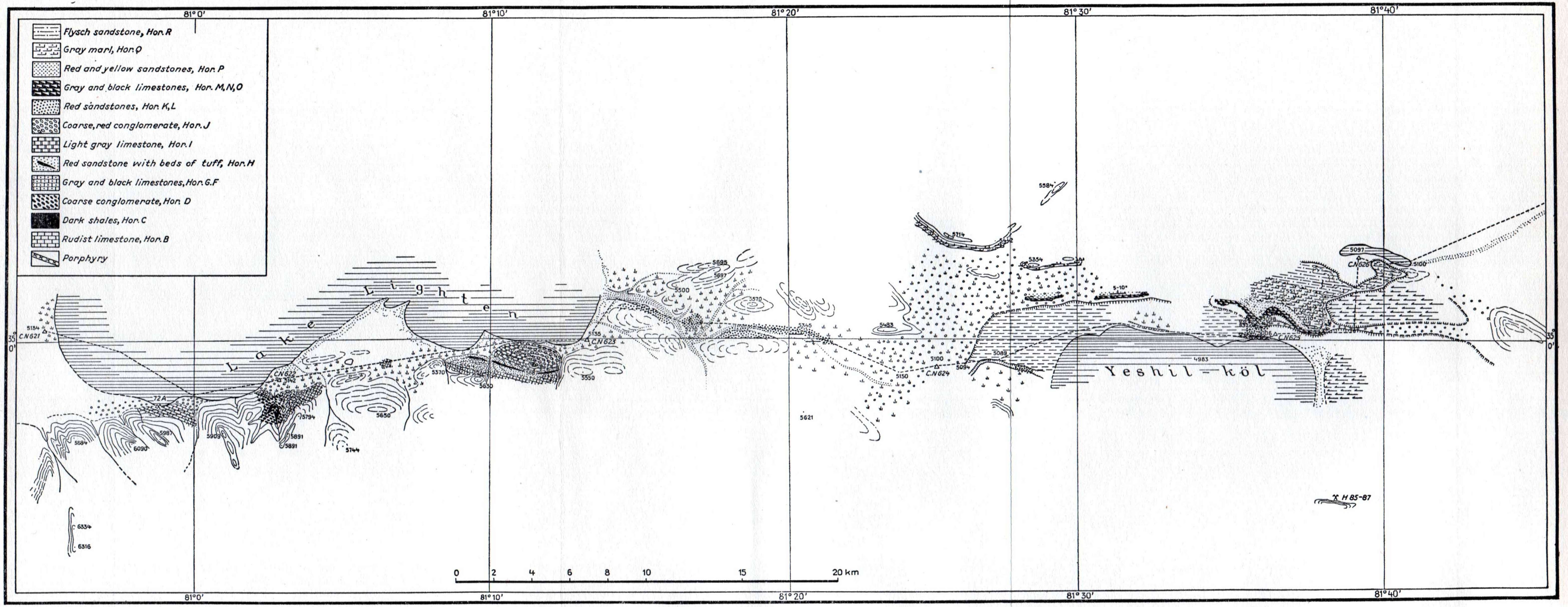


Fig. 9. Folded slates of the Kilian Group in western Aq-sai-chin.



Flysch sandstone, Hor. R
Gray marl, Hor. Q
Red and yellow sandstones, Hor. P
Gray and black limestones, Hor. M, N, O
Red sandstones, Hor. K, L
Coarse, red conglomerate, Hor. J
Light gray limestone, Hor. I
Red sandstone with beds of tuff, Hor. H
Gray and black limestones, Hor. G, F
Coarse conglomerate, Hor. D
Dark shales, Hor. C
Rudist limestone, Hor. B
Porphyry
81°0'
81°10'
81°20'
81°30'
81°40'
35° 0'
Lake Lighten
Yeshil-köl
C.N621
C.N622
C.N623
C.N624
C.N625
C.N626
0 2 4 6 8 10 15 20 km

Fig. 8.

The graywacke-slate complex along the Qara-qash Valley between Qizil-yilga and Chong-tash was referred by STOLICZKA (1878) to the Silurian. At the latter place, the present author found peculiar formations of closely packed calcite pipes resembling corals (Coll. 900) in strongly crystalline limestone associated with agglomeratic beds. This complex extends close to the outcrops of Ordovician rocks east of Qizil-yilga, where fossils have been collected by DAINELLI and the author, but is separated from these by a zone of strongly disturbed Late Paleozoic and Cretaceous strata.

Granitic intrusions have been observed by the author nowhere in the crystalline complex within the area of our reconnaissance. In the slates on the peak 5533, which rises in the middle of the Mangrik Basin, AMBOLT noticed, however, a fairly large intrusion of a granitic rock (porphyry?) of which, unfortunately, no specimen was collected.

To the scarceness of granitic intrusions is due the moderate intensity of the regional metamorphism, which usually does not exceed the stage of chlorite-muscovite-schist facies. Similar large graywacke formations, less strongly or not at all metamorphosed, probably of Late Paleozoic and some possibly even of Mesozoic age are important constituents of the more easterly parts of the K'un-lun north of Yeshil-köl and Lake Markham. The very rare occurrence of fossils makes it an exceedingly difficult task to clear up the mutual relation and the stratigraphic and facial development of these marginal formations.

Trachyandesitic beds of very youthful appearance are widely distributed over the K'un-lun Plains especially east of long. 81°. Thus, beds of latites and tuffs, locally at least 350 m. thick, cover an area of some 500 sq. km. with the centre at lat. 35° 30', long. 82° 45'. The beds, which consist of hyaline or fine-grained pyroxene-latites, seem to emerge from a broad cone-shaped mountain which is the highest point on the domed, dissected plateau, and may possibly represent an old volcano.

Similar extensive fields of Post-Cretaceous lavas occur in the basin of Achiq-köl at the sources of the Keriya River (ZUGMAYER 1908, LEUCHS 1913).

In the middle of the plain of Aq-sai-chin, near our camp N616, pebbles the size of a fist or more of pumiceous, hyalopilitic, augite-andesitic lava, are scattered over the surface for a distance of six kilometres eastward. No outcrops were found along the slopes of the neighbouring hills. As this extremely friable rock could not have survived any longer stream transport, it may either occur *in situ* below the alluvials or have been washed out from the morain which covers the slopes. The rock is certainly very young.

The absence of Late Paleozoic, Triassic, Jurassic, and Lower Cretaceous marine deposits of Tethys facies on the K'un-lun Plains is most remarkable in view of their enormous development in, and south of, the Loqzung Ranges. Denudation hardly accounts for their absence. If these regions were of a similar tectonic character, it is hard to understand that no trace of the deposits in question have been preserved

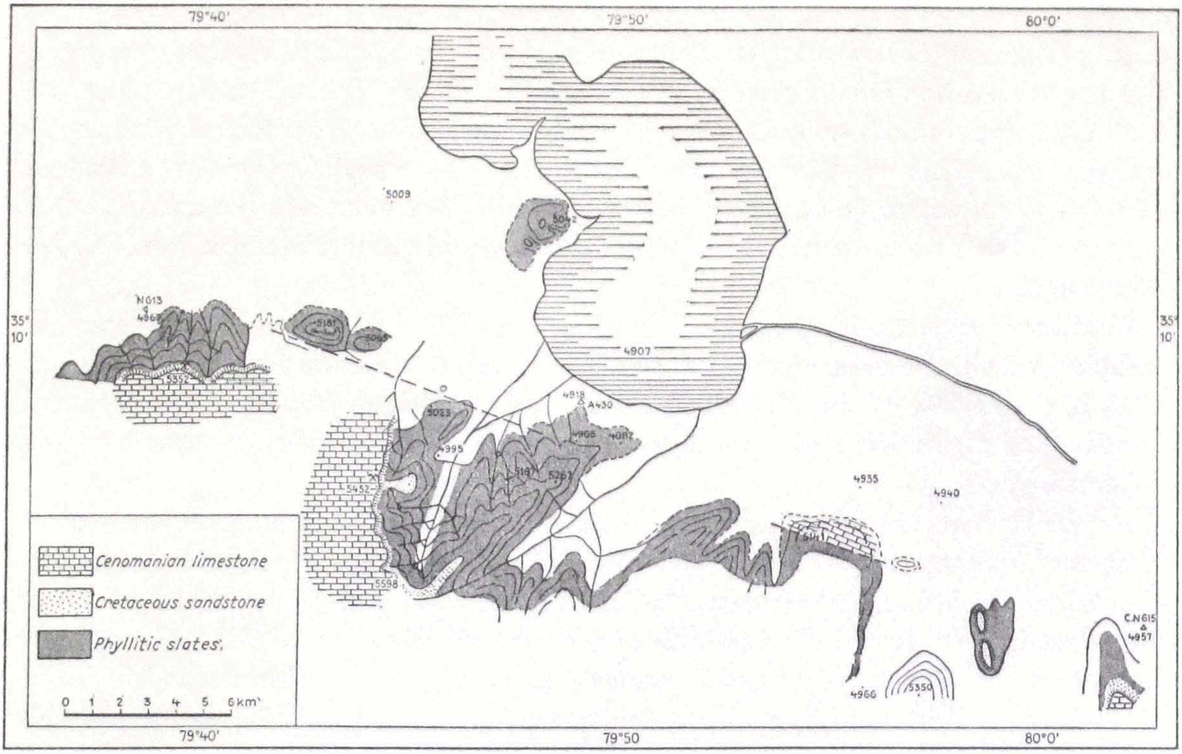


Fig. 10. The Cretaceous plateau south of Lake Aq-sai-chin.

in the north in the shape of infolded strips or in fault troughs, the more so as Upper Cretaceous deposits are widely distributed here. The K'un-lun Plains were evidently outside the reach of these late Paleozoic and Early Mesozoic transgressions. The peculiar distribution of the Mesozoic formations indicates, that some major tectonic event intervened between the Lower Cretaceous and the Cenomanian transgressions, whereby the border of the Tethys expanded over new extensive areas of the K'un-lun foreland. Tectonically, this latter belongs to the Angara Region, whereas the Aghil Ranges mark the northern border of the Tethyan Realm.

The rocks of Kilian facies which, contrary to the Late Paleozoic and Mesozoic deposits, have suffered regional metamorphism, and which very likely may be of Lower Paleozoic age as assumed by De Terra, form the fundament of the Upper Cretaceous formations in the basin of Aq-sai-chin (Fig. 10). The contact relations are very clearly exhibited at the classical exposures south of the lake, first studied by Hedin in 1906, later by De Terra in 1927, and by the author in 1932.

Here rises an extensive plateau-shaped massif to an altitude of 5,598 m. Its northern and north-eastern parts consist of greenish gray phyllitic slates, in part sandy, alternating with beds of fine-grained, dark quartzitic and calcareous graywackes and bluish black argillites. The rocks are penetrated by quartz veins. The folding is generally rather moderate with south-easterly strike. The top part of the hills is very smooth, the phyllites are coloured red by weathering products and are locally capped by patches of red sandstone. This smooth, peneplained surface extends over the hills to the east and also over the hill 5042 on the western side of the lake. Here, a thin dike of red sandstone was seen to penetrate from the surface into the rocks.

In the central and western parts of the massif, the phyllites are overlain, distinctly unconformably, by red medium- to fine-grained calcareous sandstone with beds of red, sandy shale in the upper part; the thickness amounts to about 40 m. The absence of a basal conglomerate shows that prior to the Cenomanian transgression, we had here a deeply weathered, flat land surface covered with earthy weathering products, which subsequently were redeposited by the transgressing sea.

Above follow conformably light gray and reddish limestones with a preserved thickness of some 10 m. at Point 5452. The sediment is full of large colonies of rudists, 10—20 cm. high; a representative collection made by my companion Dr LIU, has not been available for study because of the war.

At Point 5452, the Cretaceous beds dip 5--10° north, coinciding with the flat slope. Further west, in the plateau 5329 and south of HEDIN's Camp VIII (N613), the strata rest in a slightly domed position with a steep escarpment to the north, where the subjacent phyllitic rocks are exposed. This escarpment is due to a fault which also is traced south of the lake and accounts for the sudden increase in dip in isolated outcrops of Cenomanian limestone at the foot of the plateau, *e. g.* 1 km. N. E. of Point 5023.

In "Southern Tibet" Vol. IV, p. 34 and, more fully, in his field diaries, HEDIN has given an account of the geology of the plateau south of Camp VIII, which is in good agreement with observations made by the author. The lower part of the escarpment consists of greenish, fine-grained, phyllitic graywacke-slate dipping 60° towards N. 35° E. Above follow red sandstone with gravelly layers in nearly horizontal position and, at the top, the same rudist limestone as at Point 5452. Here, HEDIN collected the specimens 40—42 *in situ,* and 43—63 amongst detritus on the slope. HEDIN further states in his diary, that the limestone forms a broad, low vault, the southern end of which reaches the plain north of Camp HVI (Fig. 11).

Fig. 11. Cross section of the Cretaceous plateau south of Lake Aq-sai-chin, according to HEDIN.

The specimens collected by HEDIN at Camp VIII were studied by DOUVILLÉ (in HENNIG 1916) who identified *Praeradiolites hedini,* DOUV., n. sp., *Orbitulina conulus* DOUV., and *Choffatella* sp. (n. sp. ?); he places the horizon in the Barremian. BROTZEN, however, has shown that the beds are not younger than the Cenomanian and not older than Aptian-Albian.

In spite of HEDIN's clear description of the stratigraphic conditions, HENNIG (1916, pp. 19) has misunderstood it, and assumes that the sandy slates, which HE-

DIN has shown to be the fundament of the Cretaceous beds, are the younger, and of Post-Eocene age. "Die Turmalinkörner (in Handstück 39) sind deutlich allothigen; ihr Dasein im Gestein beweist folglich keine pneumatolytische oder Kontaktmetamorphose desselben; ich glaube eher, dass der sandige Schiefer auf Kosten eines Turmalin-Muscovitgranites gebildet worden und also posteocän ist". The presence of allothigenous tourmaline has no significance whatever as to the age of the sediment, because this mineral is remarkably abundant also in the Sub-Permian sandstones in the neighbouring regions.

DE TERRA (1932, p. 101), who visited the outcrops south of the lake, writes about the phyllitic complex: "Diese Sandsteine, die am Nordrand recht verschiefert und örtlich phyllitisch sind, biegen sattelförmig um und fallen am Fuss der das Seebecken im S umrahmenden Berge mit 80° nach N ein. Hier sind sie stark verschiefert und von Quarzgängen durchsetzt. Direkt südlich des Sees, in der Nähe von HEDIN's altem Lagerplatz C. 9 werden sie von roten bis graugelblichen, harten, etwas sandigen Kalksteinen konkordant überlagert, die ebenfalls steil zum Seebecken einfallen. In ähnlichen Kalken fand HEDIN *Praeradiolites hedini n. sp.,* den DOUVILLÉ ins Ob. Cenoman stellt. Die Sandsteine also werden konkordant von Ob. Kreide überlagert. Zwischen beide Formationen schiebt sich ein rötlicher Orbitulinenkalk von Barremien-Alter (DOUVILLÉ) ein, der in der westlichen Fortsetzung dieses Berglandes von rötlichem Kalksandstein unterlagert ist, und der vermutlich zu den grüngrauen Sandsteinen überleitet deren Alter damit als unterkretazisch sichergestellt ist".

Concerning the red sandstones at the base of the Cenomanian, which cap the phyllites, he states: "Diese Deckschichten überlagern horizontal die Schieferantiklinale, was besonders schön 6 km nordöstlich des 'Quellenlagers' zum Ausdruck kommt, wo sich eine isolierte rote Bergkuppe aus flachlagernden roten quarzitischen Sandsteinen und Schiefern aufbaut, die den First einer E-W streichenden Schieferantiklinale überdecken. Der Sandstein ist kreuzgeschichtet und lagenweise verkieselt. Er ähnelt den roten tertiären Sandschu-Schichten im K'un-lun Vorland. Seine Mächtigkeit beträgt hier etwa 90 m und seine horizontale Verbreitung über den Kreidekalken ist auch südlich vom See recht ausgedehnt. Die Unterlage der roten Deckschichten ist offenbar eine Verebnung (II b), die hier um 5200 m hoch liegt und die auf dem Lingschi-tang wie auf dem Aksai-tschin von grosser Ausdehnung ist. Das leichte Einfallen der roten Sandsteine gegen das Seebecken deutet auf Kippung durch Bruchbildung hin. Es ist sicher, dass diese roten Schichten nachkretazischer Bildung sind, und dass sie nach der heftigen Faltung der marinen Kreide zum Absatz gelangten". (*Op. cit.* p. 102).

The observations of HEDIN and the author make it superfluous to discuss further the age of the phyllitic series. It is curious, however, that, on his general map, DE TERRA refers the rocks of the hill on the western side of the lake to the Kilian Group, whereas the phyllitic rocks south of HEDIN's camp IX close by are shown as Cretaceous, although the rocks are, petrographically, perfectly identical.

There can be little doubt from the section given by DE TERRA, that by the red cap deposits *(die roten Deckschichten)* is meant the basal Cenomanian sandstone on the plateau, Point 5598.

The distribution of the Cretaceous deposits along the southern border of the wide plain, which extends between Lake Aqsai-chin and Lake Lighten, is seen on the general map. As far as Camp N618, the plain is bounded by smoothly moulded hills of phyllitic rocks, locally capped with small rests of red sandstone and gray limestone in horizontal position or with low northerly dip. The fault traced south of Aqsai-chin passes along the southern side of the ridge, Point 393, and further along the southern side of the ridge 5276 between the camps N618 and N619.

The lowest part of the steep southern frontier of the former ridge consists of red sandstone, of which a thickness of a few metres is exposed, overlain by gray, greatly cracked rudist limestone with moderate dip towards N. N. E. The plain in front of it is white by fragments of milky quartz evidently originating from the fault breccia. On the higher plateau-like hills to the south, the Cretaceous beds rest in nearly horizontal position with a broad low shelf of phyllitic slates.

Further east, the fundamental phyllitic rocks are exposed in low outcrops all the way along the southern side of the ridge 5391—5403, in the plain in front of the high plateau 5641, and in the low hilly terrain around the lake south of Camp N618 (Map, Fig. 7). Here the phyllites contain beds of black argillites and dark, crystalline limestone. They are bounded in the north by Cretaceous strata, usually with low or moderate northerly dip. These form the long, straight ridge 5391—5403 and the lower hills east of this, as well as the isolated massif 5329 and the dome-shaped long ridge north and north-east of the lake. In the neighbourhood of Camp 619, the phyllites are capped by red calcareous sandstone without any basal conglomerate, forming a flat vault overlain to the north and east by yellowish gray and reddish limestone. Close to the sandstone contact, the fossiliferous limestone Spec. 924 was collected. Dr BROTZEN has supplied the following information about the microfauna of this rock:

"Harter hochpolierbarer Kalk mit geringem Gehalt an Quarz (0,41 %) und sehr kleinem Anteil von Ton im Salzsäurerückstand. Schlecht erhaltene Rudisten mit einem Diameter nicht über 15 mm. und Steinkerne einer kleinen Schnecke. Daneben einige Scheiben grosser Foraminiferen mit einem Diameter über 14 mm. Es liessen sich 9 Scheiben der neuen Foraminiferengattung und Art *Soritoides norini* n. sp. und 2 Exemplare einer grossen *Cyclammina* (*C. tibetensis* n. sp.) makroskopisch feststellen. In Anschliffen und Dünnschliffen fallen die vielen bis 1 mm. grossen Miliolinen auf, die zum Teil den grossen Miliolinen *(Quinquclioculina)* in dem Handstück N72 entsprechen. Ausser *Quinqueloculina* gibt es *Massilina* und verwandte Formen, die später eingehender berücksichtigt werden sollen. Auch *Cyclam-*

mina tibetensis ist in den Schliffen neben sehr kleinen Orbitolinen und Rotalinen beobachtet worden. Eine Bestimmung von *Orbitolina* ist nicht möglich.

Die Fauna dieses Gesteins stimmt gut mit der von DOUVILLÉ 1915 beschriebenen, von HEDIN 1906 am Lager 8 eingesammelten Stufe Nr 40 überein (cfr above p. 35). DOUVILLÉ bildet auf Tafel IX, Fig. 1 (HEDIN: Southern Tibet Vol. V. Petrographie und Geologie von A. HENNIG 1916) einen hervorragenden Schliff der *Soritoides norini* n. sp. ab, den DOUVILLÉ als *Choffatella* sp. bezeichnet. Die vielen Exemplare dieser Art, die mir jetzt zur Verfügung stehen, gestatteten eine einwandfreie Bestimmung und Identifizierung der Abbildung bei DOUVILLÉ. Ausserdem zeigen die Schliffe des Stückes Nr 40 (Originale aus dem Reichsmuseum, Stockholm) die gleichen dickschaligen Miliolinen und *Cyclammina*. Die von DOUVILLÉ abgebildeten Stücke von *Orbitolina* lassen eine Bestimmung als *Orbitolina conulus* nicht zu. Dies erklärt auch die unsichere Altersbestimmung (bei DOUVILLÉ) des Gesteins als Barreme, trotzdem unmittelbar darauf Rudistenkalke des Cenomans folgen sollen. Das gemeinsame Vorkommen von Rudisten und Orbitolinen lassen darauf schliessen, dass hier Schichten der mittleren Kreide vorliegen, die nicht jünger als Cenoman, aber auch nicht älter als Apt-Alb sein können. Ich möchte im Anschluss an die Probe L72 A (cfr p. 39) und der dort festgestellten *Exogyra* zunächst das Gestein in das Cenoman setzen."

The phyllitic zone is bounded in the south by a snowy range (5981—5725) of Cretaceous strata, which seem to form the escarpment of a huge plateau, extending in a straight line towards E. N. E. over a distance of some 25 km. The photograph Pl. II, show the beautiful scenery it presents. The surface is very smooth without any prominent peaks. South-west of the lake, a large subsidiary plateau (5641) divided into two lobes by a broad valley protrudes towards the north, and here the tectonic relation to the foreland seems to be exposed. It rises some 500 m. above the gravelly plain with very steep slopes. Its flat surface has a low slope towards the north. Low hills and shallow outcrops of phyllitic slates occur at several places in the plain. Their distribution north and east of the plateau makes it probable, that they form the fundament of the plateau sediments.

The slopes of the plateau are deeply buried in detritus and the first outcrops visible consist of thickly bedded, light gray and reddish limestone in horizontal position, the exposed thickness of which here amounts to about 400 m. In the steep cliffs, no trace is seen of the dark gray and black limestones and thick conglomerates which — as will be seen in the following — form the middle part of the Cretaceous series south of Lake Lighten.

The eastern side of the plateau is determined by a fault in S. S. W.—N. N. E., and at this point it borders on a narrow block of Cretaceous strata, tilted steeply towards the W. N. W., exposing the lower horizons of the rock series. Although the author had not the time to visit this place, it could be seen from the distance that here a brilliant red formation crops out, probably the basal red sandstone and, east of it, the dark rocks of the phyllitic complex.

Higher horizons of the Cretaceous complex are exposed in beautiful, clear sections on the southern side of Lake Lighten. (Cfr Map Fig. 8). Steep cliffs of light gray, yellowish, and reddish rudist limestone descend to the south-western shore below the peaks 5987 and 5909. Here, LIU collected some fossil bearing specimens which were presented to the author (Loc. L72 A). The fossils were investigated by Dr BROTZEN, who states: "Hellgrauer, leicht rötlicher, sehr harter Kalk mit zahlreichen kleinen, gewölbten, länglichen *Exogyren*, die in der Längsachse schmal und stark gebogen sind. Sie stehen der *Exogyra africana d'Orb.* nahe, die im Cenoman vorkommt. Ausserdem kommt eine kleine flache *Terebratula* vor. Im Schliff erweist sich der Kalk als sehr reich an Molluskenschaltrümmern in einer dichten Grundmasse, mit einzelnen kleinen Kalkkristallen und sehr wenigen und kleinen Quarzkörnern. An Mikrofossilien sind mehrere *Dentalina-* und *Nodosaria*-Formen, *Globigerina* und *Globotruncana* vorhanden. Die *Globotruncana* gehört zur Gruppe *G. appenninica* RENZ, die recht bezeichnend für die Schichten der unteren mittleren Kreide (Cenoman- Turon) ist. Die *Exogyra* und *Globotruncana* weisen also auf Cenoman."

A short distance to the east, in the valley emerging south of Camp N622, the following section was taken (Fig. 12): The foot of the hill 5289 consists of light gray, dense limestone (Hor. G) of unknown thickness, resting upon a bed, some ten metres thick, of bluish black limestone (Hor. F). Below follows gray, fine-grained (0.2 mm.) "Pepper-salt" sandstone with indistinct plant remains in the lower levels; more than 100 m. thick (Hor. E). The sandstone consists of quartz, strongly altered feldspars, and accessorily turmaline, zircon, and a few flakes of muscovite. Within this part of the section the strata dip 20—30° towards N. N. E.

We are now 500 m. up the valley, where a larger tributary joins from the S. S. W. Here appears conformably below the sandstone, a huge, coarse conglomerate with a thickness estimated to at least 200 m. (Hor. D). It consists exclusively of pebbles and boulders of gray, yellowish, and reddish limestone, the size usually varying between that of a hen's egg and the size of a head, in part well water-worn, in part sub-

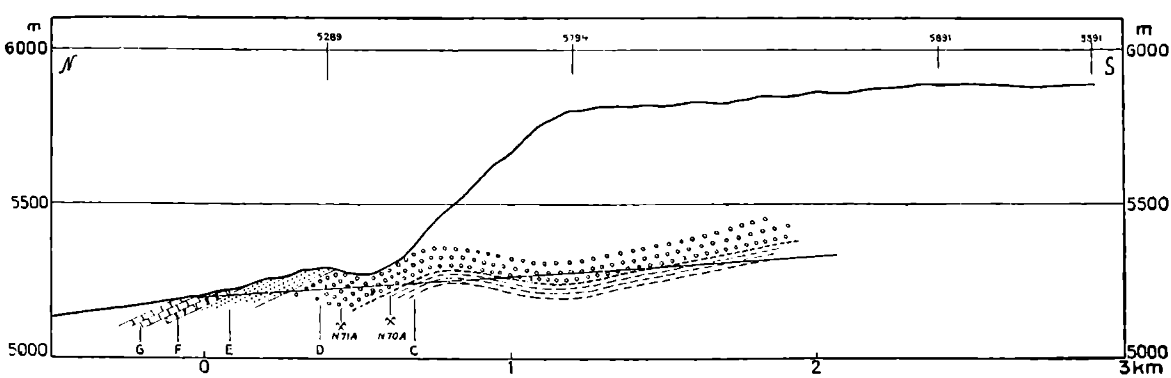


Fig. 12. Section of the Cretaceous formations south of Camp N622 on the southern side of Lake Lighten

angular. Certain levels have rather the character of talus breccia. Many boulders are richly fossil-bearing, mainly some small species of *Hippurites* (Coll. N71 A), proving that much of the material, if not all, has been derived from the neighbouring rudist limestone. In the lower levels, the conglomerate is interstratified with beds of gray calcareous sandstone. The formation may represent a talus deposit, accumulated at the foot of an ancient mountain range.

Dr. BROTZEN has supplied the following information about the fossils contained in the pebbles of the conglomerate (Coll. N71 A): "Die Rudisten sind kleine Stangen mit geringem, selten über einen Centimeter, Diameter. Im Schliff liegen zahlreiche Bruchstücke von Rudistenschalen in einer feinkörnigen, kalkigen Grundmasse und zahlreiche eckige Stückchen Quarz. Mikrofossilien sind häufig; es liessen sich feststellen: *Quinqueloculina* sp. (meist kleine dünnschalige Individuen), *Nodosaria, Lenticulina, Astacolus, Guttulina, Gümbelina, Rotalinidae.*

Die bedeutend reichere Foraminiferenfauna in diesem Rudistenkalk scheint auf eine höhere Stufe in der Kreide zu weisen als die Gesteine der liegenden Stufen mit Rudisten und Austern. Eine genaue Altersangabe ist nicht möglich, sicher ist nur das Oberkreidealter der Probe."

A coarse, rather similar conglomerate has been described by DE TERRA (1932, p. 100) in the Loqzung Mountains north of Sarigh-yilganing-köl, 120 km. to the west-south-west. He found steeply dipping "feine, gelbliche Mergelschiefer . . . ., die nach wenigen Metern sandig und grobkonglomeratisch werden. Diese groben, grauweisen Kalkkonglomeraten lagern ihrerseits einem Rudistenriff an, aus dessen Trümmern sie sich aufbauen. Der klotzige aufsteigende, kieselige und massige, weiss bis graubräunliche Rudistenkalk enthält koloniebildend zwei typische Fossilien von turonischem Alter: *Sauvagesia garianica* und *Hippurites aff. requieni* sp., welche von F. KLINGHARDT als solche bestimmt wurden . . . . Das Konglomerat könnte als Rifftrümmergestein gelten aber die relativ gute Abrollung der Fragmente in dem post-turonischen Konglomerat und die Beteiligung von Ob. Triaskalk schliesst solche Annahme aus und macht es mehr wahrscheinlich, dass es sich um ein dem Rudistenkalk diskordant aufruhendes Erosionsprodukt triassisch bis ob. kretazischer Formationen handelt." Thus, this conglomerate seems to be a regional feature in the Loqzung Mountains.

A short distance above the junction (section, Fig. 12), the fundament of the conglomerate is exposed in a low vault, the dip gradually becoming southerly by a few degrees, but the strata soon ascend again, assuming a persistent dip of about 10° towards the north-north-east. The rather thin, gray, calcareous sandstone at the base of the conglomerate grades into light gray argillaceous limestone or marl (Hor. C) with beds of black, bituminous calcareous shale in the upper part (Loc. N70 A). Dr BROTZEN says about the organic remains contained in this rock: "Dieser dunkle Schiefer enthält ausser undeutlichen Pflanzenresten zahlreiche *Valvata*-ähnliche sehr kleine Schnecken und glatte, nicht näher bestimmbare Ostracoden

(Süsswasserostracoden?). Marine Mikrofossilien fehlen dem Gestein. Durch die Stellung im Profil müssen die Lagen als cretaceisch angesehen werden."

About half way to the peak 5891, the valley contracts between steep cliffs. Here, Hor. C still forms the base of the exposures and is overlain, in the slopes, by the conglomerates. Numerous boulders of bluish black and gray limestones show that these higher members of the series crop out in the higher parts of the cliffs. It is also apparent from the strike and the dip of the strata, that the rudist limestones of the massif 5909 must appear at the base of the series not far to the south. This relation could, however, not be ascertained because of the inaccessibility of the head of the valley. The succession of strata is summarized in a schematic way in Table II.

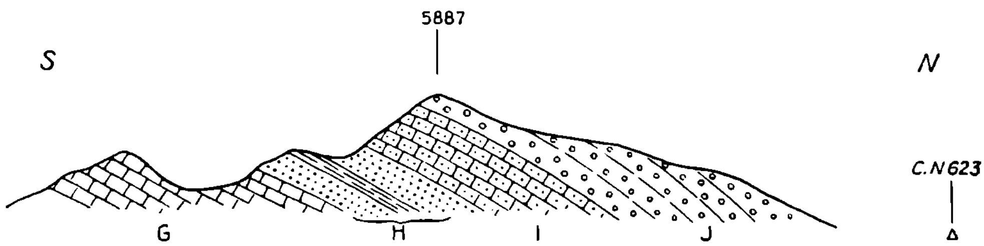


Fig. 13. The Upper Cretaceous formations at Camp N 623, Lake Lighten (Legend, see the text).

Some 15 km. further east, another very beautiful section of still higher Cretaceous beds was obtained in the valley which breaks through the high ridge 5887—5550, south-west of Camp N623 (Figs. 8 and 13). Here, as in the former section, the beds strike W. N. W.—E. S. E.; the dip decreases from 30° N. N. E. in the northern part of the section to 20° in the southern. The succession of strata is the following: The entire northern slope of the hill 5887 as well as its top part consists of a gravelly conglomerate of usually small, rounded pebbles (the size of an egg) of gray limestone in a red matrix (Hor. J). The exposed thickness amounts to considerably more than 100 m. This formation differs conspicuously from the conglomerate Hor. D of the former section by its red colour and the smaller size of the pebbles. There can be no question of identity.

Below follows conformably light gray, massive limestone (Hor. I) with a thickness estimated at 100—150 m. It rests upon red, fine-grained (0.3—0.5 mm.) calcareous sandstone (926) interstratified with sedimentary beds of pale greenish chlorite-siltstone (927); the aggregate thickness of this horizon (Hor. H) amounts to about 50 m.

Below the sandstone comes a formation of light gray massive limestone of great thickness, which greatly resembles Hor. G of the section Fig. 12. This correlation is further strengthened when tracing the beds westward. Thus, the red sandstone (Hor. H) can be traced to the slope of the hill 5544 where it rests upon the light gray limestone. In an isolated outcrop 3 km. further west, bluish black limestone very similar to Hor. F appears and — judging by the position of the strata — underlying the light gray limestone mentioned. This latter may therefore be identical to Hor. G of Fig. 12.

The sandstone Hor. H consists mainly of limestone detritus and gneissogenous quartz together with altered feldspars, chert, acid hyaline porphyries, and some ore in a calcareous and ferrugineous matrix. The greenish siltstone, Spec. 927, which appears as distinctly sedimentary beds in Hor. H, is very peculiar. In handspecimen it has the appearance of a very fine-grained, pale greenish tuff with solitary small geods filled with quartz and calcite. Under the microscope, the rock is seen to consist of an extremely fine-grained aggregate of a fibrous, nearly isotropic, colourless mineral resembling serpentine impregnated with calcite and also containing some ore dust and larger porphyroblastic individuals of serpentine.

The chemical and petrographical composition of this sediment is discussed at length in Chapter VI. It is either a lamprophyric tuff or has been derived by some kind of sorting of material originating from altered lamprophyric alkaline rocks.

Leaving Camp N623, we passed northward along the shore of the lake to the embouchure of a large open valley which leads to the watershed of the basin of Yeshil-köl. It is bounded in the south by a broad, softly moulded ridge largely covered with detritus which, on the northern slope, consists of mainly red sandstone. A similar, softly moulded elevation ascends to the north, culminating in the massif 5697. Judging by the detritus, this massif as well as the isolated massif 5570 consist of pinkish and light grayish, dense limestone. At the point 5270, we crossed a low plateau covered with large slabs and fragments of red sandstone which evidently occurs *in situ* at no great depth. The first actual outcrops were encountered south of the massif 5570, where brownish gray, fine-grained sandstone (928 a), in part gravelly, interstratified with black and gray shales is exposed on the southern side of the valley. Brown, red, and gray sandstones, in part gravelly (928 b), crop out at the broad and flat pass 5345. Because of the strong disintegration of the rocks, the dip is hard to ascertain; east-westerly strike seems to prevail. HEDIN records here a dip of 47° towards N. 40° W. Judging by the detritus, light gray and pink limestone forms the massif Point 529.

On the eastern side of the pass follows, in a deep ravine, gray sandstone with gravelly and conglomeratic beds dipping 60° towards N. N. E., but only a short distance further appears reddish brown, clayey sandstone with beds of silt in flat, undulating position.

In the plain of Yeshil-köl, in the neighbourhood of his camp XIX, HEDIN found a small outcrop of andesite dipping (?) 60° towards S. 20° W., and in a ravine, reddish gray sandstone.

As is seen on the map Fig. 8, the distribution of these red and gray, sandy and gravelly sediments suggests the occurrence of a connected zone of these strata in the depression between the great conglomerate, Hor. J, and a zone of light gray and

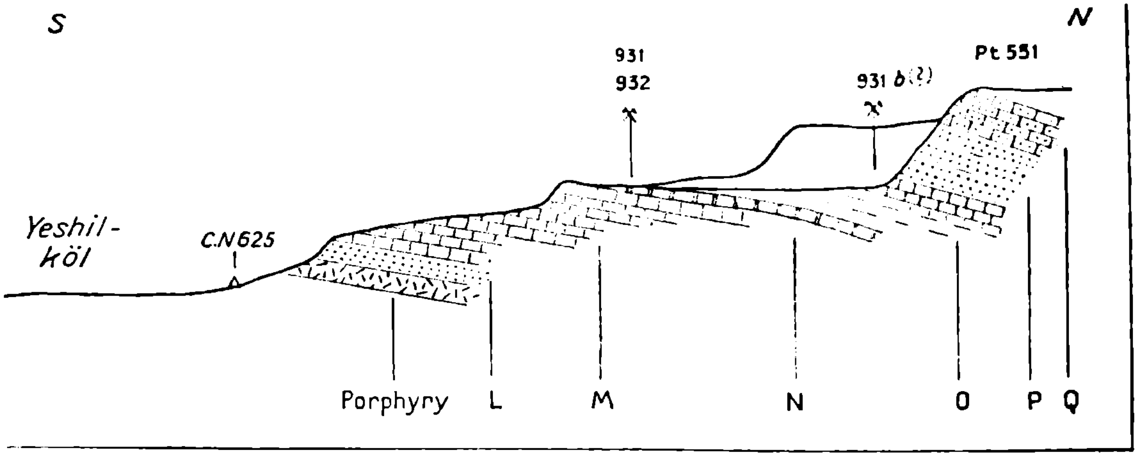


Fig. 14. Section at Camp N 625 on the northern shore of Yeshil-köl (Legend, see the text).

pink limestones, which borders the sandstones to the north. This arenaceous complex has been distinguished as Hor. K.

From Camp N 624, we crossed the saltencrusted ancient lake bed of Yeshil-köl and followed the northern shore of the present lake to Camp N 625. The first exposures of living rocks, *viz.* red, fine-grained sandstone, appear in shallow outcrops close to the shore some three kilometres west of this camp. A short distance further east, the rocky fundament is extensively exposed right up to the massif Point 551, the strata dipping 10° towards N. 10° E. on an average. Here the following section (Fig. 14) was obtained:

1) Near the shore is exposed a bed of reddish brown, fine-grained quartz-porphyry (929) with phenocrysts of ortoclase, one or a few millimetre in size, more sparcely of quartz, in a partly spherulitic groundmass, stained with ore dust; accessorily zircon. The exposed thickness amounts to .... about 10 m.

It is overlain by

2) red brown, fine-grained sandstone and yellowish white, shaly, calcareous sandstone (Hor. L) .... 10—20 m.

3) Light gray, stratified, crystalline limestone (Hor. M) with thin layers of black chert (930) .... about 100 m.

4) Grayish black bituminous limestone (Hor. N) with layers filled with small Ostreas (931, 932) .... at most 10 m.

5) Calcareous shale and light gray limestone (Hor. O) about 30 m. From here possibly originates Spec. 931 b, collected in the detritus.

6 a) Yellowish gray, fine-grained sandstone 6 b) Red brown fine-grained sandstone 6 c) Yellowish gray, fine-grained sandstone 6 d) Red brown, fine-grained sandstone	about 30 m. (Hor. P).
7) Light gray, thinly stratified, clayey limestone (Hor. Q) .... This horizon forms the main part of the hilly terrain around Point 551. It becomes shaly and sandy in the upper part, where some small shells were collected by LIU.	probably about 50 m.
8) Flysch-like greenish gray, soft, sandy shale and fine-grained shaly sandstone with fragments of coal and coaly film occasionally on the bedding plane (Hor. R). It crops out south of Camp N 626, and covers the northern part of the hilly terrain between Camps N 625 and N 626 with very low northerly dip. It forms also the plain north and north-east of Camp N 626. This is the highest formation of the Cretaceous complex known in this region.	Great thickness.

The fossil-bearing specimens (931 and 932) collected in the horizons N and O are described by Dr BROTZEN:

"Spec. 931 (Hor. N), dunkler bituminöser Kalk.

Der dunkle bituminöse Kalkstein ist stark von Kalkspatgängen durchzogen. Das Mikrobild weist neben der dichten Grundmasse und den vielen oft recht feinen Kalkspatgängen unregelmässig gezackte Spalten mit Bitumenanreicherung auf. Diese letzteren sind meist durch die jüngeren Kalkspatgänge gestört. Die grösseren Fossilien in der Grundmasse sind meist stark verzerrt und zwar fallen Echinodermenstachel und Schalenreste besonders auf. Kleinere Gastropoden und Bryozoen sind nicht selten. Von Foraminiferen liess sich sicher nur *Globigerina* nachweisen, die sehr selten vorkommt. Auf Grund dieses Befundes ist eine Altersbestimmung nicht möglich.

Spec. 931 b, dichter, grau rötlichgelber Kalk.

Dichter Kalk, sehr feinkörnig mit einzelnen nicht näher bestimmbaren Molluskenschalen. Mikroskopisch zeigt sich die Grundmasse sehr feinkörnig und teilweise kleinkristallin, darin einzelne Molluskenschalstücke und etwas sehr feinkörniger Quarz. Mikrofossilien sind sehr selten; es liessen sich feststellen:

Quinqueloculina, sehr klein;
Globigerina (in Bruchstücken);
Haplophragmoides oder nahe stehende Formen;
Gümbelina sehr selten.

Von diesen ist nur die letzte von grösserer Bedeutung. *Gümbelina* kommt hauptsächlich in der Kreide vor und nur sehr selten im unteren Tertiär, doch nicht über dem Eocän. Soweit diese selten auftretenden Gümbelinen in diesem Gestein von stratigraphischem Wert sein können, würden sie dafür sprechen, dass immer noch in dem mächtigen Profil Kreide vorliegt. Spätere Forschungen auf Grund grösserer Fossileinsammlungen werden dies erst endgültig entscheiden können."

The uppermost limestone formation, Hor. Q, which forms the culminating parts of the hilly terrain around Point 551, seems to form also the flat ridge 5354 and the steep southern frontier of the plateau-shaped massif 5714. The very conspicuous red and yellow sandstones, Hor. P, and the subjacent gray and black limestones, Hor. M-O, can be traced by their colour in the terrain along the southern slope of Point 551 westward to a string of flat ridges near the terrace edge of the plain, here too with low northerly dip. The same horizons with low or moderate southerly dip, seem to form the ridge Point 552 and others behind this on the southern side of the lake. On the northern slope of this ridge is HEDIN's camp XXI. In an outcrop close by, HEDIN collected some specimens of black and gray limestones (Spec. 85—87) "of the same kind as the boulders in the lake at the northern shore" (HEDIN's field diary 1906, p. 1950). The dip of the beds was found to be 25—30° towards southeast.

	Section I C. 619		Hor.	Section II C. 622		Hor.	Section III C. 623		Hor.	Section IV C. 625		Hor.	Thickness
										Grayish green, flysch-like sandstone, locally coaly		R	Great thickness
										Light gray thin-bedded fine-grained marl	Liu Coll.	Q	About 200 m.
										Red and yellowish fine-grained sandstones		P	
										Light gray limestone and shale		O	About 100 m.
										Grayish black limestone	931, 932	N	
										Light gray cherty limestone	930	M	
										Red sandstone		L	About 20 m.
										Quartz porphyry			About 10 m.
										Red conglomeratic sandstone		K	?
							Red limestone conglomerate		J				About 100 m.
							Light gray limestone		I				About 100—150 m.
							Red sandstone		H				About 50 m.
				Light gray limestone		G	Light gray limestone		G				>100 m.
				Black limestone		F	Black limestone		F				Some 10 m.
				Fine-grained, gray sandstone		E							>100 m.
				Coarse gray conglomerate of rudist limestone	Loc. 71 A	D							Several hundred metres
				Gray calc. sandstone									
				Bituminous calc. shale, Light gray argillaceous limestone	Loc. 70 A	C							?
Cenomanian	Light gray, yellowish and reddish rudist limestone	Loc. L 72 A Loc. 924	B										More than 400 m.
	Red calcareous sandstone		A										About 40 m.
	Phyllitic series												>2,000 m.?

CHAPTER III

THE AGHIL RANGES AND THEIR EXTENSION INTO WESTERN TIBET

Under the name of the Aghil Ranges were comprised by VISSER (1935, I, p. 192) the ranges of strongly folded Late Paleozoic and Mesozoic Tethys deposits between the crystalline zones of the Karakoram Main Range and the K'un-lun. Within the regions investigated by VISSER's expeditions this definition of the Aghil System is satisfactory, but when we follow the zone towards the south-east into western Tibet, its boundaries towards the Karakoram ranges and the K'un-lun Plains become exceedingly diffuse. This depends, foremost, upon the decreasing intensity of the Alpidic folding in this direction, resulting in more open folds with less amplitude than in the west. The comparatively easily eroded Mesozoic sediments have been largely removed within the anticlinal areas, and the subjacent partially strongly metamorphosed Paleozoic formations, which also enter as important constituents in the structure of the Karakoram, have become extensively exposed. This decreasing intensity of the folding eastward was realized also by WYSS (1931, p. 291) during his work in the Qara-tagh Highland. Here "erheben sich enggescharte Faltenzüge paläozoischen bis jurassischen Gesteins bis 6,500 m. empor. Nach Osten verebben diese Falten in gleichem Masse wie Karakoram und Kuenlun auseinanderstreichen".

The crowded ranges of the Aghil System grade, in the drainageless regions of western Tibet, into ridges and broad swellings, which may attain great absolute altitude, and between them extend broad plains and basins. In the western Chang-thang, the Aghil Zone is, thus, dissolved into the following main divisions:

1) The Loqzung Mountains, which extend along the southern border of the K'un-lun Plains. This range seems to belong only in part (the Western Loqzung Mountains) to the Aghil System proper; its eastern part beyond long. 80° (the Eastern Loqzung Mountains) may be of a different nature, having developed from a parageosyncline formed at the beginning of the Cenomanian in the K'un-lun foreland.

2) The plains of Lingzhi-thang and Sumtsi-ling is a region of similar geological structure as the Aghil Ranges in the Depsang Region, but the ranges

are reduced to low ridges and are largely covered with Quaternary lacustrine and alluvial deposits.

3) The Chang-lung—Mawang-kangri Range is a broad, longitudinal zone of large horst-like, heaved blocks of mainly Paleozoic strata with phacolithic intrusions of granites. Here, the Mesozoic sequence of strata has been removed by denudation but for remains locally preserved in fault troughs.

The Loqzung Mountains.

VISSER (1935, I, p. 102) distinguishes in the Aghil Mountain System, between the longitudinal course of the Yarkand-darya (Zarafshan) and the upper Shaksgam Valley, three main divisions, *viz.* 1) the Red Aghil Range (in Turky "Qizil Aghil"), 2) the Aghil Main Range, and 3) the Shaksgam Aghil Range.

The crest zone of the Qizil-aghil passes, according to observations of WOOD, MASON, VISSER, and DE TERRA, over Bazar-dara on the Yarkand-darya in a south-easterly direction south of Darwaz-sarigh-ot and beyond, to find its continuation in the Western Loqzung Mountains. It forms, within the area of the general map, the crowded ranges between the upper Yarkand-darya and the Aq-tagh—Kufelang Valley, as well as the more open mountain land, which forms its extension into and south of the Aq-tagh Plain. To the Qizil-aghil belongs also the southern part of the Qara-tagh Highland where Tibetan topography with its characteristic block structure and broad irregular valley flats begins to develop, as is beautifully reproduced on KHAN AFRAZ GUL KHAN's excellent map (VISSER 1935, I, Sheet I). Still farther south-east, on the other side of the Qara-qash, this mountain zone becomes more narrow and is represented by the Western Loqzung Mountains, a zone 10—15 km. broad, of high, sharp, parallel ridges with jagged crests, which often reach above 6,000 m., enclosed between the plain of Lingzhi-thang and the notably lower K'un-lun Plains. Broad plateaus of Upper Cretaceous strata with low dip towards N. E. locally fringe the range along its northern slope. (Pl. III, Fig. 2).

About long. 79° 45′, the mountains dwindle into hills and isolated low ridges, which extend with east-south-easterly strike separating the Lingzhi-thang from the Sumtsi-ling Plain. Here, the Western Loqzung Mountains terminate abruptly against the large Paleozoic mountain block of Mawang-kangri, the huge frontier of which rises on the opposite side of the Sumtsi-ling with north-easterly trend.

North of Sarigh-yilganing-köl an easterly branch diverges from the Western Loqzung Mountains and, rapidly increasing in magnitude, extends without a break 150 km. eastward to about long. 81° 20′. It rises above the K'un-lun Plains with a very steep frontier, 800 m. high or more, which runs in an almost straight line in N. 78° E. Its width varies between 15 and 25 km. The southern frontier is very irregular; the range is here dissolved into a complex of large mountain blocks, separated by broad valleys and irregular plains. The largest of these blocks is the snowy massif east of Sap-bulaq-köl, which reaches 6,589 m. (Pl. IV, Fig. 1).

Contrary to the Western Loqzung Mountains, in which the Tethyan sedimentary sequence is fully represented, the Eastern Loqzung Mountains consist mainly of Upper Cretaceous formations deformed into shallow folds and subsequently split by faults. The Cenomanian rests here transgressively and unconformably upon more or less strongly metamorphosed Paleozoic rocks and crystalline schists. Whereas in the Western Loqzung Mountains the orographical trend lines coincide more or less closely with the strike of the folding axis, the orography of the Eastern Loqzung Mountains is largely dominated by younger fracture lines, which cut the geological strike more or less obliquely. This is seen very clearly in the range on the southern side of Lake Lighten (Fig. 8). The large fracture which determines the steep northern frontier of this range, can be traced westward intersecting the Western Loqzung Mountains, to find its continuation along the southern border of the plain of Tso-thang, with a total length of 215 km. Roughly parallel to this is the large fracture which determines the northern frontier of the Mawang-kangri and over the Lanak-la merges into the Changer-char—Changchenmo fracture. The extension of this fracture passes along the lower Shayok and the middle course of the Indus whereby its total length amounts to more than 700 km., next to the Indus—Brahmaputra fracture one of the largest in the Karakoram—Himalaya System. Thus, the great mountain arches in the western Chang-thang are a complex feature due to the intersection of two different systems of tectonic trend-lines: in the west the fractures follow the ancient axis of folding, in the east younger germanotypic trend-lines.

In the north-west, the Qizil-aghil borders on the Suget Range of the K'un-lun Mountain System with a tectonic contact. According to De Terra (1932, p. 118) the Tethyan sediments are here exceedingly strongly compressed with formation of recumbent folds and displacements along faults and overthrusts. Further south-east, the boundary passes over the plains of Aq-tagh and Kushku-maidan, probably along the northern slope of the Qizil-koram Range, for Wyss (1940, p. 377) records crystalline schists associated with quartzite on its northern side.

The boundary must then pass right across the Qara-tagh in a south-south-easterly direction almost perpendicularly to its steep north-western frontier, for phyllitic slates form the western slope of the Qara-qash Valley between Chong-tash and Qizil-yilga. At the mouth of the Shu-lungspo-lungpa (Shor-yilga) appear dark limestones and shales intensely deformed like a kneaded dough, and at Chong-tash, an isolated cliff in the middle of the valley, occur pencil slates and brecciated greenstones with beds of crystalline limestones and doubtful corals, probably belonging to the Kilian Group, dipping steeply towards S. 25° W.

At Qizil-yilga, where the Qara-qash Valley makes a sharp bend to the south-west, the phyllitic complex disappears abruptly and definitely. Here appears, at the boundary, a zone of Mesozoic limestones and shales, about 7 km. broad and striking E. S. E., the "Monte della Piega" of DAINELLI. Its southern slope consists, according to DAINELLI (1933, II, p. 183) of Upper Cretaceous limestones and marls compressed into isoclinal folds overturned to the south, and resting on Late Paleozoic and Ordovician strata with moderate northerly dip. The Ordovician beds extend as a narrow arch from Qizil-yilga over Qizil-davan and then north-east along the Qizil-su. On the northern side of the Mesozoic range follow crystalline schists of Kilian facies with moderate north-north-easterly dip, constituting the margin of the wide crystalline terrains of the Aq-sai-chin.

Further east, the contact between the formations of the Loqzung Group and the crystalline foreland has not been observed being conceiled below transgressive Upper Cretaceous beds. Also these became involved in the last great paroxysm of Alpine folding and were subsequently dislocated along fractures, which attained their greatest magnitude along the ancient boundary zone. Movements have been taking place here still in Quaternary time.

The Plains of Lingzhi-thang and Sumtsi-ling.

Along the southern side of the Loqzung Mountains extends a belt of broad plains or flat drainageless depressions at a remarkably constant altitude about 5,200 m. separated from each other by low flat passes or swellings. They curve parallel to the mountains from north-west to due east and east-north-east. In the west are the plains of Lingzhi-thang, the deepest part of which descends to 5,200 m. Its eastern part is the basin of Sarigh-yilganing-köl with a central salty lake at 5,239 m. A flat watershed at 5,400 m. between low and broad longitudinal ridges separates this basin from the extensive plain of Sumtsi-ling with a length of more than 125 km. by a width between 10 and 20 km. Its central, deepest part is occupied by the large lake of Tsaggar-tso at 5,050 m. with intensely salt water. 43 km. east of this is another fairly large lake, the Horpa-tso (Arport-tso), at 5,241 m. with only slightly brackish water. It drains to the basin of Yeshil-köl on the K'un-lun Plains into which here the Sumtsi-ling merges by the termination of the Loqzung Mountains at about long. 81° 30'.

The region of Lingzhi-thang is divided into two sharply defined depressions by tectonic trend-lines striking north-west—south-east, along which movements have been taking place in very recent time.

The north-eastern depression, which has a width of about 10 km. by an average altitude about 5,250 m., forms the flat piedmont plain of the Loqzung Mountains. It is drained by the head-waters of the Thaldat Stream which breaks through the range in a narrow canyon at long. 79° 12'. In the north-west, this plain is separated from the drainage of the Qara-qash by a very flat and low watershed some ten kilometres south of Yapchan. Here rises, on the eastern side of the pass, the magnificent, snowy pyramide 6448, crowned by a double peak. This conspicuous landmark which resembles a tibetan chorten, is seen all over the Lingzhi-thang, presenting an excellent fixed point for orientation. The frontier of the Loqzung Mountains is rather irregular and is locally dissolved into isolated usually rounded hills (Pl. V, Fig. 1). Isolated, smoothly moulded low hills resembling *roches moutonné* are also scattered over the plain. The surface of this latter is covered with splintery gravel with patches of playa. Locally occurs some burtsa and solitary tufts of *Carex* grass on the slopes of the hills.

The plain is bounded in the south-west by a threshold or elevated zone of softly moulded hills which extends from the snowy massifs between Dong-lung and Sum-do towards the south-east. This threshold is about 250 m. high at the place where it is crossed by AMBOLT's route. The irregular escarpment, moulded by denudation, is due to a fault. South-eastwards, the threshold dwindles and is dissolved into isolated low hills or mesas. This threshold forms the north-eastern, warped margin of the drainageless Lingzhi-thang proper or Tso-thang (*i. e.* "Lake Plain"). Its flat surface, covered with gravelly detritus, slopes gently to the south-west and merges into the plain.

The plain of Tso-thang is about 30 km. broad where it is crossed by AMBOLT's route. DREW (1875, pp. 336), who seems to have followed nearly the same route in the opposite direction, gives an excellent description of the surface features, the ancient lake deposits, and the beach lines. Contrary to the northern plain, no hills break the monotony of the plain of Tso-thang, which extends flat like the sea to the horizon in the east and the west. The extreme western part reaches into the drainage area of the Shayok by a wide gap in the western mountain border, thus, "that streams which flow down to the Shayok interramify with those that flow into Lingzhi-thang, that the watershed between is quite unmarked" (DREW 1875, p. 350). The plain is traversed by several fairly large stream beds which end of July 1933 carried a considerable volume of slowly flowing water, and which have built a large delta on the south-western side of the lake, to which is due its peculiar shape. The largest of these streams have their sources in the snowy massifs far to the north-west.

The plain consists of light coloured silt, locally with a thin cover of gravel disintegrated by insolation. Sections exposed in ravines and mesas show "that below, as at the surface, there is a whitish or drab clay, some of it is massive clay, some of it is laminated; some of it is calcareous. Interstratified with the clay is sand, some so fine as to be impalpable. Again there are laminae of flat water-plants, and in places a mass of these plants some inches in thickness with earth intermixed" (DREW 1875. p. 339). DREW recognized the lacustrine character of these sediments, and concluded from their distribution that they had been deposited in a lake, the extension of which is outlined by the highest beach marks along the border.

The lake of Tso-thang has an altitude of 5,298 m. In spite of the large inflow, the lake must be very shallow for when DREW visited it in August—September 1869, it had dried up entirely. It has no outlet; an imperceptible, flat and broad swelling separates it from the plain of Sarigh-yilganing-köl in the east. The former wider extension of the lake is shown by numerous very well preserved beach lines along the southern slope of the threshold which bounds the plain in the north-east. DREW records beaches of shingle up to 150 feet (45.7 m.) above the plain. "At a higher level still there is a line of rocky cliff between 50 and 100 feet high; at the foot of it are distinct beaches; above it is a mass of rounded stones forming the top of the hill which may be as much as 300 feet above the plain at Tso-thang" (DREW op. cit., p. 340).

The Sarigh-yilganing-köl is situated some 40 km. east-south-east of the lake of Tso-thang and at a level about 60 m. lower. The eastern part of the Lingzhi-thang is here about 20 km. broad but becomes more narrow further east and is ultimately closed by a threshold of moderately high, broad ridges striking E. S. E., filling out the broad gap between the Chang-lung Range and the Loqzung Mountains.

The author crossed the basin from the north, touching the western end of the lake. We passed at first over the flat, gravelly piedmont plain about 3 km. broad. It terminates with a terrace, which represents the uppermost beach line of the present lake basin, 29 m. above the lake. Below extends a number of gravelly beaches marking later stages of desiccation. The lake bed consists of hard, cream coloured silt. Approaching the southern border, there is a slow ascend of the ground, yardang topography, about one metre deep, begins to develop, due probably to soil flowage. The upper beach was again crossed 24 m. above the lake as measured barometrically.

The sections exposed in the terrace and in numerous ravines which dissect the *sai,* show that it largely consists of bedded, white and cream-coloured silt similar to the corresponding deposits on the Tso-thang and, like these, evidently lacustrine. They have been studied and described by TRINKLER (1932) and DE TERRA (1932), who made a lengthy stay at the lake in 1927. Rare traces of a rocky beach 50 m. above the Sarigh-yilganing-köl in the hills to the south represent, according to TRINKLER, the shore of this lake, which is supposed to have formed, and probably did form, the eastern extension of the lake of Tso-thang at its maximal stage. TRINKLER further assumes that this lake also was connected with another ancient lake, which once occupied a large part of the basin of Sumtsi-ling by means of the broad and flat valley which extends to the east-south-east from the southern end of the Sarigh-yilganing-köl. Such was, however, not the case. The pass at the head of this valley reaches 5,400 m. or 160 m. above the latter lake. The lake deposits can be traced only a short distance up its lower course and for the rest it is filled with gravel and detritus.

The valley continues, on the eastern side of the flat pass 5400, in the same direction as before broad and straight to the east-south-east, and finally opens into the large basin of Sumtsi-ling. This extends, crescent-shaped, in front of the huge dome-like mountain mass of Mawang-kangri, the most imposing and the most heavily glaciated mountain region in the western Chang-thang (Pl. VI, Fig. 1). In the north and west, the plain is bounded by rather low softly moulded hills and behind rise, on this fundament, huge blocks of Cretaceous beds with steep escarpments towards the south and crests covered with perpetual snow (Pl. IV, Fig. 1).

The lowest part of the basin, at the head of the curvature, is occupied by the large and irregular salt lake of Tsaggar-tso at 5,050 m., surrounded by a broad belt of salt incrusted white silt. Eight kilometres to the west expands the smaller Nopta-tso at 5,100 m. The lake was only partially frozen on the 10th of October 1932 although during the weak 7—13th October the minimum temperature varied between — 16.3 and — 22.4° C.

The basin is surrounded by excellently preserved ancient beaches, the highest of which is sharply sculptured in the cliffs on the north-western side of the Nopta-tso, fringed by terraces of the basin sediments. At Camp N 707, the highest beach is cut in soft detritus 137 m. above the level of the Tsaggar-tso. Opposite, on the northern side, it extends between AMBOLT's points 5191 and 5177 or about 135 m. above the lake. At the most eastern end, where the beach turns to the north below Camp N 709, a value of + 148 m. was obtained barometrically.

In the western part of the basin, in the neighbourhood of Camp N 705, which is situated 136 m. above the Tsaggar-tso, the basin sediments are much eroded and form broad plateaus delimited by terraces 10 m. high. A fairly large stream (2—3 cub. m.) from the glaciated valleys in the south, takes a winding course over the plain. The terraces consist of stratified, fine sand without any coarse material. At several places, layers of black ice, a few decimetres thick, are interstratified in the sediment. This is evidently a delta deposit formed by streams at the western end of the ancient lake. (Map Fig. 22).

The plain ascends gradually towards the mountain frontier in the south where it reaches altitudes between 5,400 and 5,500 m. From Camp N 705 the view is magnificent. In the west-south-west is seen a broad longitudinal valley which forms the sharply marked boundary between the softly moulded, low ridges of the Lingzhi-thang and the snowy Chang-lung Range. In the south-west dominates the large dome 6722 completely covered with snow fields and bounded in the east by a broad saddle, which seems to offer a fairly easy passage to the depression of Changer-char on the other side. In the south and south-east extends the broad, vaulted crest of the Mawang-kangri deeply buried in perpetual snow with a maximal elevation of about 6,800 m. The valleys are rather short and most of them contain glaciers, some of which extend almost down to the piedmont plain.

In spite of this abundance of glaciers and perpetual snow, traces of more extensive Quaternary glaciation were remarkably rarely seen. A very striking exception is found, however, in the basin of Mangtsa-tso or Mang-tsaka south of the Tsaggar-tso. This extends to the south like a Norwegian fjord between high cliffs smoothed by a glacier, which once filled it as well as the large cirque-like basin behind. The trough is now occupied by the salt lake of Mangtsa-tso at 5,100 m. This is separated from the basin of Tsaggar-tso by a softly moulded, crescent-shaped, rocky threshold which is locally exposed under a cover of gravelly detritus. Typical moraine, possibly the remains of the lateral moraine of the ancient basin glacier, covers the northern slope of the Sumtsi-kangri behind Camp N 707.

The Chang-lung—Mawang-kangri Ranges.

Along the southern border of the plain of Tso-thang rises a softly moulded, hilly threshold about 35 km. broad, which slowly ascends to a mean altitude about 6,100 m. with a maximum elevation of 6,186 m. Seen from the lake of Tso-thang, it looks like the slightly warped edge of the plain, and extends smoothly along the southern horizon with patches of perpetual snow but without any prominent peaks (Pl. V, Fig. 2). It is known by the reconnaissances of SCHLAGINTWEIT (1880, IV), JONSSON (1867), DREW (1875), members of the Second Yarkand Mission (TROTTER 1875), HEDIN (1917), and AMBOLT that this threshold is an ancient surface of denudation largely covered with detritus into which the streams have carved broad, shallow, winding valleys. The southern rim of this plateau, which reaches a considerable distance beyond the watershed southward, descends with precipitous cliffs to the valley of Chang-chen-mo a thousand metres below. Seen from this valley, the escarpment has the appearance of a mighty range, which was called the Karakoram-Lingzhi-thang Range by GODWIN-AUSTIN (1884). According to DE TERRA (1934), the mountains on both flanks of the Chang-chen-mo Valley are called the Chang-chen-mo Range by the local people. Thereby is, however, comprised in one name two ranges of rather different structure, which are separated by one of the major zones of disturbance in the region. DE TERRA therefore rightly restricts this name to cover only the range on the southern side of the Chang-chen-mo. The range on its northern side may conveniently be distinguished as the Chang-lung Range after the principal passes (Chang-lung-la, Chang-lung-barma, Chang-lung-yogma).

Eastward, the Chang-lung Plateau has been split by longitudinal fractures, and the blocks descend northward in front of the main crest zone, which extends as a snowy, narrow range north of Lanak-la and finally wedges out north of the basin of Dyap-tso.

The eastern extension of the Chang-lung Range is the Mawang-kangri, which extends almost due east an unknown distance into Tibet. This range is a broad longitudinal zone of upheaval, the broad crest of which reaches a mean altitude about 6,400 m. It consists mainly of Paleozoic strata with large phacolithic intrusions of granodiorite. Its northern frontier runs east-north-east from Lanak-la to long. 80° 20′, cutting off, horst-like, the east-south-easterly strike of the Mesozoic ridges in the eastern Lingzhi-thang, which are the offshoots of the Western Loqzung Mountains; it takes then an easterly direction along the southern shore of Tsaggar-tso, where the sediments of the basin border on the range with minor overthrusts. Further east, between Tsaggar-tso and Horpa-tso, the frontier becomes very irregular by a row of high ridges of limestones and calcareous shales, probably Mesozoic, striking E. S. E.—W. N. W. and intruded by broad sills of quartz-diorite-porphyrite. Thus, here, like in the Eastern Loqzung Mountains, the orographical trend-lines of the range do not coincide with the axis of folding.

South of Tsaggar-tso, the range has broken in along cauldron faults by which the depression of Mang-tsaka has been formed. In the steep cliffs on its western side is exposed a large phacolithic body of gneissose granodiorite overlain by quartzite and strongly metamorphosed fossil-bearing Paleozoic limestones, which extend in nearly horizontal position over a considerable area. The massif 5887, in the middle of the basin, is a part of the sunken roof.

On the southern side of the watershed and down to lat. 34°, the only rocks exposed in the splendid section along the large meridional valley of Camp N 723, belong to one single, very thick Paleozoic sedimentary series which, lithologically, strikingly resembles the so called Agglomeratic Slate Series in Kashmir, to which it probably also corresponds stratigraphically. This part of the range has the appearance of an undulating plateau at a mean altitude well above 6,000 m., split in a rather regular way by two systems of fractures, the one longitudinal, the other perpendicular to this. These fractures determine the trend of the valleys and the ravines, which are incised to a depth of 500—1,000 metres in the black rocks, and are usually richly covered with grass.

As a natural southern boundary of the Mawang-kangri presents itself here the large depression of Changer-char, which extends in a longitudinal direction between long. 80° 10′ and 79° 55′. This peculiar basin is a synclinal *Graben* in which the former cap deposits of the plateau, elsewhere largely removed by erosion, have been preserved. They consist of Permian limestone overlain by red gravelly sandstone and a thick series of effusive acid porphyries and pyroclastics of probably Tertiary age (cfr Pl. B, Sections IV a and IV b). In the east, this trench curves to the north-east and wedges out before reaching the basin of Mang-tsaka; in the west, it is blocked abruptly by a huge meridional horst block, about 12 km. broad by an observed length of 40 km., which extends as a snowy range transversely to the Mawang-kangri from the pass of Napo-la due north to the basin of Sumtsi-ling. The great snowy dome 6722 south of Shum is its northern end.

In this horst-like block, the extension of the Changer-char disturbance is indicated by a fault along the northern side of the peak 6710 with a downthrow amounting to several hundred metres. The perfectly straight and very steep western frontier of the horst, which forms the eastern border of the broad, meridional basin of Dyap-tso, is due to a steep flexure, beautifully exposed at Camp N 729 near the southern end of the lake (Pl. VII; Pl. B, Section V).

The orography of the Mawang-kangri is, thus, largely determined by young, tectonic movements of germanotypic character. The Late Paleozoic sedimentary formations of this range appear again with similar facies in the Sumtsi-ling and in the Western Loqzung Mountains, although generally more strongly deformed, but the very great sequence of Mesozoic deposits, which are the dominating rocks in these parts of the Aghil System, are conspicuously absent in the Mawang-kangri. Their absence here can only be accounted for by denudation in connection with the horst-like upheaval of the range. Their former extension over this region is clearly indicated by the east-south-easterly strike of the Mesozoic formations in the eastern Lingzhi-thang. The folding axis abut here against the Mawang-kangri frontier in the same way as the syncline of Changer-char abuts against the great meridional horst east of Dyap-tso.

In the west, the synclinal trough of Changer-char finds its continuation in the great zone of disturbance along the Chang-chen-mo Valley. This *graben* differs, however, from the former by containing a thick sequence of Triassic limestones, whereas the great complex of rhyolitic lavas, which are enclosed in the *graben* of Changer-char, has not been encountered here. De Terra (1932, p. 92) mentions, however, a boss-like intrusion, 2 km. broad, of granite-porphyry which locally grades into quartz-porphyry, in the slates near the embouchure of the Rimdi Valley into the Chang-chen-mo. Red and yellowish conglomeratic sandstones of supposedly Tertiary age, not unlike those found at the base of the volcanic series in Changer-char, are described by the same author near Kyam. It is therefore possible, that the volcanic series once occurred also here but has later been removed by erosion.

The large *enclave* of Triassic limestones begins in the saddle between the Tartary Peaks and the massif 6537, descending to the Chang-chen-mo along both sides of the broad Toglung-marpo Valley. At the base of the very thick limestone series appears here a coarse conglomerate, 100—200 m. thick, which consists almost exclusively of pebbles and large boulders of grayish blue limestone in a red matrix. It rests with a tectonic contact on a strongly disturbed series of quartzites, black shales, and beds of fossiliferous (Permian?) limestones (Coll. 1157). Near the contact, the dip of the conglomerate amounts to 30—45° towards N. N. E., decreasing rapidly to 10° down the valley. A similar conglomerate appears again below the limestone series south of Lumkang in the Chang-chen-mo with moderately steep dip towards the S. S. E., resting unconformably upon graywackes and quartzitic rocks according to De Terra. The former conglomerate may, however, possibly be equivalent to the supposedly Tertiary, red conglomerate described by De Terra at Kyam lower down the Chang-chen-mo.

The position of the Chang-chen-mo—Changer-char disturbance leads us to consider the Mawang-kangri as the eastern extension of the Chang-lung Range. The reconnaissances of A. Schlagintweit (1880. IV), Stoliczka (1878), Drew (1875), and De Terra have shown that strongly folded Late Paleozoic and Lower Paleozoic formations are the principal constituents of this range, overlain by Mesozoic Tethys deposits on its northern as well as on its southern side. The author's study of the rock specimens collected by HEDIN in the valley of Chang-lung-yogma has revealed that also sediments of the Horpatso Series, the most characteristic rock formation in the southern Mawang-kangri, are represented.

If we follow the Changer-char—Chang-chen-mo disturbance from the east towards the west, a significant tectonic feature is apparent. In the east, the folding is rather slight, the Paleozoic beds rest generally in an undulating position or are even nearly horizontal over considerable areas; in the west, in the Chang-lung Range, the Paleozoic formations are intensely folded and largely foliated. There is, thus, a distinct increase in the intensity of the folding westward on approaching the huge mountain knot, towards which the Transhimalaya and the K'un-lun converge assymptotically.

The decrease of the intensity of the folding eastward takes place rather suddenly, roughly coincident with the general curving of the whole mountain system to the east about long. 79°. The probability that these interbasinal ranges could be traced right across the Tibetan Plateau as suggested by BURRARD (1907), HEDIN (1922, VII, p. 575), and others, is very slight indeed. Only the most southerly of the Karakoram Ranges, the Transhimalaya, can be expected to represent a truly regional feature.

Younger than the Chang-chen-mo—Changer-char *graben* is another zone of disturbance with approximately east-north-easterly trend, which determines the northern frontier of the Mawang-kangri and passes westward over the Lanak-la into the Chang-chen-mo. To this fracture are confined the known occurrences of hot springs in this region: in the Chang-chen-mo Gorge below Pamsal, at Kyam, and 1.3 km. east of Camp N 708 south of Tashliq-köl. This slightly curved line of dislocation runs roughly parallel to the large fracture, which determines the northern frontier of the Chang-lung Range and the Eastern Loqzung Mountains, also here accompanied by thermal activity as indicated by the hot springs on the northern and western side of the Yeshil-köl.

The Relation between the Karakoram and the Aghil Ranges.

The Chang-chen-mo Valley below Kyam, is considered by DE TERRA (1932, p. 95) as the geological boundary between the mainly Lower Paleozoic rocks of the Karakoram in the south, and the Upper Paleozoic and Mesozoic Tethys deposits of the Aghil System in the north. In the Karakoram Mountain System is included by VISSER (1935) the whole complex of more or less clearly defined ranges between the Aghil System as defined above on the one hand and the Indus Valley on the other. He distinguishes three main divisions, *viz.*

1) the Karakoram Main Range, 2) the Saltoro Karakoram, and 3) the Ladakh Range or the Ladakh Karakoram.

According to the Karakoram Conference Report (Journ. R. Geogr. Soc. 1938), the Karakoram Main Range or the Great Karakoram is the main crest zone of the Karakoram, from the mountain Koz Sar (lat. 36° 43′ 10″, long. 74° 05′ 19″) in the west to the great bend of the Shayok Valley at long. 78°; the crest reaches above 7,000 m. over the greater part of its length, culminating in the peak K 2 at 8,610 m. As the Lesser Karakoram or the Saltoro Karakoram are distinguished a number of mountain groups between the Main Range and the middle Indus—Shayok Valley from Hunza in the west to the Shayok-Nubra Junction. These parts of the Karakoram consist largely of granite and crystalline schists which are imbricated with less strongly metamorphosed Paleozoic sediments especially on the northern side of the main range.

East of the Shayok, the Karakoram Main Range forms the Chang-chen-mo Highland, the range curves slightly to the east and its width increases. The line of maximum elevation is a row of snowy massifs as much as 6,566 m. high, the Chang-chen-mo Range of De Terra, between the valleys of Chang-chen-mo and the Pangkong. It extends further in an east-south-easterly direction south of Dyap-tso into unknown regions of western Tibet. The opinion expressed by De Terra (1934, p. 27) that the Chang-chen-mo Range and, consequently, the main Karakoram axis here curves into due east to find its continuation in the Mawang-kangri, is certainly wrong in view of the geological data now available.

The Ladakh Range or the Ladakh-Karakoram is the most southerly of the Karakoram ranges, enclosed between the lower Shayok and the upper Indus. It consists of a large body of Pre-Tertiary granite covered, on the northern slope, with gneisses and crystalline schists as well as less strongly metamorphosed Paleozoic graywackes and calcareous sediments, rocks similar to those, which form the more northerly ranges. Whereas the northern boundary of the Ladakh Range is, thus, very diffuse, the southern boundary is, on the other hand, exceedingly sharply outlined. It is a tectonic line of the first magnitude, which marks the northern boundary of the Himalayan structure with its large overthrusts towards the south.

An intimate connection between the Ladakh Range and the Transhimalaya is indicated by their occupying a similar tectonic position. Like the Ladakh Range the Transhimalaya formed the northern border of the nummulitic sea; like the Ladakh Range, the southern ranges of the Transhimalaya rise above a foreland of Cretaceous flysch and ophiolitic eruptives, which were considered by Suess (1909, III. 2, p. 644), Wadia (1935, p. 419), Kossmat (1936), Heim (1939), a. o. as the eastern extension of the similar zone of the Indus—Dras valleys. The brilliant survey of the Central Himalaya and the transhimalayan foreland by Heim and Gansser in 1936, has revealed that this zone represents the root region of the so called "exotic blocks" or *Klippen* of the Malla Johar, Kiogar, and Chirchun areas. Heim and

GANSSER could show that the exotics "are the remains of a thrust sheet coming from the Tibetan side . . . . The complete difference of facies from the Himalayan substratum, proves that this thrust mass derives from a long distance" (HEIM 1939, p. 161). "As a preliminary view, subject to alteration, it is supposed that the ophiolitic flows and intrusions occurred in Late Cretaceous or Eocene time in a remote Tibetan zone on the outside of the Transhimalaya at the bottom of the deep sea and below it."

HENNIG'S study (1916) of the rock specimens collected systematically by HEDIN in the Transhimalaya, led him to the conclusion that granite and fundamental crystalline rocks are widely exposed, capped by Neocomian sandstone, Gaultian to Cenomanian limestones, and Post-Eocenian sandstones together with large masses of Late Cretaceous or Post-Cretaceous mainly acid effusives and pyroclastics. A similar rock complex is described by DAINELLI (1933, II. 2, p. 153) near Shushol on the northern side of the Ladakh Range, where he found multicoloured, continental and marine deposits, in part of Cretaceous age, associated with effusive greenstones, andesites, and quartz-keratophyres. These deposits seem to disappear westward because of the rise of the geoanticlinal axis of the Ladakh Range. Of similar kind are also probably the supposedly continental Tertiary beds and associated acid volcanics in the *graben* of Changer-char. The marine Eocene (Nummulitic Limestone) has not been found north of the Ladakh Range—Transhimalaya, which evidently formed a barrier to this transgression in the north.

The data presented above, and further evidences which will be forthcoming in the following, tend to show that the Karakoram and Aghil zones are closely related geologically, the main difference being a gradual disappearance of marine Tethys deposits and increasing acid Alpidic volcanism towards the southern border of the former.

CHAPTER IV

THE LATE PALEOZOIC FORMATIONS OF THE WESTERN CHANG-THANG

In the Late Paleozoic sequence of the western Chang-thang, the following main divisions have been distinguished:

II. The Tashliqköl Series

3. Massive white and cream coloured limestone with *Protomichelinia microstoma* (Middle or Upper Permian) (Loc. N 78) .... about 100 m.

Disconformity

2. Dark limestones and calcareous shales (Lower ? and Middle Permian) (Loc. N 77, 79, 80, 81, 83) .... several hundred metres.
1. White and light gray quartz sandstone .... at least 100 m.

Disconformity

I. The Horpatso Series .... more than 1,000 m. (Permo-Carboniferous ?)

4. Sandy shales with solitary thin beds of limestone
3. Upper detritus bearing siltstones
2. Grayish and greenish quartzites with beds (or dikes) of dolerite, lava, and ash
1. Lower detritus bearing siltstones.

The Horpatso Series is of special interest because of its very great similarity, lithologically and stratigraphically, to the so called Agglomeratic Slate Series in Kashmir and the lower divisions of the Krol Series (Blaini and Infra-Krol) in the Lesser Himalayas, as well as to the Carboniferous—Permian sequence of Southern Australia. This peculiar sequence is most extensively exposed in the Mawang-kangri and has been further traced into the Chang-lung Range, where it is associated with horizons indicative of the *Syringothyris* Limestone which, in Kashmir, appears below the Agglomeratic Slates. The similarity to the Kashmir sequence is further emphazised by the great development of eruptives of Panjal Trap character.

The upper division of the Late Paleozoic complex, the Tashliqköl Series, has been traced westward to the neighbourhood of the Karakoram Pass with essentially uniform development.

DESCRIPTIONS OF SECTIONS.

1. Section at Tashliq-köl (Lat. 34° 40′, long. 80° 40′).

This, the most complete and least disturbed succession of Permian strata so far known in the Tethys Karakoram, is exposed in the hills around the small lake of Tashliq-köl in the eastern part of the basin of Sumtsiling. Because of the poor condition of our caravan at the end of the autumn of 1932, we could spend only one day for the study of this interesting section, the principal features of which are embodied in Pl. B, Fig. I. The beds are deformed into a broad, normal anticline striking N. 50° E.; the dip fluctuates between 35 and 45° in the southern limb. Foraminifera occur abundantly in the limestones throughout the series, but brachiopods are rare; we spent much time searching for fossils in the shales without result.

The highest beds, which are exposed along the southern shore, consist of light gray and cream-coloured or nearly white, massive, dense or slightly crystalline reef limestones very rich in corals and foraminifera. The dip is here hard to ascertain because of the absence of distinct stratification or bedding. At Camp N 718, near the shore, the fossils of Loc. N 78 were collected. The following corals were identified by HERITSCH (Appendix A): *Protomichelinia microstoma* YABE et HAYASAKA, *Amplexus* sp., and *Palaeosmilia* sp. METZ identified one bryozoon as *Fistulipora* sp. The result of KAHLER's study of the foraminifera is not yet available to the author.

A narrow zone of the same limestone formation crops out on the northern side of the lake at its narrowest part. Here also occur many large boulders of a conglomerate with rather large pebbles consisting exclusively of gray and bluish black limestone in a calcareous matrix. No outcrops were found.

The next exposures, which occur a few hundred metres from the shore, consist of dark grayish blue and light gray, much cracked crinoid limestone. A few fossiliferous specimens were collected (Loc. N 79) in which METZ identified *Cyclotrypa megastoma* n. sp. and fragments of *Ascopora* (?).

A low ridge half a kilometre to the north, consists of dark grayish blue and brownish gray limestone of considerable thickness, rich in foraminifera and solitary corals (Loc. N 80). It is interstratified with and overlain by grayish blue calcareous shales. In the hollow on the northern side follow calcareous shales and grayish black, sandy shales with a few beds of dark limestones. Below follow, in the slope of the ridge 5458, light gray, fine-grained, calcareous sandstone (1129) and a thick formation of white, quartzitic sandstone (1130), in part nicely stratified in the deeper levels. It is very fine-grained throughout without any gravelly interbeds. The sandstones form a perfect, symmetric anticline in the core of the ridge.

On the northern flank of the anticline follows the same succession of strata as on the southern side. Near the bottom of the basal shales, a thick lumachelle of light bluish gray crystalline limestone was found (Loc. N 81), consisting mainly of crowded valves of some small species of *Spirifer*.

At a distance of 13 km. south-west of Tashliq-köl, at the foot of the Mawang-kangri, the Permian beds were again encountered (Pl. B, Fig. I, km. 16—18). The location is visible from afar by the glistening white knobs of quartzitic sandstone. The quartzite has here a northerly dip of about 10°. Its basal part is strongly brecciated and rests upon brecciated sandy slates and siltstones. Springs with fresh, tepid water emerge along the contact. The sediment consists almost exclusively of quartz, slightly stained with some dark dust. Many of the grains are crushed to a fine powder in connection with movements within the rock. Contact metamorphism has produced a granoblastic texture and the formation of solitary slender prisms of zoisite.

In the plain in front of these quartzitic hills extends a zone of low ridges parallel to the mountain frontier. These ridges are entirely covered with detritus of brownish gray, bluish and black limestones and calcareous shales intermixed with soil, but no exposures of rocks *in situ* were found. The uniformity of the material and its sudden appearance at a well defined boundary, together with the absence of rock material derived from the neighbouring mountains, which consist of much more strongly metamorphosed quartzites, slates, and crystalline limestones, are evidences proving that the detritus of the ridges originate from the immediate fundament.

The limestones are, lithologically, very similar to those of Localities N 79 and N 80 on the northern side of Tasliq-köl. They are very rich in fossils, especially foraminifera and bryozoa (Coll. N 77). There occur also slabs of a limestone conglomerate with well water-worn pebbles of dark foraminiferous limestones embedded in a calcareous matrix, which also contains foraminifera abundantly (Coll. N 77 b).

In the collection of Loc. N 77, METZ has identified the following species of bryozoa: *Ramipora hochstetteri* TOULA, *Dichotrypa inflata* n. sp., *D. clavaeformis* n. sp., *Cystodictya sphenoides* n. sp., *Batostomella spinigera* BASSLER var. nov. *acanthostellata, Batostomella* sp., *Polypora* sp., *P.* sp. *e. gr. orbicribrata* KEYS.

In the succession of strata at Tashliq-köl described above, two main divisions stand out conspicuously *viz.* 1) the dark limestones and associated shales with their thick basal formation of white quartz-sandstones, and 2) the upper series of white, massive limestones.

The age of the former series cannot be more definitely stated before the result of Dr KAHLER's investigation of the foraminifera are available. Its upper part, to which belong most probably also the limestones of Loc. N 77, represents, according to METZ, the lower Trogkofel Limestone of the Carnian Alps, *i. e.* the Lower Middle

Permian. The fossiliferous, conglomeratic limestone (Coll. N 77 b) observed as boulders at Loc. N 77, shows that a stratigraphic break is to be found somewhere in this part of the series. Its significance may be elucidated by the study of the foraminifera in the pebbles and in the surrounding matrix.

The author cannot state whether or not this conglomerate is the same as the one found as boulders on the northern side of the Tashliq-köl near the boundary between the dark limestone series and the upper series of white limestones with *Protomichelinia;* the contrast between these divisions is very striking. HERITSCH places the coral bearing horizon, which occurs rather high in the upper series, in the zone of *Polythecalis yangtzeensis, i. e.* in the Upper Artinskian.

2. Section on the north-eastern side of the Horpa-tso. (Pl. B, Section II).

In this section, situated 40 km. east of Section I, the lower part of the Tashliqköl Series and its thick basal formation of quartz-sandstones are exposed in normal, apparently conformable contact with its fundament, a very thick complex of detritus-bearing siltstones, quartzites, graywackes, and basaltic rocks, which are comprised under the name of the *Horpatso Series.* This peculiar rock series forms a remarkable parallel to the so called Agglomeratic Slate Series in Kashmir, and occupies probably a similar stratigraphic position.

The lowest beds of the Horpatso Series exposed in Section II b, consist of light gray or greenish gray, fine-grained (0.2—0.7 mm.) quartzitic arkose (1121) dipping 60° toward E. N. E., bordering on the Cretaceous limestone of the massif 5875 over a fault. The arkose is intruded by a steep dike or sill of rather strongly altered dolerite (diabase) (1122). A bed of very fine-grained volcanic ash or devitrified amygdaloid lava (1120) appears higher in this formation. The arkose grades into light gray, highly calcareous quartzite (1119) consisting of well water-worn quartz sand (0.2—0.4 mm.); it contains, occasionally, thin layers of black chert. Higher, this quartzite becomes more fine-grained and thinly laminated by layers of black, coaly silt, about a millimetre thick (1118).

Next comes a rather uniform succession of thick, diffusely delimited horizons of grayish black, detritus-bearing siltstones (1117, 1116), interstratified with dark, sandy slates. The detritus consists largely of quartzy gravel and sand, but also solitary subangular pebbles and boulders, which may attain the size of a fist, of various porphyries, quartzites, slates, and limestones. The matrix usually consists of dark silt, more rarely it has a marly composition. These sediments extend to the northern end of Section II b, the dip averaging about 45° towards E. N. E.

Higher beds of this series and the contact with the Tashliqköl Series, are exposed in Section II a, which extends northward from Point 5548 of the former section. Here, the detritus-bearing siltstones are succeeded by dark, sandy shales and brownish gray calcareous shales with a few thin beds of argillaceous limestone dipping steeply towards N. 60° E. Then follows, with the same steep dip, the characteristic sequence of the Tashliqköl Series of which a thickness of about 1/2 km. is exposed; the upper white limestone division of the type section is, however, missing. The limestones are strongly brecciated and coloured red by ferrugineous solutions in the most northerly outcrops.

The total thickness of those parts of the Horpatso Series, which are contained in Section II, is estimated at about 2,000 m. There is no indication of repetition by folding and, on the whole, the strata seem to represent a connected sequence.

The Tashliqköl Series borders, along the stream bed of Horpa-gol, on a broad, shallow syncline of Cretaceous limestones with a thick basal formation of red sandstones and conglomerates. The northern limb of this syncline rests, in the ridge 5453, on bluish and black limestones and shales which are greatly cracked and not unlike those of the lower division of the Tashliqköl Series. They grade, however, into a subjacent sequence of dark gray, sandy shales and fine-grained quartzitic graywackes with layers of black chert, which is widely distributed in the region between Horpa-gol and Yeshil-su. As no fossils have been found their age is unknown.

Sections through the Horpatso Series on the southern side of the Mawang-kangri.
(Pl. B, Sections III—V).

The watershed of the Mawang-kangri south of the cauldron of Mang-tsaka is a low, hilly threshold, which we crossed over a pass at 5,522 m. Here, typical rocks of the Horpatso Series crop out with moderately steep (35—45°) north-north-easterly dip. It is a succession of black sandy shales and detritus-bearing siltstones interstratified with grayish and greenish, fine-grained quartzites and with sills of diabase (1138, 1139).

On the southern side of the watershed, two fairly large longitudinal valleys unite to form a transverse gorge through the large mountain block in the south. At the upper entrance of the gorge, the lower part of the cliffs consists of fine-grained, grayish quartzite dipping 20° S. overlain by grayish black siltstone (1140), 20—30 m. thick. Upon this again follows, lower down the valley, a thick bed of quartzite succeeded by detritus-bearing, black siltstone of considerable thickness, alternating with beds of calcareous quartzite (1141) and shales with low, undulating dip.

At a distance of 5 km. below the entrance, the eastern slope exhibits partially nicely stratified dark siltstones, calcareous shales, and argillaceous calcareous sediments dipping about 10° towards W. N. W. In the gravel at the foot of the slope, a few pebbles of fossiliferous argillaceous limestone were found (Coll. 82).

At Camp N 723, the cliffs on the eastern side of the valley consist of black slaty siltstones with low northerly dip. Half a kilometre down the valley, massive, black detritus-bearing siltstone (1142) crops out below the former in the shape of a low anticline about 1/2 km. wide. The same rocks, in undulating position, were traced a further five kilometres to Point 5090.

In the western slope other horizons of the series are exposed. At first, thick beds of grayish and greenish fine-grained arkosic quartzites, with low westerly or south-westerly dip, overlain by dark shales and diabase. At km. 22, diabase (1143) forms the lower slope, overlain by dark slates and quartzites.

At km. 25 our route leaves the main valley and enters a westerly tributary from the pass 5470. Here, the lower outcrops consist of black shales overlain by black siltstone (1144) with low northerly dip, upon which follows arkosic quartzite with beds of dolerite (diabase) in the higher parts of the cliffs. At the pass 5471, five kilometres west of the former, a low anticline of grayish blue and dark gray limestone and shales is exposed, striking E.—W. Below follow, on the western side of the pass, black calcareous quartzite (1145) and, lower, grayish black detritus-bearing siltstones (1146—1148). The lowermost outcrops near Camp N 725 consist of grayish quartzite of the ordinary type.

We now enter the richly watered and grass covered, broad, longitudinal depression of Changer-char, bounded in the north by the slope of the Mawang-kangri, the large glaciers of which jut out between huge cliffs at the border of the plain, each with a wide arch of ancient moraine and alluvial cones outside on the piedmont plain. In the south, the straight frontier of another huge mountain block rises steeply to an altitude about 6,300 m. At the eastern end of the basin, the collected drainage forms a considerable stream, which escapes by a large transverse valley towards the south and probably emerges, according to ZUGMAYER (1909), in a large lake to the south-east of Kanze-tsaka.

The structure of the depression of Changer-char is shown on the cross sections IV a and IV b (Pl. B). The mountain frontier south of Camp N 726 consists of grayish limestone locally transformed into white marble by intrusions of granite. At Camp N 726, a conglomerate consisting of pebbles of the neighbouring limestone and overlain by red sandstone (1149) crops out with steep northerly dip. In the more easterly ridges, this sandstone is associated with beds of red rhyolite dipping 70° towards N. 30° W. By their brilliant red colour, these rocks are easily traced in numerous low ridges scattered over the northern and eastern parts of the plain, and are seen to extend to the neighbourhood of the pass at its north-eastern corner.

At the foot of the steep spur 6280 on the northern border of the plain, the crystalline limestone crops out again with moderately steep southerly dip, underlain by gray quartzite and a large body of granite, which here forms much of the higher slope of the Mawang-kangri.

In the southern mountain frontier, granite, usually associated with quartzite, crops out only at the south-eastern corner of the basin, and for the rest the frontier seems to consist mainly of the same more or less strongly crystalline limestone as south of Camp N 726, possibly associated with quartzitic rocks at some places. At Camp N 727 and further west, the limestone is only slightly metamorphosed and locally richly fossil-bearing. It is a thick series of bluish gray and nearly black limestones interstratified with calcareous shales, which extend to the vicinity of the pass 5706 on the southern watershed, where it rests apparently conformably on arkosic quartzites. At the mouth of the valley leading to the pass, the beds dip steeply towards N. N. E. (Section IV b).

In the ridge at Camp N 727, the limestone is partially brecciated and covered with a red varnish. It contains foraminifera and bryozoa abundantly (Loc. N 83). Dr. METZ has identified the following species of bryozoa: *Polypora goldfussi* EICHW., *P. sp., cx. gr. tripliseriata* BASSL., *P. tibetana* n. sp., *Fenestella* aff. *pulchradorsalis* BASSLER, *F. permiana* STUCK., *F. var. nov. pentagona, F. cf. kolymaensis* NEKHOROSHEW, *Dichotrypa inflata n. sp., Ramipora hochstetteri* TOULA. According to METZ, this assemblage corresponds to Loc. N 77 of the Tashliqköl Series, i. e. the Lower Middle Permian (Lower Trogkofel Limestone of the Carnian Alps).

The contact between the bryozoa limestone and the porphyry series is not exposed in Section IV b. No outcrops were found before the ridges at km. 6, near the northern border of the plain, where a thick series of beds of violet red and yellowish gray, acid lavas (1150—1152) occur, interstratified with tuffs, and dipping 45° south. Some felsophyres (1151) show beautifully the surface features of lava beds with twisted rolls and large lithophysa. At the foot of the Mawang-kangri, the slope of which is very flat at this point, the lava series borders on strongly metamorphosed quartzite with moderate southerly dip.

The southern part of Section IV b covers the large mountain block between the Changer-char and the longitudinal valley of Tajung. Our route follows here the large tectonic valley, which borders the huge horst block of Napo-la in the east. The limestone series of Camp N 727 extends to near the pass 5706 and is here underlain by greenish arkosic quartzites of great thickness, interstratified with dark slates and black siltstones. These rocks continue in undulating position with low dips all the way down the valley to its junction with the Tajung. At Camp N 728, the upper part of a thick sill of light gray quartz-pyroxene-diorite-porphyrite (1153) appears in a low anticlinal vault.

On entering the Tajung drainage area, we pass into a new topographical region characterized by sharply incised, deep valleys, which are fringed with terraces at many levels, in striking contrast to the drainageless Chang-thang proper, where fluvial terraces are rare and usually non-existent. The Tajung, therefore, probably drains into the Pangkong Lake System, which until quite recently belonged to the Indus drainage area.

The structure of the horst block of Napo-la as exposed along the upper course of the Tajung Valley, is shown in Section V. At the junction, Point 5377, greenish arkosic quartzite forms the lower part of the cliffs overlain, at km. 2, by black siltstone (1154), diffusely stratified by alternating layers of pure silt and fine, sandy silt. Numerous boulders of quartz-diorite-porphyrite in the talus show that an intrusion of this rock is to be found in the higher slope. From there originate probably also boulders of dark limestone associated with the blocks of porphyrite.

At km. 6, the valley is blocked by a glacier, the terminal moraine of which is located 200 m. below the naked snout. This glacier emerges from a large northerly tributary at km. 7. At the snout, the same black siltstones as before crop out with low dip to the S. S. W. Many of the boulders found here are of black detritus-bearing siltstone, which contains solitary boulders some of which have the size of a fist. The same rock crops out 1.5 km. farther up the valley with low north-easterly dip.

Between this point and the pass, the southern slope consists of quartzites in undulating position whereas the northern slope consists of black sandy siltstone (1155), in part slaty. The same sediments, in undulating position, continue on the western side of the pass to km. 10.5, where a bed of black detritus-bearing siltstone (1156), about 50 m. thick, appears below them. The transition is gradual. Below this horizon follow again dark shales dipping 10° N. W.

At km. 12, the strata suddenly bend downwards assuming steep westerly dip. Here appear at first the siltstones, in part shaly, followed by a thick formation of arkosic quartzite overlain conformably by grayish blue and dark limestones and shales, similar to those of the Tashliqköl Series in the Changer-char. The white, basal Permian sandstones are absent also here.

Our route then crosses the basin of Dyap-tso, which at this point is 23 km. broad. In the centre protrudes an isolated plateau-shaped massif like a cape into the lake basin, rising about 300 m. above it. The flat top of this massif is due to an almost horizontal bed of fine-grained, grayish quartzite which conformably rests upon black slates and black detritus-bearing siltstone of the same facies as in the Mawang-kangri. The same rocks form also the hilly terrain to the west between Camps N 730 and N 731.

In the valley leading to the pass of Domjor-la (Kone-la) appear gray, fine-grained argillaceous sandstones interstratified with dark gray argillaceous limestone and black sandy shales with indistinct Equisetalean stem-fragments, but no determinable specimens were found. The relation between these beds and the Horpatso Series is not known.

The occurrence of detritus-bearing siltstones of Horpatso facies in the Chang-lung Range is evident from the rock specimens collected by HEDIN near Gogra in the Chang-chen-mo. Lower in the same valley, in a tributary from the Konka-la, DE TERRA (1932, p. 95) collected in the detritus pieces of dark slaty limestone with *Chonetes lipakensis, Ch. hardrensis var. tibetensis, Thomasia margaritaceus, Avonia* sp. These are characteristic species of the "*Syringothyris* Limestone" of Kashmir of Lower Carbonic age. The fact that the Horpatso Series is intimately connected with Permian beds, makes it highly probable that this Lower Carbonic horizon belongs either to the lower part of the Horpatso Series or occurs below it.

PETROLOGY OF THE HORPATSO SERIES.

The very uniform lithological character of the sediments of the Horpatso Series, and the absence of any characteristic index horizons, make a correlation of the various sections uncertain. The most comprehensive succession of strata is contained in Section II with about 2,000 m. of sediments, where three main divisions may be distinguished, *viz.*, in descending order

1. sandy dark shales with solitary thin beds of limestone;
2. detritus-bearing siltstones, which constitute the main part of the sequence;
3. fine-grained, grayish arkosic quartzites with dikes or sills of diabase.

The thick formations of arkosic quartzites with sills of dolerite (diabase), which form the lowest exposures in Section II and the main part of Section III, is evidently a stratigraphic member common to the sections on the northern and the southern side of the Mawang-kangri. This correlation being accepted, we find in Section III another thick complex of detritus-bearing siltstones below the quartzites of Division 3. The base of the series has not been seen anywhere in this region because of the shallowness of the folding. It may be expected to appear in the valley of Chang-chen-mo, where not only Permian but also Lower Carboniferous and older Paleozoic formations are known to occur.

In the basin of Changer-char as well as in the basin of Sumtsiling, the Horpatso Series is overlain by the marine Tashliqköl Series of Permian age. The conspicuous white quartz sandstones, which form the base of this series in the latter basin do, however, not appear in any of the sections on the southern side of the Mawang-kangri or in the Chang-chen-mo. The thick formations of generally greenish quartzites which here form the fundament of the Tashliqköl Series, are of a rather different appearance and are not to be distinguished from the quartzites of the Horpatso Series, the more so as their association with the subjacent siltstones is very intimate. It is very possible that, in the Changer-char, the main part of Divisions 1 and 2 of the Horpatso Series had been removed by denudation during the emergence prior to the Tashliqköl transgression.

The Detritus-bearing Siltstones.

A very large part of the stratigraphic column of the Horpatso Series consists of detritus-bearing siltstones or mudstones. These are coaly black and grayish black, very tough, argillaceous rocks usually unstratified but for a rough bedding caused by interstratified shaly and quartzitic horizons. The silt or clay is more or less richly

TABLE III.

Composition of Detritus bearing Mudstones.

	1	2	3	4	5	6	7	8	9	10
	Above the Main Arkose				Below the Main Arkose					
% Vol. of	1117	1116	1142	1156	1146	1147	1148	T'ien-shan	N. Norway	Greenland
Matrix	*56.6*	*59.9*	*64.8*	*58.0*	*67.9*	*39.5*	*29.8*	*58.0*	*59.0*	*57.9*
Detritus:										
Quartz	20.2	25.3	28.7	25.3	21.8	34.9	40.0	17.9	27.4	32.9
Feldspars	12.4	6.5	5.0	11.2	8.5	12.0	15.9	6.9	3.6	3.4
Limestone	0.7	0.6	0.4	1.9	0.1	0.4	0.7	17.0	10.0	5.8
Slates	4.7	2.1	1.1	—	1.2	1.6	1.2	—	—	—
Quartzites	0.4	2.4	—	2.2	0.5	0.5	1.5	—	—	—
Granite, gneiss	1.2	0.5	—	—	—	1.5	1.2	—	—	—
Acid porphyries	3.0	2.5	—	—	—	4.3	2.8	0.2	—	—
Basalt, andesite	0.8	0.2	—	1.4	—	5.3	6.9	—	—	—
	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Measured mm	298	327	265	316	289	152	305		157	355
Slides	2	2	2	2	2	1	2		1	2

Spec. 1117 from Section II b, km 1, Horpa-tso
„ 1116 „ „ II b, km 0.4 „ „
„ 1142 „ „ III, km 20.5, southern slope of the Mawang-kangri
„ 1146 „ „ III, km 24
„ 1147 „ „ III, km 24
„ 1148 „ „ III, km 24
„ 1156 „ „ V, km 11, Napo-la

Col. 8. Detritus bearing siltstone from Quruq--tagh, Eastern T'ien-shan.
„ 9. Matrix of tillite from Leirpollen, Varanger, northern Norway.
„ 10. Matrix of tillite from Tillite Canyon, Ella Island, Greenland.

intermixed with detritus of various rocks: quartz, feldspars, quartzites, slates, chert, acid porphyries, basalt, porphyrites, granite, gneiss, and limestones (Pl. VIII—X). The coarseness of the detritus varies greatly; the greater part enters as minute, angular debris but the rock is spotted with scattered larger, angular fragments of the same kind, one or a few centimetres in size, and solitary rounded or subangular pebbles rarely more than 10 cm. With the disappearance of the detritus, these beds grade into black siltstones and claystones of the same kind as the matrix of the detritus-bearing rock.

Table III gives geometrical analyses of seven specimens of detritus-bearing siltstones from different localities within the extensive area of these deposits. With the exception of Spec. 1147 and 1148, which contain much basaltic tuffaceous material, the sediment of the various localities shows a remarkably similar composition with rather narrow amplitude of variation, although the extreme localities 1116 and 1156 are situated 135 km. distant from each other in a straight line.

Amongst the specimens investigated, 1116, 1117, 1142, and 1156 represent beds above the main quartzites, Division 3, and Specimens 1146, 1147, and 1148 beds below it. The composition of Horizon 1146, which is free from tuffaceous material, agrees rather closely with the beds above the main quartzite, showing that the intensity of the process of sedimentation and the geographical environment were essentially identical before as well as after the event, which caused the formation of the quartzites. The occurrence of basaltic lava in Section II shows that basaltic volcanic activity continued also during this late stage.

The uniformity of the sediments and the huge thickness prove that the sedimentation proceeded very rapidly. Large quantities of clayey detritus must have covered the neighbouring areas of denudation.

In the typical detritus-bearing siltstones, the amount of clayey and silty matrix varies between 56,6 and 68,0 % Vol., when all material of a grain size below 0.02 mm. has been included in the matrix. The main part of it is, however, much finer, appearing as a cryptocrystalline, nearly isotropic mass. Occasionally, *e. g.* in Hor. 1142, the content of carbonate of lime may be considerable and the matrix acquires a marly character.

The chemical composition of the matrix as defined above, is elucidated by chemical analyses of Hor. 1116 and 1156, situated at a distance of 135 km. from each other (Table IV). The bulk analyses of the rocks are given in Col. 1 and 4. In Col. 3 and 6, the composition of the matrix (=Total—Detritus) has been recalculated to 100 %. The chemical composition of the detritus is calculated from the values found in Col. 2 and 4 of Table III.

The composition of the clayey fraction of these two sediments, thus calculated, is very similar (Col. 3 and 6). Its characteristic features are: high content of alkalies with a slight preponderance of K_2O over Na_2O; high Mg strongly predominant over CaO; high TiO_2, P_2O_5, and organic coal; the excess of Al_2O_3 over alkalies and lime is moderate. These features exclude the possibility of the matrix being of volcanic origin, *e. g.* volcanic ash. Its composition agrees very closely with the average composition of igneous rocks given by CLARKE and WASHINGTON 1924. The material has, thus, suffered only inconsiderable chemical changes by weathering, and has been derived mainly by mechanical disintegration of various rocks. Only the plagioclase seems to have been decomposed and leached to a certain extent, as indicated by the comparatively low content of CaO.

In normal clayey sediments outside the arctic zone, the leaching of Na, Ca and Mg, and the formation of compounds rich in Al is a very conspicuous result of the chemical weathering processes. Within the arctic zone, on the other hand, these

TABLE IV.

	1	2	3	4	5	6	7	8	9	
	Spec. 1116			Spec. 1156			Mean value of matrix Col. 3 and 6	Glacial clays	Coal measure clays	
	Total	Detritus	Matrix	Total	Detritus	Matrix				
SiO_2	72.04	35.32	61.03	68.44	34.93	57.34	59.19	58.94	60.25	SiO_2
TiO_2	0.79	—	1.31	0.87	0.02	1.45	1.38	0.79	1.07	TiO_2
Al_2O_3	10.84	1.91	14.84	12.55	2.71	16.84	15.84	15.87	22.79	Al_2O_3
Fe_2O_3	0.75	0.09	1.25	1.03	0.18	7.15	6.65	3.28	4.23	Fe_2O_3
FeO	3.04	—	4.90	3.33	—	—	—	3.69	—	FeO
MnO	0.05	—	0.08	0.05	—	0.09	0.08	0.10	—	MnO
MgO	2.00	0.04	3.26	1.87	0.11	3.01	3.14	3.33	0.87	MgO
CaO	1.82	0.50	2.19	2.14	1.33	1.39	1.79	3.19	0.73	CaO
Na_2O	2.17	0.60	2.61	2.16	0.79	2.34	2.47	2.05	0.35	Na_2O
K_2O	2.39	0.48	3.17	2.28	0.79	2.55	2.86	3.95	2.47	K_2O
H_2O+	1.72	—	2.86	1.90	0.06	3.15	3.00	3.01	—	H_2O+
H_2O-	0.15	—	0.26	0.17	—	—	—	—	—	H_2O-
CO_2	0.26	0.26	—	0.31	0.85	—	—	0.60	—	CO_2
C	0.65	—	1.08	2.00	—	3.42	2.25	—	—	C
P_2O_5	0.70	—	1.16	0.75	0.01	1.27	1.22	0.21	0.20	P_2O_5
	99.37	39.20	100.00	99.85	41.78	100.00	99.87	99.01	92.96	
Sp. grav. .	2.68									

Col. 1. Detritus bearing mudstone, Spec. 1116, from Horpa-tso, Section IIb, km 0.4. Analyst: S. PALMQVIST.

Col. 4. Detritus bearing mudstone, Spec. 1156, from Napo-la, Section V, km 11. Analyst: S. PALMQVIST.

Col. 2 and 5. Composition of the detritus of the resp. specimens according to the planimetrical analyses, Table III, whereby in calculating the oxyds of the various components the following standard have been used: for granite, porphyry, and basalt, DALY's averages of 1933; for "slates" an analysis of phyllite from Hardangervidda, Norway, in ROSENBUSCH-OSANN 1923.

Col. 3 and 6. Matrix = Total less detritus, the rest being recalculated to 100.00 %.

Col. 7. Average of Col. 3 and 6.

Col. 8. Average composition of 68 Quaternary clays from Southern Norway, according to V. GOLDSCHMIDT (1932).

Col. 9. Average composition of 32 shales and clays from the Late Paleozoic coal bearing formations of North America.

reactions have rarely advanced beyond the initial stage because of the low temperature.

In Table IV, Col. 8, has been added for comparison, the average composition of 68 Quaternary clays from southern Norway according to GOLDSCHMIDT 1932. The agreement with the average of the matrix in Hor. 1116 and 1156, found in Col. 7, is most remarkable. The distinctive character appears still more strikingly on comparing this sedimentary type with the average composition of 32 shales and clays from the Late Paleozoic coal-bearing formations of North America (Col. 9), which have been deposited within the sub-tropical or tropical zone of that time. These are all typical residual clays, the material of which has been derived from rocks subjected to intense chemical weathering and leaching. They are characterized by very high excess of Al_2O_3 and very low Ca, Mg and Na, thus, sediments of an entirely different climatic type than those described above. We may therefore be allowed to conclude, that the material of the detritus-bearing mudstones in the western Changthang have been derived from a region with an arctic or sub-arctic climate.

Excepting the tuffaceous beds 1147 and 1148, the amount of detritus in the siltstones is always less than 50 % Vol., the average being 38,6 %. Quartz by far predominates constituting 63,9 % of total detritus as an average. This great predominance of quartz and, as will be seen in the following, quartz of a peculiar kind, is a fact which every explanation of the genesis of the sediment must account for.

Feldspars form about 22 % of total detritus. Potash feldspars predominate; fresh, quadrille structured microcline is rather common, fragments of fresh oligoclase are found occasionally. Next in importance are quartzites, slates, and black chert (about 7 %), mainly derived from earlier consolidated horizons of the series or from formations of similar composition.

The amount of detritus derived from granitic rocks is hard to estimate because of the difficulty of identifying as such the usually small fragments. Pebbles of granite and gneisses are not rare. Still more common are, however, various acid porphyries: cryptocrystalline felsites with phenocrysts of quartz, felsophyres, keratophyres, and granophyre.

Solitary fragments of basalt or porphyrites occur in all the detritus-bearing horizons investigated, but are exceptionally abundant in Hor. 1147 and 1148. Most common are fragments of pilotaxitic porphyrites with fluidally arranged laths or microlites of plagioclase in a serpentinized base. These fragments have often an oval rounded shape like lapilli.

The important rôle of the quartz in these deposits appears clearly in the tables of analyses. It stands out as conspicuously in the microscopic picture as seen on the micrographs Pl. VIII—X. The most remarkable feature with the main fraction of this quartz, is the usually perfect rounding of the grains all over the very extensive area of sedimentation, in striking contrast to the angular shape of the other minerals and rock fragments. The only mineral except quartz, which usually shows this perfect rounding, are a few grains of garnet and very fine-grained quartzite, but only a very few grains of feldspar of this shape have been detected in the large number of slides investigated.

The petrographic character of this quartz varies. A large part of it has strongly undulous extinction, mortar texture is not infrequent, Böhm lamellae ("böhmsche Streifung") is common. Much of the quartz contains an abundance of minute acicular interpositions as is common in quartz derived from paragneisses and crystalline schists. Other grains are rich in liquide inclusions. In some cases, the grains are surrounded by a narrow rim *(Anwachszone)* of secondary quartz. Again, a considerable part of the quartz shows no strain shadows at all. Some grains with corrosion channels, like those found in porphyry quartz, evidently originate from acid porphyries.

By the perfect rounding of the grains, the greater part of the quartz sand stands out as a unity; it must have been derived from a widely distributed deposit of this material. If this quartz sand originated from a fossil formation of quartz sandstone, one could expect fragments of this mother rock to be represented in the detritus, or at least remains of the primary cement should occasionally adhere to the loosened quartz grains. No trace of it has been seen. This makes it probable that the quartz originates from a formation of unconsolidated, very pure quartz sand of very wide distribution. An almost inexhaustible source of such quartz sand is available in the white beach sand of the shallow shores of the continents, where the sand is steadily rolled and ground to a perfect rounding of the grains by the perpetual action of the waves. At the same time, sorting according to specific gravity produces a nearly monomict deposit. The mode of deposition of this sand is clearly in evidence in Hor. 1140, where the detritus appears as pockets and isolated lumps in black siltstone (Pl. XI, Fig. 1). This quartz is referred to in the following as "beach quartz".

Well over 50 % of the total quartz is typical beach quartz. The remainder is derived from the same source as the rest of the detritus, and is of an angular and sub-angular shape like the latter. Adhering remains of feldspar or porphyry groundmass indicate granitic rocks, porphyries, and various quartzites as the mother rocks.

The Arenaceous Sediments.

A very conspicuous feature of the Horpatso Series are the thick beds of gray or greenish, fine-grained quartzitic arkoses which line the slopes of the valley between Camp N 422 and N 423 in Section III on the southern side of the Mawang-kangri. Below and above follow dark detritus-bearing siltstones, and thinner beds of such material are also intercalcated in the arkose. The total thickness amounts to several hundred metres. This sediment seems to have split parallel to the bedding more easily than the massive siltstones, and therefore sills of diabase appear preferably in or near this formation.

In Section II, which represents the middle and upper parts of the Horpatso Series, we find only one formation comparable to this quartzitic arkose as regards thickness and petrographic composition, *viz.* the thick horizon 1121 near the base of the section. Here also appear sills of diabase. Higher in the section, arkoses are subordinate and are usually of marly character.

Similar gray, fine-grained, quartzitic arkoses of great thickness appear in the

TABLE V.

Mineral Composition of Some Late Paleozoic Sandstones
% of Volume.

	1	2	3	4	5
	Horpatso Series		Tashliqköl Series		
	1121	1119	1123	1129	1130
Matrix:					
calcareous	0.0	44.0	0.0	37.4	1.6
argillaceous	0.0	0.0	0 0	0.0	0.0
lyditic	0.0	18.9	0.0	0.0	0.0
Detritus:					
Quartz	58.8	35.8	92.4	59.7	97.7
Feldspars	38.7	1.3	6.2	2.5	0.2
Biotite	—	—	—	—	—
Hornblende	—	—	trace	trace	trace
Ore	1.5	—	"	"	"
Zircon	r.c.	—	r.c.	0.2	r.c.
Lydite	—	—	1.4	0.2	0.5
Slate	1.0	—	—	—	—
	100.0	100.0	100.0	100.0	100.0

sections between the depression of Changer-shahr and the Tajang Valley forming the uppermost exposed part of the Horpatso Series here. Intrusions of augite-diabase have not been observed. Whether or not this formation corresponds to the main arkose of the more easterly sections is uncertain.

Characteristic features of these widely distributed arkoses are their apparent homogenity and their very fine grain; gravelly or conglomeratic beds have not been observed anywhere.

Specimen 1121 of Section II b is a typical representative of the quartzitic arkoses. The sediment consists almost exclusively of quartz and feldspars with practically no matrix. The coarseness of the sand averages 0.3 mm. It is rather imperfectly water-worn, but solitary larger grains of perfectly rounded beach quartz, often 0.6 mm. in diameter occur, although much more sparingly than in the detritus-bearing mudstones. The quantitative mineral composition is given in Table V, Col. 1.

Quartz predominates strongly (58.8 % Vol.). Most of it has strongly undulatory extinction and Böhm striation; grains with acicular interpositions are common. Most of the quartz may have been derived from metamorphosed granitic rocks.

The feldspars (38.7 % Vol.) are sometimes perfectly fresh or else stained, more or less, with sericitic substance. Potash feldspar predominates. The composition of the plagioclase varies between oligoclase and oligoclase-albite. Further occur solitary grains of chert, fine ore dust, a few grains of muscovite, hornblende and apatite; zircon is fairly common. The preponderance of quartz and feldspars in the sediment shows that large areas of mainly granitic rocks were exposed to denudation under climatic conditions unfavourable to chemical weathering processes.

At Camp N 724, the quartzitic arkose grades at the base into stratified, black siltstones (1144), consisting of very fine-grained (0.02—0.04 mm.) quartz and feldspar detritus, richly intermixed with argillaceous material.

In Section II, the arkose is overlain by basaltic lava, and then follows bluish gray, very fine-grained (about 0.15 mm.) sandy marl with thin layers of black lydite (1119). The fairly well water-worn sand grains consist almost exclusively of quartz embedded in a calcareous matrix, which forms 44 % of the volume of the sediment (Table V, Col. 2). Cryptocrystalline chert, stained with coaly dust, occurs as an impregnation, as patches, and as sharply defined layers about 5 mm. thick, which also enclose quartz fragments in varying abundance. In contrast to the subjacent arkoses, the content of feldspar is very low (1.3 % Vol.).

Upon this horizon follows detritus-bearing dark mudstone, and then grayish black, thinly and nicely laminated siltstone (1118). The very regular periodicity in the stratification of this sediment, shown on the micrograph Pl. X, Fig. 3, suggests an annual period of deposition. The thickness of the "varves" averages about 2 mm. The summer zone of each varv consists of grains of quartz and feldspars, about the size of 0.1 mm., appearing in the proportion about 3: 2, and cemented by a calcareous matrix. The winter zone consists of bituminous clay with inconsistent streaks of very fine-grained carbonates. The sediment closely resembles certain Quaternary distal varve deposits in Fennoskandia.

Mode of Formation of the Detritus-bearing Mudstones.

The above description of the detritus-bearing mudstones, and the sediments associated with them, shows that we are dealing with a special, well defined type of sediment with many distinctive characters. A number of peculiar features have been revealed which collectively make it possible to arrive at a definite conclusion as to the mode of formation of the deposit.

1) The sediments consist of two components of different origin, *viz.*
    a) clayey mud, rich in carbonized vegetable remains, forming 50—70 % of the deposits; this is a normal distal lake deposit, the chemical composition of which shows that its material has been formed mainly by mechanical disintegration of various granitic rocks under arctic or temperate climatic conditions;
    b) polymict coarse detritus to an amount of 30—50 %, unassorted and not deposited by normal lacustrine or fluviatile agencies.
2) The predominance of well water-worn beach quartz, to an amount of about 30 % of the total detritus, shows that by far the greater part of the detritus has been

derived from shallow beaches along a coast covered with loose quartz sand. Hence, the agency by which the detritus was transported and deposited is to be looked for amongst the forces active on the beaches.

3) The uniform composition of the deposit over an area of thousands of square kilometres shows that the intensity of deposition was practically independent of the distance from the shores and the sources of the detritus.
4) The occurrence of seemingly annually laminated silt indicates a seasonal variation in the supply of sediments and rather cold winters.
5) Apart from the occurrence of basaltic porphyritic tuffaceous material in some horizons, by far the main part of the series shows no signs of volcanic origin, chemically or petrographically, but is a typically clastic formation. The possibility of it being an agglomeratic formation is thus excluded.

The only agency capable of satisfying these facts, is the ice formed along the beaches by the freezing of the sea during the winter. By the combined action of ice pressure, waves, and tides, large ice barriers could accumulate. On the breaking up of the ice cover in the spring, the beach ice would drift out to the open sea, depositing enclosed and adhering detritus from the beaches on melting. Considering the huge quantities of detritus involved, it is necessary to assume a frequent repetition of this process, such as the annual breaking up of the frozen sea in the spring. No permanent ice cover would satisfy the facts.

Sediments of the type concerned seem to be of frequent occurrence within the border regions of former areas of glaciations. Some striking parallels are to be found in certain horizons of the Sub-Cambrian glacigenous formations of Tien-shan, Northern Scandinavia, and Greenland, as appears from some typical micrographs of such sediments reproduced on Pl. IX, Fig. 4 and Pl. X, Fig. 1—2. In these cases too, the sediments consist of clayey or calcareous mudstone, which forms the main part, intermixed with polymict detritus of greatly variable coarseness (Table III, Col. 8—10). By far the greater part of the detritus in these cases also consists of extremely well water-worn quartz sand of a type similar to that in the Horpatso Series. More subordinately occurs detritus of feldspars, limestones, and other rocks, which usually are much less water-worn and of angular or subangular shape. In these cases too the sediments must have originated in a similar way as the detritus bearing mudstones of the Horpatso Series: flotation of beach deposits by ice rafts. But we have there abundant proofs as well of an extensive glaciation on the neighbouring continental areas, and the glacigenous character of the sediments is well established.

Sediments of this type, however, are not necessarily a proof of glacial conditions; on the contrary, they require the presence of an ice-free coast where beach sand could accumulate. But they are the sign of a seasonal freezing of the sea with abundant accumulation of ice along the beaches, conditions most nearly comparable with those prevailing today in the sub-arctic regions of Scandinavia, Spitsbergen, northern Asia, and Greenland.

Apart from the large granitic intrusions in Mawang-kangri, two important eruptive formations occur in the Horpatso Series, *viz.* various diabases and quartz-porphyrites. Both occur in the shape of sills or dikes intruded with preference into the arkosic quartzites in the middle part of the series. The greenstone beds are, in part, effusive, a fact which combined with the abundance of basaltic tuffaceous material in certain horizons shows that this volcanic activity was partially contemporaneous with the formation of the sediments. The quartz-porphyrites are certainly much younger, probably Late Mesozoic or Tertiary. They will be described together with other granitic rocks in Chapter VI.

The diabases are strongly altered basaltic or porphyritic rocks in which usually only the monoclinic pyroxene has escaped secondary transformation. Amongst the specimens collected, Spec. 1122, a sill or dike near the base of the main arkose in Section II, has best retained the primary features, and may be classed as dolerite or diabase. It is a fresh-looking, grayish black, fine-grained rock of doleritic texture, consisting of long prisms of zoned andesine (An_{35}—An_{08}), colourless monoclinic pyroxene ($2V\gamma = 58°$, $c/\gamma = 44°$), ilmenite with leucoxene, and interstitial masses of serpentine occasionally with some actinolite, biotite, calcite, and long thin needles of apatite.

The chemical composition is as follows:

TABLE VI.

Diabase. Spec. 1122, from the Horpatso Series, Horpa-tso.

Analyst: S. PALMQVIST.

	%	Norm		Niggli values	
SiO_2	43.69	Or	6.11	qz	−23.8
TiO_2	4.23	Ab	22.44	si	107.8
Al_2O_3	14.83	An	25.53	ti	9.8
Fe_2O_3	3.90	Sal	54.08		
FeO	11.45			al	21.6
MnO	0.20	Di	6.83	fm	51.0
MgO	5.36	Hy	16.58	c	19.5
CaO	7.39	Ol	2.12	alk	7.9
Na_2O	2.65	Mt	5.65		
K_2O	1.03	Ilm	10.05	k	0.2
P_2O_5	0.42	Ap	1.01	mg	0.4
H_2O+	4.52	Fem	42.24		
H_2O-	0.40	H_2O+	4.52		
	100.07		100.84		

Quantitative System: 111:5:3:4 — *Camptonose*
Niggli's System: *Normal gabbroic magma type.*

As a rule, however, the basaltic intrusions are much more strongly altered and have the appearance of dark, grayish green, spotted greenstones (Spec. 1138, 1139). The only primary mineral left is idiomorphic monoclinic pyroxene, which stands out conspicuously in the mass of fine-grained decomposition products (zoisitic dust, clinozoisite, quartz, pale greenish chlorite, ore, and sparsely actinolite). In this the outline of plates of plagioclase, replaced by nearly pure albite, zoisite, and some sericite, can be distinguished.

In horizon 1143, a more fine-grained, porphyritic variety, carbonatization plays a certain role. The plagioclase is completely altered into albite (An_{07}) and zoisite, the latter usually dissolved and expelled. The groundmass consists of zoisite, clinozoisite, quartz, nearly colourless chlorite, muscovite, some actinolite, and ore with leucoxene, and is spotted with brownish masses of fine-grained carbonates, which occasionally enclose the remains of colourless monoclinic pyroxene.

Effusive basaltic rocks have been observed in the Horpatso Series at one place only, *viz.* Horizon 1120 in Section II; they may, however, be more common than is now realized. This rock, in hand specimen black, felsitic and amygdaloidal, is seen under the microscope to consist mainly of brown or golden yellow, vesicular, pumiceous volcanic glass, in part isotropic, in part devitrified. No primary crystallizations are to be seen, but the glass encloses scattered minute, angular fragments of quartz and fresh plagioclase. The vesicles, 0.04 to several millimetres in diameter, are filled with coarse- or fine-grained calcite or spherulitic chlorite.

Comparison with the Agglomeratic Slate Series of Kashmir.

When encountering the detritus-bearing mudstones of the Horpatso Series in the field, the author was struck by the close resemblance between these rocks and the so called Agglomeratic Slates of Kashmir, well known to him after geological work in that province in the years 1925 and 1926.

The Agglomeratic Slate Series, which locally attains a thickness exceeding a thousand metres, is enclosed between the *Fenestella* Shales and Permian continental beds with *Gangamopteris* flora (Cfr Table VII). Fossils have been found at several levels by MIDDLEMISS, BION, and THOMPSON. The lower part of the series (Lower Marbal Beds), characterized by *Syringothyris cuspidata var. lydekkeri* and *Protoretepora cfr ampla,* was referred by BION (1928) to the Carboniferous; the upper part of the series with typical Australian *Eurydesma* fauna is referred by BION, MERLA (1934), RAGGAT and FLETCHER (1937), a. o. to the Lower Permian, by SCHUCHERT (1935) and HERITSCH (1939) to the Lower Middle Permian.

The Agglomeratic Slates are described by MIDDLEMISS (1910) as follows: "That it is a clastic rock of some kind seems to admit of no doubt. Much of it from its dark gray colour and the nature of its matrix might be described as a fine grit or greywacke, composed chiefly of angular grains of quartz set in a still finer matrix which was probably once of the nature of clay, rock flour or ash, or it may partly be cataclastic mylonite. But dotted about at random through this matrix occur larger fragments, sometimes rounded, but more generally sharply angular (like the smaller grains of quartz) and composed of quartz, feldspar, slate and quartzporphyry, with occasional quartzite, pegmatite and even tourmaline-granite fragments. These range in size from bits as large as a pea to others the size of a fist. When they become very large the rock becomes generally much more quartzose and the larger pieces are then more rounded. The finer-grained rock is the predominant rock and is easily recognised wherever occurring by the angular fragments or by the cavities whence such fragments have been weathered out on exposed surfaces. It is generally imperfectly cleaved, in common with all the fine-grained rocks of this region.

But having acquiesced in its clastic origin, it is not so easy to define the exact nature of the agence by which it was accumulated. It is certainly not a simple stratified deposit laid down under the action of water. Although the sharply angular nature of the smaller quartz grains forming the matrix might not have been altogether adverse to this conclusion, the angular state of the larger fragments demands some other explanation. There seem to be two main natural agents by which such a wide-spread and uniform deposit might have been accumulated, namely, (1) explosive volcanic action, and (2) frost with ice transport . . . . Although unable to discuss the subject here I incline to the explosive volcanic theory and so include the agglomeratic slate as a lower member of the volcanic series. That is to say I regard it as an accumulation of clastic and sedimentary material formed round ruptured portions of the earth's crust which eventually became foci for the extrusion of basic lava flows. At the same time the alternative hypothesis should not be lost sight of, nor the possibility that the formation was a joint product of both sets of activities combined with ordinary sub-aërial sedimentation."

The occurrence of *Eurydesma cordatum* in the uppermost part of the Agglomeratic Slate Series would place this horizon at about the stratigraphic level of the Speckled Sandstone overlying the Talchir Tillite in the Salt Range (BION 1928, REED 1932). The duration of the Late Paleozoic Ice age in India is not known. In Australia and in South America, several periods of glaciations have been distinguished extending from the Carboniferous well up in the Permian. The absence of traces of these earlier glaciations in Peninsular India may only mean that their deposits have been effaced by the younger glaciations, in the same way as in Scandinavia the deposits of the earlier Quaternary glaciations were almost completely effaced by the last glaciation. But for the preservation of these earlier moraine deposits in the marginal zone of the glaciated regions, we would know nothing of the earlier glacial history.

There is thus a possibility that also in the Indian region glaciations occurred even as early as the Carboniferous. If the Agglomeratic Slate Series is a marine glacigenous sediment in the sense suggested by MIDDLEMISS, deposited in the Paleo-Tethys on the Gondwana continental shelf, also earlier stages of the Gondwana glaciations may be recorded here.

The second alternative of MIDDLEMISS, *viz.* the volcanic origin of the Agglomeratic Slates, has long been fervently advocated by WADIA (1928, pp. 233, 1934, pp. 150, 1944), but no convincing petrographic facts have been presented in support of this view. Three slides of rocks specimens are described from the Pir Panjal Pass, Poshiana, and Bhagsar. According to the descriptions, none of them has any resemblance to basaltic tuff, contrary to what could be expected if the Panjal Trap were the mother rock as assumed by WADIA. The alleged occurrence of devitrified volcanic glass should be confirmed by more thorough analysis, because of the difficulty of distinguishing this substance from fragments of chert, which are of common occurrence in the Agglomeratic Slates.

In his description of these rocks, MIDDLEMISS (1910, p. 233) says: "If we accept the former (agent i. e. explosive volcanic action) as being congruent with the lavas which followed, we have to admit the entire absence of glassy or pumiceous material in the rock matrix as now seen, although subsequent devitrification or silicification with crushing and development of mylonite, sericite, calcite, and other secondary minerals might account for the condition of the rock as we now see it."

Hence it appears, that the data at present available do not suffice to form a definite opinion as to the mode of formation of the Agglomeratic Slate Series. It is to be hoped that the questions in dispute may be solved by a regional petrographical and chemical investigation of the deposit.

Above the Agglomeratic Slates there comes a great thickness of massive beds of augite-andesites and basalts, occasionally also small masses of trachyte and rhyolite. According to WADIA (1926, 1928) the primary constituents of the trap are plagioclase and augite in a fine-grained semi-crystalline groundmass with accessory magnetite and ilmenite. The lath-shaped plagioclase has suffered wide-spread decomposition into zoisite, epidote, and calcite. In some varieties, usually in the lower part of the beds, the feldspar phenocrysts are arranged in star-shaped aggregates (glomero-porphyritic texture). The augite is in rounded irregular grains, almost entirely replaced by epidote, sometimes by chlorite. The rock is free from olivine.

The upper limit of the Panjal lava-flows is usually clearly defined, being fixed by the directly overlying beds with *Gangamopteris* of Lower Gondwana facies which in turn are immediately succeeded by the marine Upper Permian Zewan Beds. In the section described by MIDDLEMISS (1928) at Nagmarg, north of Srinagar, the *Gangamopteris* Beds appear, however, at the top of the Agglomeratic Slate Series and are overlain by the volcanic series, a proof of the short space of time represented by the eruption. In a few cases the basalt eruptions have been found to extend as high as the Triassic, a few flows being found locally interbedded with limestone of that age.

According to WADIA (1926, p. 359), the Panjal slates and volcanics are also developed in Ladakh, extending further to the north-east in the direction of the Chang-chen-mo Valley to the very farthest borders of the Kashmir territory. We are here only a few kilometres west of the most westerly identified outcrops of the Horpatso Series in the basin of Dyap-tso. The identity of these two great series of sediments of similar lithological character is, thus, *a priori* rather probable.

Lithologically, the Horpatso Series agrees closely with the Agglomeratic Slate Series. In both regions a thick formation of quartzites or arkoses separates an upper complex of detritus-bearing mudstones from a lower complex of similar composition. In both cases the series contains sills of diabase or strongly altered augite-basalt, in part contemporaneous with the sediments.

The Late Paleozoic Deposits in the Loqzung Mountains and in the Chipchaq Valley.

Extensive exposures of the Permian limestone series and its thick basal formation of quartz-sandstones and quartzites are found in the Western Loqzung Mountains north of Sarigh-yilganing-köl and further to the north-west.

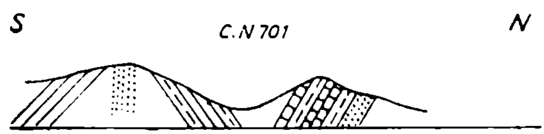


Fig. 15. The Permian beds at Camp N 701, Western Loqzung Mountains.

The section Fig. 15 shows the position of the Permian beds in the neighbourhood of Camp N 701. The lowest beds exposed consist of light gray fine-grained quartz-sandstone and gray, sandy shales similar to the basal beds in the type section at Tashliq-köl. Above follow grayish black and dark bluish gray limestones interbedded with calcareous shales. Some of the limestones are filled with discs of crinoids. In the middle of the syncline, at the foot of an isolated hill close to Camp N 701, a fine colony of corals in black limestone (Spec. 1092) was collected amongst the talus. HERITSCH identified it as *Tetrapora halysitiformis* YOH, previously known from the zone of *T. elegantula* in southern China (Lower Middle Permian). These beds thus correspond to the dark bryozoa limestones of the type section. The higher, white *Protomichelinia* Limestones are missing.

The characteristic Permian quartzites appear again at Camp N 698, some 40 km. further to the north-west in a broad depression enclosed between high ridges of Cretaceous limestones (Fig. 16). Here, the Permian beds represent a broken anti-

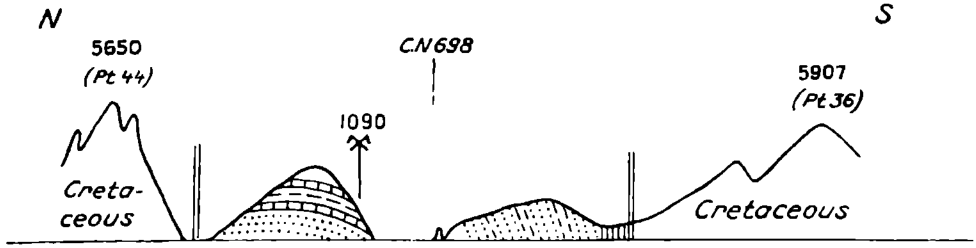


Fig. 16. The Permian basal beds at Camp N 698, Western Loqzung Mountains.

cline. The southern limb consists of grayish green, fine-grained quartzites (1089) of great thickness dipping 70° towards W. N. W., overlain by grayish black, calcareous and sandy shales, which are separated from the strongly brecciated Cretaceous limestones of the ridge 5907 by a fault. In the middle of the depression rises a rather high ridge, the base of which consists of the same quartzites in nearly horizontal position capped by dark shales with beds of black shaly limestones filled with fragments of shells and large fusulinidae of Late Paleozoic type (Coll. 1090).

The quartzites (1089, 1093) of the localities described above agree closely with the basal Permian quartzites in the Sumtsiling Basin. They consist of edge-worn, pure quartz sand (about 0.2 mm.) with only solitary grains of feldspar, mainly microcline, cemented with newly formed quartz. A characteristic accessory is in both regions tourmaline (ε = colourless, ω = brownish green) which together with zircon enters rather abundantly.

The most extensive and finest outcrops of what is probably the Permian quartzitic series are found along the eastern Chipchaq Valley, which opens into the Qara-qash Valley at Dong-lung (Sketch maps Fig. 17 and 18).

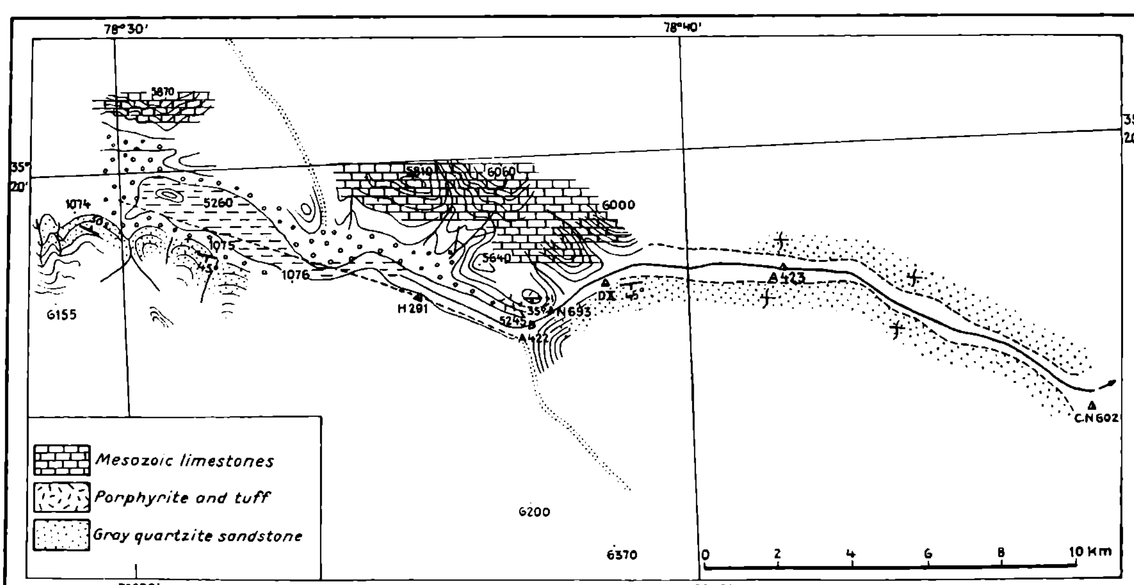


Fig. 17. The Paleozoic and Mesozoic beds in the Chipchaq Valley, upper Qara-qash drainage.

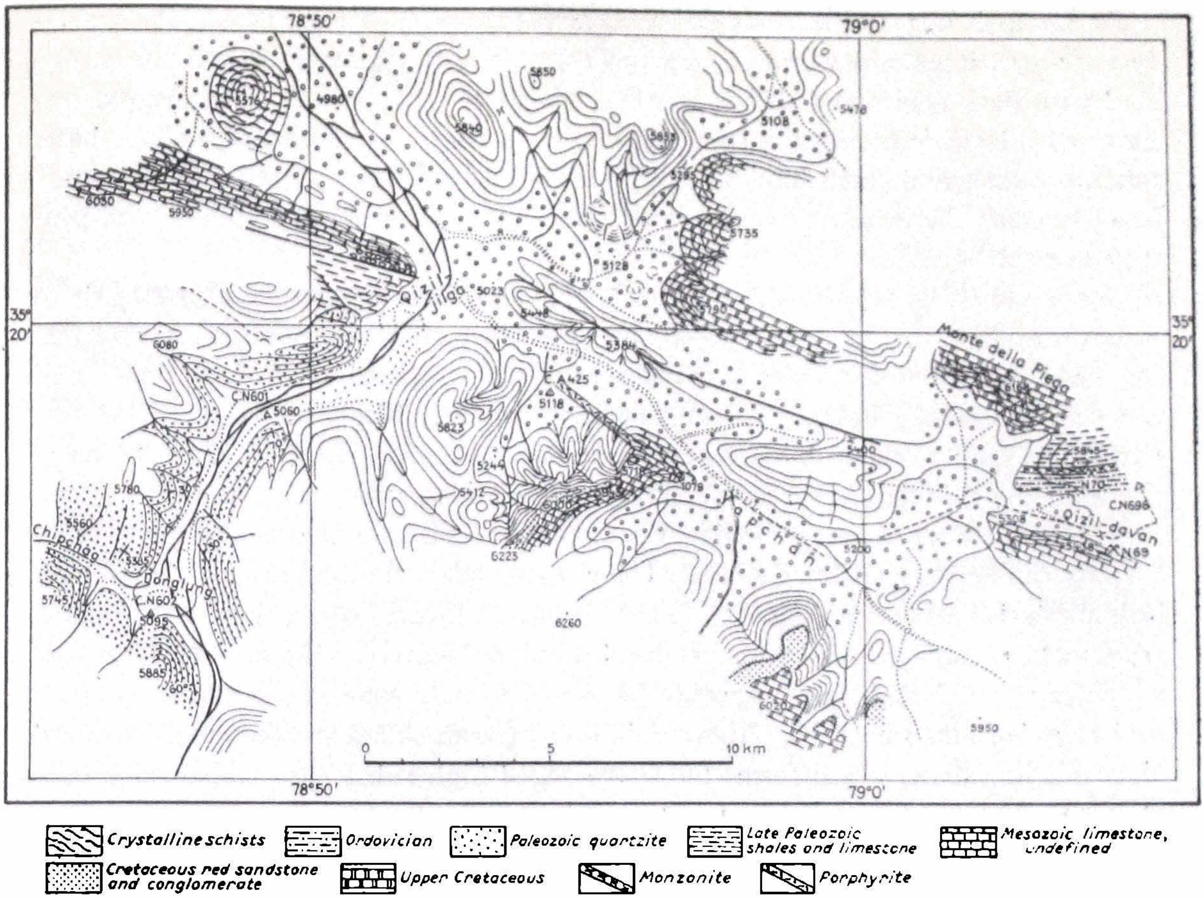


Fig. 18. Geological sketch map of the upper Qara-qash region around Qizil-yilga, Western Loqzung Mountains.

A short distance above the very flat and undefined watershed of this peculiar, broad, longitudinal valley, DAINELLI (1934, p. 518) made the following observations (freely translated): "When we reached that part of the valley where the drainage changes to easterly into the Karakash, calcareous lenses and sandy, red limestones appear in the upper part of the slopes. Farther away, apparently stratigraphically higher than the largest calcareous lenses, sandy shales and real compact, greenish sandstones crop out. In a dark limestone, which probably represents a rather high horizon in the series, MERLA identified *Archaeocidaris* sp. and *Tetrapora* sp. indicating Middle Permian."

Between Camp N 692 (HEDIN's Camp 290) and Camp N 693 (DAINELLI's Camp X), is exposed in the southern slope of the valley a very uniform series mainly of brownish gray (1073), light gray (1074) or nearly white, and bluish black (1075) quartzites, which are always very fine-grained and occasionally interstratified with dense argillaceous beds (1076). The strike varies between E. S. E. and due E. with undulating dip about 30°.

At Camp N 693, where the valley contracts to a width of some 150 m., the quartzites are associated with porphyritic lava (1077) in part agglomeratic and interstratified with dark shales and thin limestone beds dipping 35° south. The slaggy, originally hyalopilitic porphyrite contains, in the isotropic or crypto-crystalline base, much ore dust and small laths and microlites of feldspar and phenocrysts of colourless pyroxene. Vesicles and cavities are filled with pale yellowish epidote and penninite or calcite.

Down the valley all the way to Dong-lung and further along the Qaraqash to near Qizil-yilga, the valley is enclosed between steep cliffs of quartzites in undulating beds. At Dong-lung, the quartzites are interstratified with dark shales and the stratigraphically lowest exposures consist of nearly black, nicely stratified siltstones not unlike certain horizons in the Horpatso Series. Nowhere does the amplitude of the folding exceed the thickness of the series, which must be rather great.

A short distance above Qizil-yilga, the quartzitic series assumes a persistent northeasterly dip and disappears definitely below dark sandy and calcareous shales with beds of dark limestones (Fig. 19). Then follows a breccia of more or less angular fragments of dark gray limestone embedded in a red matrix. Higher in this horizon, which dips 70° N. E., the fragments become distinctly water-worn and are in part well rounded and smoothed. Above follow calcareous shales and then multicoloured Mesozoic limestone, which forms the sharp-edged high ridge 5950. This thick conglomerate is very similar to the basal Triassic conglomerate in the valley of Chang-chen-mo.

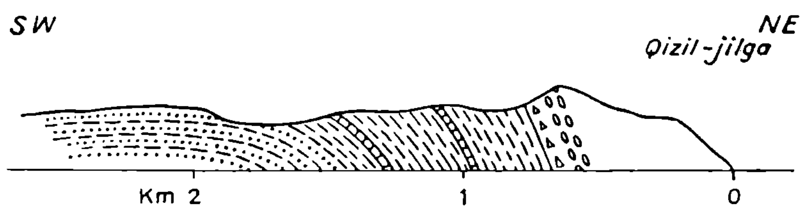


Fig. 19. Contact between the Paleozoic and the Mesozoic sequences at Qizil-yilga.

Petrographically, the quartzitic series in the Chipchaq Valley agrees very closely with the Permian quartzites in the Sumtsiling Basin, although the thickness is much greater than in any exposures in the latter area. The samples of quartzites collected (1073, 1074, 1075, 1078) are all of the same general type, consisting of nearly pure quartz sand, sparsely intermixed with fresh feldspar; characteristic accessories are tourmaline, pleocroic in bluish green, zircon, and occasionally apatite. Spec. 1075 contains about 10 % of coaly, argillaceous matrix. The sand grains are often fairly well water-worn. Spec. 1073, 1075, 1078 contain a finer fraction, about 0.1—0.2 mm., intermixed with more strongly worn grains, about 0.4—0.7 mm. No gravelly or conglomeratic beds have been observed.

Correlation of the Late Paleozoic Formations in the Karakoram—Chang-thang Region and in Kashmir.
(Table VII.)

Based upon the apparently nearly complete section of the Late Paleozoic deposits in the western Chang-thang, the Permian strata of which have been shown to extend into the region of the Karakoram Pass, an attempt may be justified to place the fragmentary and much disturbed Late Paleozoic sections of the latter region in our general section.

Brownish red sandstones interstratified with calcareous shales and containing an Upper Permian (Lopingian) fauna were found by DAINELLI (1934, II, p. 506) in the basin of the Rimo Glacier, and beds of similar age with *Richthofenia* sp. and *Bakewellia cfr ceratophaga* (RENZ 1940, p. 281) were discovered by WYSS in the Lungnak-lungpa of the northern Chipchaq drainage.

REICHEL and RENZ (1940, p. 90, 243), who have studied the Paleozoic fossils collected by WYSS in the Tethys-Karakoram, distinguished the following main divisions in descending order:

6. *Upper Artinskian.*	White, in part strongly crystalline limestones with *Fusulinidae* and *Verbeekinidae.*
5.	Light gray limestone with *Fenestella.*
4. *Lower Artinskian.*	Yellowish brown sandy limestone with *Parafusulina erucaria var. caracorumensis, P. cfr verneuili var. levidensis.*
3. *Upper Uralian.*	Gray sandy limestone with *Triticites wyssi, Pseudofusulina vulgaris var. globosa, Parafusulina aghilensis,* a. o.
2.	Bluish gray limestones and marly limestones with Bryozoa.
1. *Lower Uralian.*	Bluish black, very tough limestones.

REICHEL states that the foraminifer fauna of Divisions 3 and 4 shows affinities to Darwas and the Salt Range as well as to the Uralo-Artinskian of Eastern Asia, whereas the fauna of Division 6 is closely related to the latter. "Mit dem Übergang zu den oberen Fusulinen-Schichten (*i. e.* Div. 6) tritt ein markanter Faunenwechsel ein. Wir sind hier oberhalb der Pseudoschwagerinen-Zone, aber wahrscheinlich noch im unteren Perm der klassischen Stratigraphie, das heisst im Artinskian . . . . . Alle Arten sind entweder identisch mit solchen, die man aus Indo-China, China und Japan beschrieben hat, oder stehen ihnen sehr nahe."

The white, crystalline limestones, Div. 6, correspond to the thick, white crystalline limestone with *Protomichelinia* in the Tashliqköl section, which forms the highest known marine Permian horizon here. It is, according to HERITSCH, equivalent to the zone of *Polythecalis yangtzeensis* or possibly a higher Permian horizon.

The divisions 1—3 of REICHEL'S table may correspond to the complex of dark limestones and calcareous shales, about 500 m. thick, which are enclosed between

TABLE VII.

Tentative Correlation of the Late Paleozoic Formations in the Himalayas and Karakoram—Western Chang-thang.

	1 Salt Range	2 Kashmir	3 Spiti	4 Karakoram-Aghil Zone	5 Chang-thang	
UPPER PERMIAN	Otoceras Beds (1). Upper and Middle Productus Limestone (1, 2, 11).	Zewan Beds (dark limestones and shales).	Otoceras Beds. Kuling Beds 3) Dark shales with limestone partings (Productus Shales). 2) Calc. sandstone. 1) Grits and congl.	Littoral deposits with *Richthofenia* and *Bakewellia* (11). White limestones with *Verbeekinidae* and *Fusulinidae* (9).	White limestones with *Protomichelinia.*	1) HERITSCH 1939, 1941. 2) SCHUCHERT 1935. 3) GRABAU 1931. 4) RAGGAT and FLETCHER 1937. 5) Rec. Geol. Surv. India, Vol. 67, pp. 22, 53. 6) DUNBAR 1933. 7) Middle or Upper Carboniferous (in the old sense) accord. to DIENER (1915). 8) Moscovian accord. to BION 1928. 9) REICHEL 1940. 10) METZ, see Appendix B. 11) MERLA 1934. 12) MERLA and HERITSCH place this horizon higher in the Middle Permian. 13) REICHEL places this horizon in the Upper Uralian. 14) RENZ 1940. 16) WADIA 1926, p. 360. 17) Probably Lower Permian accord. to GRABAU 1931, p. 518. 18) HAYDEN 1904. 19) HAYDEN 1934, p. 315. 20) DE TERRA 1932.
MIDDLE PERMIAN	Beds with *Glossopteris* and *Gangamopteris.* Lower Productus Limestone with *Parafusulina kattaensis* and *P. crucaria* (6, 12).	Shales and sandstones (250—300 m.). In the middle part beds with *Glossopteris, Gangamopteris,* a. o.	Slight unconformity.	Limestone with *Parafusulina crucaria* var. *caracorumensis* a. o. Limestones with *Parafusulina aghilensis* (13).	Disconformity (?). Dark limestones and shales rich in bryozoa and foraminifera (10). Quartz sandstone and quartzites.	
LOWER PERMIAN (URALIAN)	Speckled Sandstone with *Eurydesma* fauna (4). Black shales with *Glossopteris* a. o. (5). Sandstone (3 m.). Tillite.	Nagmarg Beds with *Eurydesma* fauna. Upper Agglomeratic Slate with *Eurydesma* fauna (4). White quartzite (16). Lower Agglomeratic Slate (8).	Sandstones, grits, and conglomerates locally developed as boulder-slate (18). White and brownish sandstones interstratified with shales. Fenestella shales (17). Shales and sandstones.	Limestones with Bryozoa. Black limestones.	Horpatso Series: Upper detritus-bearing siltstones. Quartzitic arkoses. Lower detritus-bearing siltstones.	
		Fenestella Shales (7, 19). Syringothyris Limestone Series (Dinantian).	Black shales with plant fossils (Culm). Lipak Series (limestones interstratified with sandstones. Dinantian).	Limestone with *Orthoceras calamus* (Lower Carboniferous) (14).	Limestone and shale with *Syringothyris* Limestone fauna (Dinantian) (20).	

the basal sandstones and the *Protomichelinia* Limestone at Tashliq-köl. The fauna collected in these beds corresponds, according to METZ, to the Lower Permian — Lower Middle Permian. To this complex also belongs the dark limestone with *Tetrapora halysitiformis* in the Loqzung Range (HERITSCH).

In the section at Tashliq-köl, the presence of a stratigraphic break at the base of the white *Protomichelinia* Limestone series is highly probable because of the occurrence of boulders of a limestone conglomerate in the border zone. This is in agreement with the marked change in the fauna when passing from Div. 4 into Div. 6 in REICHEL'S table.

The basal Permian quartzites in the Sumtsiling Region are connected with the very thick quartzitic series in the Chipchaq Valley by a zone of scattered outcrops in the Western Loqzung Mountains. It is apparent from the observations of DAINELLI, that these quartzites form the base of the fossil-bearing Permian in the upper Shayok area and the Qara-tagh. They are, also here associated with beds of basaltic lavas.

As far as the author's observations go, there are no evidences of an unconformity between the Permian quartzites and the subjacent Horpatso Series. No conglomerates or gravelly beds have been seen anywhere in the quartzitic series or in the upper part of the Horpatso Series; the quartzites are always fine-grained and consist of nearly pure quartz sand with the same characteristic accessories as in the quartzites of the Horpatso Series.

On the northern side of the Transhimalaya, there extends according to HAYDEN (COULSON 1933, REED 1930), between long. 86° 30′ and 91° 30′ a zone of Late Paleozoic limestones overlying shales, sandy grits, sandstones, and conglomerates intruded by basic rocks. Fossils were collected by HAYDEN at 10 localities. In his description of the fossils, REED states that the typical faunas of the Productus Limestones of the Salt Range are not present. Almost all the brachiopods are known from the Upper Carboniferous (as defined by REED) of the Urals or from parts of Asia; the prevalence of *Schwagerina princeps* is strongly suggestive of the Uralian.

Schwagerina princeps has been identified earlier in the Pamirs and Chitral (REED 1925), but it is a remarkable fact, that it has not been found in the large collections of Late Paleozoic fossils made by DAINELLI and WYSS in the intervening space of the Karakoram. Here, the lowest horizons found by DAINELLI (Rimo 1—3) are referred by MERLA (1934, pp. 190) to the Uralian because of the occurrence of numerous brachiopods considered characteristic of this stage, but there also occur corals of Middle Permian type (a primitive *Tachylasma* and *Sinophyllum pendulum* var. *simplex*). At first on the northern slope of the K'un-lun, beds with *Schwagerina* have been met with. The occurrences along the northern side of the Transhimalaya is the most southerly extension of this facies.

The fossiliferous Lower Permian fixes an upper limit of age of the Horpatso Series. A lower limit is fixed by the Lower Paleozoic formations in the valley of

Chang-chen-mo and elsewhere, which generally are strongly metamorphosed and largely transformed into crystalline schists. The relation between the Horpatso Series and the thick series of Lower or Middle Carboniferous siliceous limestones found by DE TERRA (1932, p. 105) near Darwaz-sarigh-ot on the northern side of the Karakoram Pass, is not known. These beds were also encountered by WYSS in the Qara-tagh and were referred by RENZ (1939, p. 67) to the Lower Carboniferous. When crossing the Karakoram Pass in 1932, the author noticed this limestone series, which is unlike any sediments above the Permian quartzites in the Chipchaq and Sumtsiling because of the abundance of layers of black chert. If our correlation of the Horpatso Series with the Agglomeratic Slate Series of Kashmir is confirmed, these beds should belong to the unknown fundament of the former. Here we must also place the dark slaty limestones with *Syringothyris* Limestone fauna in the valley of Chang-chen-mo, which would make the correspondence to the Kashmir sections still more striking.

In the Tethys Himalayas, there are no marine deposits comparable to the very thick Late Paleozoic detritus-bearing mudstones in the Tethys Karakoram, in Kashmir, and in the Krol Belt of the Lesser Himalayas; instead we find here, as a rule, the Upper Permian Productus Shales or the Kuling Beds resting slightly unconformably upon the Muth Quartzite or older formations, locally with a basal sequence of calcareous sandstones and conglomerates.

Only in the Spiti area this stratigraphic break, which comprises the greater part of the Devonian and the Carboniferous, is locally bridged by the Lower Carboniferous Lipak Series, which is equivalent to the *Syringothyris* Limestone Series in Kashmir, and by a complex of shales, quartzites, and conglomerates, the Po Series of HAYDEN (1904, 1934). In the plant-bearing shales, which form the lower part of this series, HAYDEN collected *Sphenopteridium cfr furcillatum* LUDWIG, *Sphenopteris cfr rigida,* and *Rhacopteris inaequilatera* FEISTM., the latter characteristic of the Culm of New South Wales, Australia. Higher follow the *Fenestella* Beds which HAYDEN (1934, p. 315) correlates with the *Fenestella* Shales of Kashmir and tentatively refers to the Middle Carboniferous; GRABAU (1931, p. 518) is, however, inclined to place them in part in the Lower Permian. Thus, in the Spiti sections, the Agglomeratic Slate Series corresponds to the disconformity between the *Fenestella* Beds and the Kuling Complex.

The local appearance of the lagoonal and fluviatile deposits of the Po Series within a wide region where sediments of this age are generally absent, indicates that the Tethys Himalayas as well as the Great Himalaya were largely above the level of the sea during the greater part of Devonian and Carboniferous time. The similarity in the faunas of the Agglomeratic Slate Series in Kashmir, the Speckled Sandstone Series in the Salt Range, and the Lower Permian sequence in Australia "is so striking that contemporaneity and free communication between these regions may be assumed" (RAGGATT and FLETCHER 1937, p. 182).

Neither in the Himalayas have any unequivocal evidences of regional Variscan folding been presented. "The latter part of the Haimanta (Cambrian) period was marked by local disturbances in Spiti and probably also in Kashmir . . . There is no evidence of any break in the continuity of marine deposits between the beginning of the Muth (Silurian) period and the middle of the Carboniferous" (BURRARD and HAYDEN 1934, pp. 335). A slight unconformity between the Po Series and the Kuling Beds is indicated in the Spiti area by the transgressive overlap of the Kuling Beds upon various horizons of the subjacent formations (HAYDEN 1904, p. 35), but in the Kumaon-Himalayas "usually, the upper edge of the Muth quartzite is conformable to the Kuling shale, in spite of the great gap of sedimentation" (HEIM 1939, p. 205). In the Simla area of the Lesser Himalayas, "no unconformity of orogenic violence is seen between the Blaini (Lower Gondwana) and the underlying Jaunsar and Simla (Lower Paleozoic) Series" (AUDEN 1934, pp. 399, 401, 449).

In Kashmir, the Muth quartzite is, according to WADIA (1926, p. 355), overlain conformably by the *Syringothyris* Limestone, which in turn passes into the *Fenestella* Shales. The *Fenestella* Shales pass, in the Marbal Valley, imperceptibly into the Agglomeratic Slate Series without any noteable unconformity (BION 1928, p. 11). In the upper Sind Valley "the Syringothyris Limestone is abruptly overlain by conglomerate — the ordinary pebble beds of the Agglomeratic Slate series. Although there is no angular discordance, I think this junction is an unconformable one and accounts for the disappearance of the Syringothyris Limestone over most of the anticline" (BION 1928, p. 9).

There is, thus, no certain evidence of any marked unconformity in the sedimentary sequence from the Muth Quartzite to the Agglomeratic Slate in these sections. At Nagmarg, however, on the western side of the Wular Lake, the Agglomeratic Slate which here is much reduced in thickness, rests with a very marked unconformity upon truncated formations containing *Cheirurus* (?), *Asaphus*, and other fossils of Ordovician or Silurian age (BION 1928, p. 7). But for the uppermost division of the Agglomeratic Slate Series, the very thick lower division of this series together with the *Fenestella* Shales, the *Syringothyris* Limestone, and the Muth Quartzite are missing, having been overlapped or denuded away. Here the evidences of Pre-Permian folding are convincing, but whether this folding is Caledonian or Variscan remains to be settled. The evidences of Caledonian folding in the Spiti area (HAYDEN 1904, p. 18) should not be overlooked.

Higher in the Paleozoic sequence we find in Kashmir a successive overlap between the Panjal volcanic complex and the underlying formations; locally the traps rest directly upon the Muth Quartzite, but in spite of this overlap the volcanic beds are generally conformable with the subjacent groups (MIDDLEMISS 1910, p. 236). The volcanics are generally overlain conformably by the continental *Gangamopteris*

Beds, followed by the Upper Permian Zewan Beds. But at Nagmarg, the *Gangamopteris* Beds appear conformably upon the Agglomeratic Slate Series and are overlain by the volcanic complex.

The question whether or not there was any regional Variscan folding in the Himalayas is, thus, still unsettled. There is, no doubt, usually a very great stratigraphic break at the base of the Upper Permian, but this break may have the character of a disconformity, and where formations of varying age form the fundament, this change may be due to broad undulations of epeirogenic character. This view is better in accord with the character of the Late Paleozoic magmatism, which is not of an orogenic facies but distinctly epeirogenic.

CHAPTER V

THE MESOZIOC FORMATIONS OF THE TETHYS-KARAKORAM IN WESTERN CHANG-THANG

The distribution of the Triassic, Jurassic, and Lower Cretaceous marine deposits in the western Chang-thang coincides approximately with the distribution of the Upper Paleozoic. They are thus found along the flanks of the Chang-lung Range and extend northward to the Loqzung Mountains, which mark their northern border. The Upper Cretaceous, on the other hand, extends much farther to the north resting transgressively upon the crystalline schists of the K'un-lun Plains. This very distribution suggests that some major tectonic event took place during the interval between the Lower and the Upper Cretaceous transgressions, whereby the border of the Tethys expanded north and east over new extensive areas of the K'un-lun foreland.

Investigations by STOLICZKA, DAINELLI, DE TERRA, WYSS, and NORIN in the Lingzhi-thang and the Loqzung Mountains have revealed that the period of geosynclinal sedimentation extends here from the Permian up to and including the Lower Cretaceous. This great sedimentary complex, which has been called the Loqzung Group on the map, is of fairly uniform composition, and consists mainly of varied coloured limestones and shales; eastward, psammitic and psephitic facies becomes of increasing importance. Apart from minor disconformities, only two important stratigraphic breaks are known, *viz.* one at the base of the Triassic (DE TERRA 1932, p. 95; NORIN) and another marked by huge conglomerates of Norian age (DAINELLI 1934, p. 413) at the top of the Triassic. It is, however, in both cases a question of monomict conglomeratic formations, the detritus of which has been derived from the immediately subjacent strata.

Triassic formations.

In the upper Chang-chen-mo, the Triassic deposits apparently rest conformably (DE TERRA 1932, p. 95, 115; 1935, p. 58) upon the Permian with a thick basal conglomerate. Marine deposits of Scythian age seem not to have been identified anywhere in the Tethys Karakoram. In the Depsang, the Triassic sequence begins, according to DAINELLI (1934, II, Vol. II, p. 405, 804), with thin-bedded, dark gray and black, cherty limestones, some hundred metres thick, succeeded by a thousand metres or more of dolomites and dolomitic limestones referred to the Middle Triassic. These are, in the lower part, light coloured and stratified, then white, occasionally brecciated, spotted red and unstratified; further, gray compact, dolomitic limestones interstratified with shales, and finally a bed filled with *Megalodon* and *Dicerocardium* overlain by pink limestone. These beds are succeeded by a series, several hundred metres thick, of red nodular limestones and marls of Carnian age, and then follows a huge conglomerate associated with yellowish sandstone and gray clays with layers of gypsum with a total thickness exceeding 700 m. which represent the Norian. The fossils collected by DAINELLI in this enormous sequence, have been studied by PARONA (1928), who emphasizes the strikingly close resemblance to the Triassic of the southern Alps.

In the Lingzhi-thang, around the basin of Sarigh-yilganing-köl, DE TERRA (1932, pp. 96) has described a number of sections which include Triassic yellowish and reddish calcareous sandstones, red and dark gray limestones (Ladinian), light gray coral limestone (Carnian), dark gray and black, veined limestones with *Dielasma julicum* (Norian), overlain by siliceous and multicoloured limestones, red sandy shales and sandstones, and, finally, thick, red conglomerates of probably Norian age according to DAINELLI (op. cit. p. 183). Black, veined limestones full of closely packed shells of *Dielasma julicum* BITTNER (FREBOLD, Appendix C) extend all along the southern slope of the broad, longitudinal valley south-east of Sarigh-yilganing-köl (Loc. N 74 a and b).

Compared to the Triassic of the Depsang Region, the Triassic sequence of the Lingzhi-thang seems to attain much less thickness, and sandy, argillaceous, and marly facies appears more frequently. The same is the case in the region north of the Karakoram Pass and in the Qara-tagh, where Ladinian, Carnian, and Norian marine formations have been identified by WYSS (1940) and DE TERRA.

Jurassic formations.

Contrary to the Triassic and the Cretaceous, which largely consist of rather pure limestones and dolomites, the Jurassic of the Tethys-Karakoram is mainly represented by shales, marly limestones, and related shallow water deposits, and, in the north, also continental and fluvial formations. The investigations of DAINELLI, DE TERRA, WYSS, and NORIN have revealed the presence of marine deposits representing the Lower, Middle, and Upper Dogger, Lower and Upper Malm, and, in the Qara-tagh, fluvial deposits with Upper Jurassic flora.

Above the great Norian conglomerate follow at Balti-brangsa on the northern side of the Karakoram Pass, conglomeratic sandstone and limestone breccia, bordering over a fault on greenish tuffaceous shales interstratified with calcareous sandstone. This is overlain by limestone with supposedly Liassic belemnites, and then follow again greenish sandstone and sandy shale (DE TERRA 1932, p. 107). The Liassic age of these beds is, however, questioned by DAINELLI (1933, II, p. 329, 870), and according to him the Jurassic marine sequence begins with the Lower Dogger.

Beds of this age are widely distributed over the Lingzhi-thang, Depsang, Qara-tagh, and the upper Shayok drainage area. Gray and yellowish calcareous shales and siliceous, dark, detrital limestones with Lower Dogger fauna are described by DE TERRA (*op. cit.* p. 98, 145) south of Sarigh-yilganing-köl. About 25 km. further to the east-south-east the author found dark gray calcareous, fossiliferous shales (Loc. N 76) with beds of black limestones, in part oolitic, in part massive and coral-bearing (Coll. 1094) dipping 45° N. E. In the former FREBOLD (Appendix C) identified *Camptonectes lens* Sow. and *Trigonia* sp.; he refers these beds to the Lower Dogger. At the broad pass 5400, half way between this locality and Sarigh-yilganing-köl, appear bluish gray calcareous shales with thin beds of gray limestone. In the former, some ammonites were collected (Loc. N 75) amongst which FREBOLD identified a form closely related to or representing *Perisphinctes furcula* NEUM., which places this horizon in the Middle or Upper Dogger. These beds appear again near Camp N 691 in the Chipchaq Valley (Loc. N 68) and are also recorded by DAINELLI (1933, II, p. 320) near the Karakoram Pass.

Other interesting exposures of Jurassic formations were met with in the Western Loqzung Mountains along the northern slope of the ridge 6144 on the southern side of the Qizil-davan. The lower part of this ridge consists of brownish gray limestone and calcareous shales underlain by gravelly brown sandstone. Amongst the fossils collected in the shale (Loc. N. 69), FREBOLD identified *Chlamys (Radulopecten)* aff. *tipperi* Cox and *Lopha* sp. indicating a Middle Jurassic (Bajocian or Bathonian) horizon.

Towards the east-south-east in the direction of the strike appears grayish brown calcareous sandstone and then a very thick conglomerate, in part resembling a breccia, interstratified with calcareous beds. The pebbles, mostly the size of a fist, seem to consist exclusively of limestone and are held together by a red argillaceous matrix. This formation may possibly represent the Norian conglomerate of Qizil-lungur and Lingzhi-thang. It borders to the north with a tectonic contact on Cretaceous limestone.

In the Qara-tagh Highland between the Chipchaq Valley and the Qara-tagh-su, WYSS has collected fossils from various Middle and Upper Jurassic horizons at a large number of places but, unfortunately, nothing has as yet been published about the stratigraphy.

In April, 1932, the author crossed the Qara-tagh over an easy pass situated only one or two kilometres to the west of the Qara-tagh-davan of VISSER and followed the narrow valley of Qara-tagh-su and Shu-lunspo-lungpa to the Qaraqash

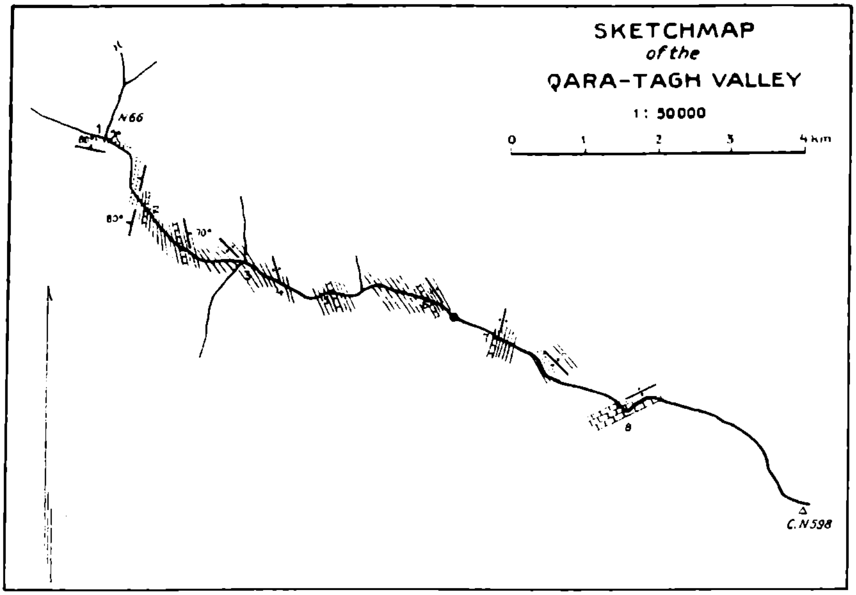


Fig. 20. Geological observations in the Qara-tagh Valley. (Legend, see the text).

Valley. Our observations along the Qara-tagh-su are summarized in the sketch map Fig. 20.

The pass and its slopes are covered with debris of dark shales and limestone, with one or two outcrops of gray and bluish black calcareous shales, which seem to have a moderate southerly dip. Near the point (1) where the tributary from the pass joins the main valley, follow black, richly plant-bearing shales (Loc. N 66), which grade into light gray, gravelly sandstone with a basal conglomerate several metres thick, dipping 80° towards N. 10° E. The well water-worn pebbles, as an average the size of a hen's egg, consist exclusively of quartz and white quartzite. Amongst the fossils collected at Loc. N 66, the following species were determined provisionally by prof. HALLE, Stockholm, in 1934:

"*Neocalamites* (?) sp., *Klukia exilis, Sphenopteris* sp. (one small fragment rather similar to the Wealdon species *Sphenopteris (Ruffordia) Goepperti), Chladophlebis* sp., *Nilssonia orientalis, Nilssonia cf. mediana, Ginkgo digitata, Ginkgo sibirica, Baiera* sp. *(B. gracilis), Podozamites lanceolatus, Pityophyllum cf. Nordenskiöldii.*

This is a typical Mesozoic flora, probably Middle Jurassic *(Klukia),* though it may possibly be younger (this will depend on the age assigned to HEER's Siberian floras)".

In an additional note on this florule in 1943, HALLE states: "According to OISHI (1940) and others, some of the species occur in beds assigned to the Upper Jurassic and even Wealdon. The species determined as *Klukia exilis* may possibly be identical with *Chladophlebis (Klukia ?) koraiensis* YABE from the Upper Jurassic Tetori Series".

Half a kilometre down the valley, the strike suddenly changes into S. 5° W.

Here appear at first dark shales with beds of sandstone not unlike the plant-bearing beds just described, and then follows a strongly folded, rather uniform complex of shales and greenish claystones interstratified with beds of limestone and some sandy horizons all the way to near Camp N 598. The strike is as an average north-north-westerly with steep or vertical dip, but becomes very irregular along the lower course of the valley.

The following succession of rocks was recorded below Loc. N 66 (cfr Fig. 20):

a) Dark shales with beds of sandstone
b) Dark shales with beds of light gray limestone
c) A thicker bed of bluish black limestone dipping 80° towards N. 85° W. (Point 2)
d) Dark shales
e) Dark limestone dipping 70° towards N. 75° E. (about 100 m.)
f) Black and dark gray shales of great thickness
g) Black limestone (Point 5)
h) Black shales (great thickness)
i) Grayish green foliated claystone interstratified with dark shales (great thickness)
j) Brecciated limestone (Point 6)
k) Dark shales with limestone beds striking S. 35° E. with vertical dip
l) Dark shales and greenish foliated claystone; old camping place with Mohammedan prayer ring.
m) Gray stratified limestone weathering with bright yellow colour, and striking S. 15° W. with vertical dip (Point 7) (a few m.)
n) Dark calcareous shales. Close by, voluminous springs.
o) Greenish gray sandstone and black shales striking S. 45° E. with vertical dip.
p) Dark limestone with layers of black chert striking N. 65° E. with vertical dip.
q) Black, chocolate-brown and greenish shales with beds of limestone.

During the Netherland Expedition of 1929—30, Wyss collected some fossils (Loc. XIV) between their camps 56 and 57 in the Qara-tagh-su, which were identified by Renz as *Halobia cordilleriana* Smith and referred to the Upper Carnian. On our route map, this locality should be situated somewhere between the points 5 and 7.

If this great sequence of littoral or lagoonary sediments belongs to the Triassic and Jurassic, as seems rather probable, it is surprising that no trace has been seen of the very thick Norian conglomerates, which are such a conspicuous feature of the Triassic-Jurassic boundary zone in the Depsang, the Western Loqzung Mountains, and the Lingzhi-thang. These conglomerates are very different, lithologically, to the quartz conglomerate at the base of the plant-bearing beds.

The Lower Cretaceous deposits of the western Chang-thang seem to be confined to the Tethys-Karakoram. They are closely associated with the Triassic and the Jurassic sequences, as a stage in a common geosynclinal development. The Upper Cretaceous formations, on the other hand, extend far beyond the northern border of this geosynclinal zone, and attain their greatest development on the K'un-lun Plains. They have been described above in Chapter II.

Because of the very great similarity of facies and lithological character of the Lower Cretaceous and the older Mesozoic formations, it is hardly possible to distinguish these deposits from each other in the field except by the find of fossils. Very good sections of the Jurassic-Cretaceous sedimentary column can probably be obtained in the region of Yapchan near Qizil-yilga, where, within a very small area, almost all the principal divisions of the Tethyan succession are known to occur (Sketch map Fig. 18).

The high ridge 6144, which rises on the southern side of the Qizil-davan, consists of various dark and brownish limestones and shales with moderately steep dip towards S. S. W. The shales contain, at the pass, Middle Jurassic fossils. What seems to be the same calcareous complex forms also the southern slope of the broad ridge north of Yapchan and the eastern end of the snowy ridge 6223 south of our camp A 425, where the strike curves to the west-south-west. At the latter place occur strongly crushed, dark gray and bluish black, dense limestones (1079) and shales with very indistinct, apparently southerly dip. They contain in the steep northern slope a bed of very fine-grained, brownish gray biotite-andesite (901, 902) and are cut by dikes of trachybasalt (904).

The microfauna of the limestone Spec. 1079 was studied by BROTZEN, who could identify a small, conic species of *Orbitulina,* besides which there occur an abundance of calcareous algae. The age of the horizon is, according to BROTZEN, certainly Lower Cretaceous and the sediment is comparable to the *Schrattenkalk* (Urgon) of the European Alps.

At the crest of the ridge 6223—5943, this series is capped with a small rest of red beds with moderately steep south-easterly dip. Judging by the debris in the talus below, it consists of a red gravelly conglomerate with pebbles of limestone overlain by varied coloured limestone, probably representing the base of the Cenomanian.

The same red beds cap with low southerly dip the plateau-shaped massif 6020 south of Yapchan and constitute the margin of a much dissected area of plateau-like hills, which extends far to the south beyond the watershed of the Lingzhi-thang.

Higher members of the Cretaceous sequence are exposed in the snowy range on the northern side of the Qizil-davan, the "Monte della Piega" of DAINELLI, so called because of the fine isoclinal folding exposed in its southern slope, where the Cretaceous beds are thrust over the Late Paleozoic and Ordovician formations (cfr Fig. 27, p. 119 and DAINELLI 1933, II, p. 183, 192, 219). In this Cretaceous sequence DAINELLI identified the following main divisions:

Limestones with *Bryozoa* and *Ostrea*	Senonian
Grayish white and yellowish rudist limestones of great thickness	Turonian
Reddish and light gray limestones	Cenomanian
Red sandstone and breccia	(Albian ?)

At the place where the Thaldat Stream breaks through the Loqzung Mountains near Camp A 722, occur yellowish massive claystones, which also extend along the northern slope of the hill 5464. At the foot of this hill occurs an isolated outcrop of richly fossiliferous bluish gray (Loc. N 72) and white crystalline limestone, strongly disintegrated by insolation and fissures, wherefore the position of the beds is uncertain. The specimens collected at Loc. N 72 are described by BROTZEN as follows:

"Dichter, dunkelgrauer Kalk mit zahlreichen Stromatoporiden-ähnlichen Resten und Molluskenschalenquerschnitten. Die Schliffe zeigen eine dichte, feinkörnige Grundmasse mit sehr kleinen Knöllchen mit Foraminiferen und fein verteilten sehr kleinen Quarzkörnern. An Foraminiferen liessen sich nachweisen

Quinqueloculina, sehr grosse und dickschalige Exemplare, wie später in der Probe 924 (p. 37);

Spiroplectammina resp. nahe stehende Formen;

Rotalinidae nicht näher bestimmbar."

The age of the bed is Cretaceous.

Similar limestones and dark shales dipping 45° towards S. 20° E. form the southern end of the small, isolated massif 5148 opposite Loc. N 72. In a dark gray limestone at the western end of this massif, the specimen 1088 was collected. It contains a rich microfauna about which BROTZEN has supplied the following information:

"Sehr dichter, grauer Kalk, der ziemlich viele Orbitulinen enthält. Soweit man in dem sehr kleinen Stück einzelne Orbitulinen erkennen kann, liegt eine flache niedrige und eine konische Form vor. Nach den Schliffen und entsprechend der äusseren Gestalt handelt es sich wahrscheinlich um *Orbitulina plana* BLUMB., resp. *O. conica.* Damit würde das Gestein dem unteren Cenoman oder dem höchsten Alb angehören, wofür auch die übrige reichliche Mikrofauna spricht. Da die Abfassung der Species bei den Orbitulinen recht unsicher ist und man gerne Generalisierungen von H. DOUVILLÉ bei der Bestimmung zu Grunde legt, so ist eine kritische Neubearbeitung nötig. — Die Schliffe des Kalkes zeigen die dichte Grundmasse mit kugeligen, resp. sphärischen, kalkigen Konkretionen, wahrscheinlich eingeschlosse-

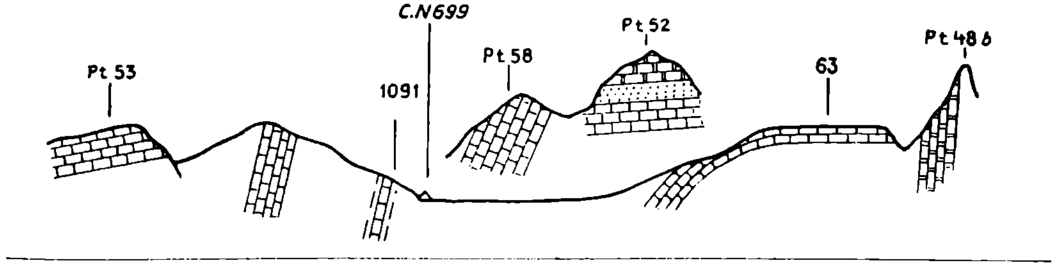


Fig. 21. Cretaceous beds at Camp N 699, Western Loqzung Mountains.

nen Foraminiferen, Orbitulinen; daneben *Quinqueloculina* (kleinere dünnschalige und einzelne grössere dickschalige; die kleinen sehr häufig), *Spiroplectammina*, *Glandulina* Al, *Alveolina* (i s. 1.), *Globigerina*, und *Rotalinidae*."

Cretaceous rocks seem to form the greater part of the large snowy massif 5970 between the Thaldat Stream and the Qizil-su. On its southern side occur, at the pass 5437, gray and reddish limestone with *Exogyra*. From this place originate also HEDIN's specimens 885—887 of grayish white limestones in which HENNIG (1915, p. 124) recognized a form of *Radiolites* resembling *Praeradiolites Hedini* DOUV. On the northern slope of this massif DAINELLI collected *Exogyra columba* (Upper Cenomanian).

Cretaceous beds have further been identified by DAINELLI 3 km. north of his Campo dell'Heran (probably the hill N. W. of Camp A 435), at "Dosso della balena" (= the hill 5497 N. E. of Camp A 434), and in the desert hills further east.

In the Western Loqzung Mountains between our camps N 698 and N 701, the broad longitudinal valleys are enclosed between high serrated ridges of Upper Cretaceous limestones. Between them occur plateau-like mountain blocks capped with red sandstone without any basal conglomerate, and tilted at a variable angle often rather low. Fig. 21 shows the position of the strata in the neighbourhood of Camp N 699. In the large pyramide *52*, dark limestones and calcareous shales, which weather with brown colour, rest in nearly horizontal position. They are overlain by a thick formation of red sandstone and varied coloured limestones, which evidently represent the Cenomanian. In the hill *58* close by, similar dark limestones dip 60° towards S. W. The same beds extend close to Camp N 699, and are, at one level, filled with calcareous algae and fragments of fossils unfortunately undeterminable (Coll. 1091). The rocks are not unlike the Orbitulina limestone series elsewhere.

The Eastern Loqzung Mountains rise on the northern side of the basin of Tsaggar-tso with a very irregular frontier. All along their base can be traced from afar a thick formation of bright red strata, which closely follows the contour of the embayments and which, thus, must have a rather low northerly dip. These red rocks form also the base of the isolated massif 5957 north-east of Tashliq-köl in the shape of a broad syncline striking E. N. E. Another synclinal relict of these cap deposits occurs east of Horpa-tso, bordering on the Permian limestone series of Section II a (Pl. B). Because of the dip of the synclinal axis towards the east, the syncline widens in this direction and encloses a large mass of varied coloured limestones, which form the snowy range 6250.

The northern limb of this syncline rests with apparently normal sedimentary contact upon bluish and black limestones, which are rather strongly cracked. No basal conglomerate occurs and the sandstone rests here, as in the Aq-sai-chin, directly upon the fundament, dipping 30° towards S. 5° E. It is a brownish red, calcareous sandstone, about 100 m. thick, which becomes gravelly in the higher levels and terminates with a coarse conglomerate with well water-worn boulders, as much as 0.3 m. in size, of dark limestones and mostly red sandstones.

Above follow at first light gray and cream coloured, partly dense, partly crystalline limestones (1114, 1115) and then dark gray limestones. Crinoid discs, up to 20 mm. in diameter, are common in some horizons, but other macrofossils are rare. The microfauna of Spec. 1114 has been studied by BROTZEN, who states:

"Kalk mit groben Kristallen in dichter bis feinkristalliner Grundmasse; keine Quarzkörner beobachtet; zahlreiche Molluskfragmente; einige Radiolarienschalen, doch sehr selten. Verteilung der Foraminiferen im Gestein:

	Exemplare	%
Quinqueloculina spp.	8	14
Lagenidae	10	17
Astacolus sp.	1	2
Nodosaria sp. i. l.	3	5
Lenticulina sp.	1	2
Rotalinidae	34	60
	57	100

Die Foraminiferenfauna zeichnet sich durch die zahlreichen nicht näher bestimmbaren Rotaliniden aus, unter denen mit Sicherheit keine Globigerinen zu bestimmen waren. Die Schalenstruktur war einfach und doppelte Wände waren mit Sicherheit nur einmal festzustellen. Die nicht seltenen Quinqueloculinen waren meist recht klein und eine einzige dickschalige Form wurde beobachtet. Under den *Lagenidae* waren einzelne einkammerige Formen neben nicht näher bestimmten Resten vorhanden. *Nodosaria* inkl. *Dentalina* und ähnliche Formen wurden 3 festgestellt und je eine deutlich bestimmbare *Lenticulina* oder *Robulus* und eine gestreckte Form *Astacolus* oder möglicherweise *Vaginuline* vom schmalen fast geraden Typ.

Die Entfaltung der Rotaliniden ist in der Kreide zu legen und die wenigen im Jura auftretenden Formen herrschen nie so in einer Faunengemeinschaft vor, wie das hier der Fall ist. Das Fehlen typischer Grossforaminiferen kann leider nur negativ gedeutet werden, und an und für sich spricht nichts in der Fauna gegen ein tertiäres oder kretazisches Alter. Der allgemeine Eindruck ist gleich den Miliolinengesteinen mit zahlreichen Rotaliniden, die durch sichere Fossilien als kretazisch aus dem innerasiatischen Hochland bekannt sind."

The Cretaceous or younger age of this limestone series is thus definite. Thanks to the easily traced red basal sandstone we may presume that this series builds up by far the greater part of the mountainous region on the northern side of Tsaggar-tso.

The geosynclinal zones of the Tethys-Himalaya and the Tethys-Karakoram. A comparison.

According to the general geological maps of BURRARD and HAYDEN (1934) and DAINELLI (1934) the Triassic, Jurassic, and Lower Cretaceous deposits within the Tethyan orogenetic zone are confined to two longitudinal belts, which increase in width eastward: the southern, known as the Tethys-Himalaya, covers Kashmir, the Zanskar Range, and its extension towards the south-east into southern Tibet; the northern or the Tethys-Karakoram covers the space between the K'un-lun and the Ladakh Range as well as the southern parts of the western Chang-thang. These zones of Mesozoic marine sediments are separated by the Karakoram Mountain System, a broad zone of granites and more or less strongly metamorphosed rocks largely of Lower Paleozoic age, locally covered with the deposits of the Upper Cretaceous transgressions and Tertiary continental sediments.

The present southern boundary of the sediments of the Tethys-Karakoram is an accidental feature, due to the extent of the denudation which, as a rule, seems to have advanced farther in the southern and eastern regions than in the more northerly. This extensive denudation is in evidence in the Mawang-kangri, where the Mesozoic sedimentary sequence has been completely removed, and within the Chang-lung Range, where a synclinal relict has been preserved in the Chang-chen-mo Valley on its southern side. The great development of the Triassic in this latter indicates that these sediments formerly extended far beyond to the south.

In the Tethys-Himalaya, the Mesozoic sedimentary record is nearly complete from the end of the Paleozoic to the Lower Cretaceous. Here, as in the Tethys-Karakoram, the Triassic rests conformably upon the Permian, but the marked disconformity between them in the latter region is not in evidence. The Triassic marine sequence, which here locally attains a thickness of about 2,000 m., begins with the Scythian stage, generally represented by only a few tens of metres of shaly strata with a fauna rather different from the contemporaneous fauna of the European Tethys (DIENER 1925, p. 126). The Anisian and Ladinian stages also attain small thickness (0—100 m.) decreasing south-eastward. The Ladinian fauna shows more close relationship to the Mediterranean, but during the Early Carnian the connection was again interrupted. To the Carnian, Norian, and Rhaetic belongs by far the main part of the Mesozoic sequence with an aggregate thickness of about 1,700 m. in the Spiti area. The sediments are mostly more or less argillaceous, but in the Upper Norian pure limestones become predominating and this facies then persists up into the Lower Jurassic. The Middle and Upper Carnian and the Middle Norian faunas show again close Mediterranean affinities, whereas those of the Lower Norian differ greatly (DIENER *op. cit.*)

The Triassic stratigraphic column of the Tethys-Karakoram differs from that of the Tethys-Himalaya in several respects. Whereas in the latter the Anisian and Ladinian are represented by a hundred metres of strata only, largely of shaly facies, the corresponding formations of the Tethys-Karakoram consist of dolomites and dolomitic limestones with a thickness of a thousand metres or more. Also the Carnian and the Norian are developed in calcareous facies and attain considerable thickness. The rich faunas collected by DAINELLI have been described by PARONA. In a review JAWORSKI (1941) sums up their palaeogeographical significance: "Überraschend sind die geringen Beziehungen zu den Triasfaunen des südlichen Tibet und des Himalaya. Viel enger dagegen ist die Verwandtschaft mit den Raibler-Cassianer Faunen Europas, insbesonders bei den karnischen Gastropoden. Die Ammoniten sind, im Gegensatz zur Salt Range und zum Himalaja, nur sehr spärlich vertreten . . . . . Ein bezeichnendes Merkmal ist ferner die Häufigkeit der Hydrozoen: *Heterastridium, Stoliczkaria, Stromatoporidium* und *Stromatopora*".

It is, thus, rather probable that the northern and the southern Tethys were separated temporarily by a barrier during the Triassic.

Of great interest is in this connection the peculiar development of the Triassic within the zone of "Exotic blocks" or *Klippen* in the Malla Johar, Kiogar, and Chirchun areas outside the Karakoram—Transhimalaya frontier (cfr p. 58). These detached blocks of organogenic limestones, which may attain the size of great hills, range in age from the Permian to the Upper Cretaceous. The strikingly close lithological and faunistic similarity between some of these blocks and the Carnian and Lower Liassic sediments in the Eastern Alps "zwingt zu der Vorstellung, dass nördlich von der Hauptzone des Himalaya innerhalb der Tethys während der karnischen und Liasepoche ein Meeresstreifen vorhanden war, in dem nicht nur gleiche physikalische Bedingungen den Absatz von Sedimenten bewirkt haben, die jenen in den Ostalpen aus denselben Epochen durchaus gleichartig waren, sondern innerhalb dessen das Meer auch von einer den homotaxen alpinen Faunen ausserordentlich nahestehenden Fauna bevölkert war" (DIENER 1925, p. 206). This zone probably represented the deepest part of the Tethyan geosyncline.

In the Tethys-Karakoram, the Norian sequence terminates with a thick, coarse limestone conglomerate overlain by sandstone and gypsiferous clays, which DAINELLI (1934, p. 804) also includes in the Norian. In the French, the Julian, and the Eastern Alps, on Crimea and in the Balcans there are faint traces of folding during this stage (STILLE 1924). There is no correspondence to this tectogenesis in the Tethys-Himalaya, where the Norian Kuti Shales pass into the very thick, Rhaetic

Kioto Limestone by a passage zone of quartzite (HEIM 1939, p. 209). Above follow here brown shales and limestones of Liassic age, and then comes the first greater disconformity in the Mesozoic sequence, which in the Kumaon Himalayas comprises the Lower Dogger. The Upper Dogger is represented by a bed of ferrugineous oolitic limestone or shale, a few metres thick only, at the top of which another disconformity cuts out the Lower Malm (HEIM *op. cit.*). Then follow conformably the Spiti Shales of Portlandian (Upper Malm) age, a series of black friable shales with numerous rounded, siliceous concretions, which extend with very constant lithology and fauna from Hazara in the west over southern Tibet and Insulinde. "Man hat es hier mit einem der grössten einheitlichen Ablagerungs- und Lebensbezirke auf der Erde zu tun" (DIENER *op. cit.*). The Spiti Shales pass, in the Himalayas, gradually into a series of glauconitic sandstones (Giumal Sandstone) 100 to 600 m. thick, which represents the Lower Cretaceous from Valanginian to Gault (SPITZ 1914).

The Jurassic of the Tethys-Karakoram is again rather differently developed. No counterpart to the thick marine Liassic of the southern zone is known here, the age of the supposedly Liassic beds at the Karakoram Pass (STOLICZKA 1878, DE TERRA 1932) being doubted by DAINELLI. Instead the Lower Dogger, which is absent in the Kumaon-Himalayas, is well represented here, mainly in calcareous facies, as well as Upper Dogger and Lower and probably also Upper Malm (WYSS 1940). To the Upper Jurassic probably belong the dark plant-bearing shales along the upper Qaratagh-su. The Giumal Sandstone of the southern zone has not been identified in the northern, where the Lower Cretaceous is represented by dark algal limestones with *Orbitulina*.

In the southern sedimentary zone of the Pamirs, which represents the western extension of the Tethys-Karakoram, the Mesozoic attains locally the enormous thickness of about 7,000 m. (YUDIN 1932). In the northern parts, from Pamirskii Post westward, the sequence begins with a series of Rhaetic-Jurassic plant-bearing, lagoonary and fluviatile shales and sandstone of Caucasian facies, locally several thousand metres in thickness and sometimes strongly metamorphosed. It grades into dark limestones of Upper Jurassic age, which in turn are overlain unconformably by Cretaceous red sandstone. In the southern and south-eastern Pamirs, on the other hand, the Jurassic is developed as concretionary, dark shales with marine fauna (the Sarikol Shales of HAYDEN 1915), whereas sandy sediments are very subordinate. The lower part of the series contains thin beds of limestone with Upper Triassic marine fauna. The thick Middle Triassic limestones of the Aghil ranges have not been found here.

The Sarikol Shales grade at the top into thin-bedded, brownish, flaggy limestones containing a. o. several species of *Perisphinctes* and referred by NALIVKIN (1932) to the Bathonian. Above follow dark, massive limestones of great thickness (the Pamir Limestone of HAYDEN) representing, according to NALIVKIN, the top parts of the Middle Jurassic, the Upper Jurassic, and the lower parts of the Cretaceous. The red Cretaceous sandstone series is missing here.

Great changes in the palaeogeography of the Tethys took place during the Middle Cretaceous probably in connection with one of the major periods of diastrophism within this orogenetic zone. This development was followed, within the Tethys-Karakoram, by the great Cenomanian transgression which also spread over a great part of the K'un-lun Plains, until then outside the reaches of the fluctuations of the Tethys.

It has been observed at several places in the Loqzung Mountains and all along the southern border of the depression of Aq-sai-chin that the ever present red sandstone at the base of the Cenomanian rests upon a deeply weathered fundament without any basal conglomerate. Only fairly high up in the formation conglomerates and gravelly beds make their appearance. This shows that the Cenomanian transgression spread over a rather flat land surface. On this foundering floor were deposited during the Cenomanian, the Turonian, and the Senonian huge masses of limestones and marls usually of light gray, reddish, and yellowish colour. The snowy ridges and isolated mountain groups formed by these rocks are the most spectacular feature of the Tibetan Plateau, beautifully reproduced on HEDIN's panoramas.

This subsidence was interrupted, during the Upper Cretaceous, by an upheaval. Violent dislocations created a rugged topography resulting in the formation of very thick and coarse conglomerates (Hor. D of Table I). Then followed here a new submergence represented by black and light gray limestones (Hor. F, G, I) containing a thick formation of red, fine-grained sandstone and light greenish lamprophyric tuff (Hor. H) in the middle part. It is noteworthy, that the first appearance of tuff sediments follows upon the tectonic stage represented by the large conglomerates, Hor. D, which seem to mark a regional break in the Cretaceous sequence in Senonian or Post-Senonian time. This break may possibly be correlated with those tectonic movements which, in the Indus region, were accompanied by the intrusion of the ophiolites.

The transgression registered by the limestone Hor. I was succeeded by a new emergence and the formation of continental deposits of predominatingly red colour (Hor. J, K, L) with intrusive sheets of quartz-porphyry. Then came the last transgression in these parts of western Tibet in Late Cretaceous time, recorded by light gray, cherty, and dark bituminous limestones (Hor. M, N, O). These are succeeded by fluviogene, red and yellowish sandy deposits (Hor. P), which grade into light gray or yellowish, thin-bedded lacustrine marls (Hor. Q), and finally large masses of grayish and greenish flysch sandstones and sandy shales (Hor. R). This Late Cretaceous or Early Tertiary flysch is unlike any sediments found lower in the Cretaceous complex and may be compared, lithologically, with the older flysch of the Upper Indus. It has, like the older members of the complex, been affected by the same tectonic movements, which resulted in the general folding of the Mesozoic strata.

A noteworthy feature of this flysch as well as the subjacent psammitic horizons Q and P, is the absence of coarse detritus and conglomerates.

Within the western extension of the Tethys-Karakoram, in the southern sedimentary zone of the Pamirs, the development was, on the whole, rather similar, and here there are in addition clear proofs of Post-Upper Jurassic folding prior to the Cenomanian transgression (NALIVKIN 1932, GUNDLACH 1934). Upper Jurassic limestones are, in the Murgab Range, overlain unconformably by red Cretaceous sandstones followed by Cenomanian rudist limestones. This Cretaceous sequence appears also in similar facies in the Trans-Alai Ranges further north, corresponding to the Cenomanian transgression over the K'un-lun Plains.

In the Tethys-Himalaya the contemporaneous development was rather different. According to HAYDEN (1934, p. 306), the Cenomanian is missing throughout the Himalaya. Upon the Giumal Sandstone of Lower Cretaceous age follows, locally, the Chikkim Limestone of no great trickness; then comes the Chikkim Flysch (locally more than 1.000 m.) consisting, in the Kumaon-Himalayas, of sandy and marly shales and multicoloured siliceous sandstones interstratified with shales and radiolarites; this series is referred to the Upper Cretaceous by HEIM (1939, p. 148).

Along the northern border of this broad sedimentary basin the Upper Cretaceous flysch and associated volcanics accumulated to a thickness of some three kilometres. This is the Indus Flysch. Its stratigraphy has been elucidated by DE TERRA 1932, 1934, 1935) and DAINELLI (1934). They have shown, that this enormous sequence begins with coarse conglomerates and fluviogenic sandstones of mainly Senonian age, which rest directly upon the hilly and deeply weathered surface of the Ladakh granite. The absence of the whole earlier Mesozoic marine sequence means either that prior to this stage, the northern part of the Tethys-Himalayan geosyncline became uplifted and its sediments were completely removed by denudation down to the sub-floor of the geosyncline, as assumed by DE TERRA (1935), or, that this fundament formed a part of an ancient divide between the northern and the southern Tethys, which subsequently became subjected to geosynclinal subsidence.

The main bulk of the Indus Flysch consists of sandstones, plant-bearing shales, marls, and thin beds of marine limestones together with volcanic rocks and pyroclastics. The sediments were formed during slow subsidence with occasional shallow ingressions of the sea. Later followed great intrusions of ophiolites. The volcanism attained its greatest intensity during the Senonian and seems to have died out in the Early Eocene (DE TERRA 1934, 1935).

Upheaval and extensive lateritic weathering are in evidence all over the Himalayas at the end of the Cretaceous. At the beginning of the Tertiary, subsidence again set in, minor marine floodings occurred intermittently, culminating with the formation of the Nummulitic Limestone during the Middle Eocene. The steadily rising Karakoram-Transhimalaya formed a barrier to this transgression towards the north. Then followed, probably in the Oligocene, a period of intense folding which caused a total change of Himalayan geography; it resulted in a general upheaval and the end of the marine history of the Himalayas (DE TERRA 1934, 1935).

The Indus Flysch differs in some important respects from the corresponding formations in the more southerly parts of the Himalayas. Thus, the Indus Flysch rests upon a fundament of granitic rocks, whereas the Chikkim Flysch follows conformably upon the Mesozoic sequence of the Tethys-Himalaya. In the Indus sections, no trace has been found, so far, of the "exotic blocks", which are such a conspicuous feature of the flysch zone in the south. Their absence may not be accidental but connected in some way or other with the different tectonics along the northern and the southern border of the flysch belt.

It has been suggested alternatively above, that the Indus Flysch rests upon an ancient inter-Tethyan divide. It accumulated along the northern shore of the great southern geosynclinal zone, and to the north of the zone of maximal subsidence which, according to HEIM (*op. cit.*), was the root region of the exotics. The Chikkim Flysch, on the other hand, was deposited along the southern side of this zone. In connection with the subsequent rupture along the Transhimalayan foredeep, and the engulfment and underthrust below the Karakoram-Transhimalaya, the Chikkim Flysch together with the exotics and the ophiolites suffered long distance thrusting towards the south. Along the Transhimalayan frontier, however, the thrusting has an opposite direction, although of less magnitude; thus GANSSER (1939, p. 188) has shown that, in the Kailas region, the flysch and associated volcanics have been thrust over the crystallines and overlying Tertiary conglomerates of the Transhimalaya. A similar vergence of the orogenetic movements may be traced also in the Indus sections, *e. g.* in DAINELLI's section at Kanda-la south-west of Leh (1933, I, Fig. 12) and in DE TERRA's section at Pashkyum near Kargil (1935, Fig. 11).

The Upper Cretaceous and Tertiary sequence along the northern slope of the Transalai and the K'un-lun bears evidence to show that the revolutions within the Tethyan orogene during the Mesozoic and the Early Tertiary made themselves felt also in this border region. Already during the Jurassic, a parageosyncline may have been roughly outlined here (NORIN 1941), and became the site of orogenetic movements during the Upper Jurassic and possibly before the Cenomanian also (LEUCHS 1937, p. 190). Later, the transgression of the nummulitic sea along the southern frontier of the Transhimalaya corresponded to a transgression in the northern parageosyncline, where the sea of Russian Turkistan entered the Tarim Basin during the Paleocene through the strait between the Transalai and the Alai Ranges, and expanded from the K'un-lun frontier northward at least to lat. 38° 30′ N., lingering throughout the Eocene. This transgression coincides more or less closely with the regression of the sea from the K'un-lun Plains at the end of the Cretaceous, proving that the geosynclinal subsidence along the Serindian border was accompanied by an upheaval of the K'un-lun and its broad, southern foreland, an upheaval which continued during the later Tertiary and the Pleistocene and now amounts to some 6,000 m.

CHAPTER VI

THE MAGMATISM IN KARAKORAM AND WESTERN CHANG-THANG

In the Kashmir-Himalayas, the Tethyan geosynclinal development was introduced by the extrusion of enormous masses of basaltic lavas, the Panjal Traps. This volcanic activity began during the Uralian, culminated in the Middle Permian, and still continued locally throughout the Triassic. Contemporaneous basaltic magmatism is also in evidence in the Tethys—Karakoram. This magmatism, which everywhere was of a simatic character, evidently represents the initial magmatism of the Tethyan geosynclinal development, and can hardly be the result of Late Variscan orogenesis. Apart from transgressive overlap of certain horizons of the Late Paleozoic sequence and minor angular unconformities noticed by BION (1928) in Kashmir and by HAYDEN (1904) in the Spiti area, I have not found in the published records any unequivocal observations indicative of the existence of any regional Variscan unconformity within the Himalayas. The very great stratigraphic break at the base of the Agglomeratic Slate Series in Kashmir and below the Upper Permian Kuling Beds in Spiti seem to have rather the character of a disconformity, and where formations of varying age form the fundament, this change may be due to broad undulations of epeirogenic character. This view is also in accord with the character of the Late Paleozoic magmatism, which is not of an orogenic facies but distinctly epeirogenic.

The next volcanic period, which has been dated with certainty, falls in the Upper Cretaceous. The effusive rocks of this period attain today their greatest development in the Transhimalayan foredeep, possibly due to the final rupture of the crust within this zone of intense subsidence, a subsidence, the magnitude of which is apparent by the enormous thickness (about 3,000 m.) of the Upper Cretaceous flysch sediments accumulated here. DAINELLI (1934, pp. 620) has presented weighty arguments to show, that this volcanism was enacted mainly during the Senonian, beginning with intrusions of dioritic magmas and their effusive equivalents, followed by more basic rocks at a slightly later stage. DE TERRA, however, who also has studied this eruptive-sedimentary complex, assumes that the main portion of the volcanics is younger than the Senonian and of Late Cretaceous or Early Eocene age (1935, p. 55).

In his great work "La Serie dei Terreni" (1933—34), DAINELLI has gathered a wealth of observations on the eruptive rocks of the Karakoram and the Dras-Indus volcanics, of fundamental importance for the understanding of the magmatic development of the great orogene. With the dated igneous rocks of the flysch belt as a starting point, DAINELLI could trace step by step the intimate petrographic affinity of the dioritic and gabbroic rocks of this zone to the large areas of similar rocks in Baltistan, where granitic rocks in addition become of increasing importance in close association with them.

According to DAINELLI's general map *(op. cit.)*, this great dioritic-granitic complex appears as the western expanding extension of the crystallines of the Ladakh Range, which largely consist of older granitic rocks, the whole being separated from the granitic core of the Great Karakoram by a zone of crystalline schists. In this great eruptive complex, which covers the greater part of Baltistan south of the Indus, DAINELLI distinguishes two main groups of dioritic rocks, *viz.* quartz-diorites and diorites free of quartz. The former by far predominate; most common are quartz-bearing biotite-hornblende-diorites of tonalitic character. They are, in the Indus Valley above Skardu and also elsewhere, closely associated with granites, sometimes distinctly intrusive into these latter, but sometimes the reverse is the case. The relation between them is evidently rather complicated in this zone, where the Pre-Senonian Ladakh Granite meets the Tertiary granite of the Deosai region. Of more rare occurrence are quartz-biotite-diorites, which usually appear as a marginal facies of dioritic massifs. Quartz-hornblende-diorites and quartz-pyroxene-diorites free of mica are recorded at a few localities.

Amongst the diorites of the second group, hornblende-biotite-diorites are the most common. They grade into the quartz-diorites by the appearance of quartz as an essential constituent. Besides these occur occasionally also biotite-diorites and pyroxene-diorites. Some of these diorites contain considerable amount of potash feldspar, being transitional into the monzonites. DAINELLI could also trace a transition into true gabbroic rocks.

The Karakoram Granites.

The petrography of the Karakoram granites is fairly well known by investigations of WYSS, ALOISI (1932), and FISCHER (in DE TERRA 1932). Three granites of regional occurrence are distinguished, *viz.* biotite-granites, biotite-muscovite-granites, and biotite-hornblende-granites, which often are intimately associated and connected by transitional varieties. They are, as a rule, more or less strongly cataclastic, the biotite-hornblende-granites, however, sometimes less so.

Amongst specimens collected in the Great Karakoram by WYSS, DAINELLI, DE TERRA, HEDIN, and the author, 51 % are biotite-granites, 20 % biotite-muscovite-granites, and 29 % biotite-hornblende-granites; the potash feldspar is described as "orthoclase" in 50 % of the specimens, as "orthoclase" and microcline in 10 %, and as quadrille structured microcline in 40 %. In this respect the Karakoram granites differ from the K'un-lun granites in which the potash feldspar, as a rule, is development as grated microcline.

The distribution of the various granites in the Karakoram and their field relations, indicate a very intimate connection between them. "Die räumlich, stofflich, strukturell und texturell enge Zusammenhörigkeit aller drei Typen unseres Granites spricht überzeugend für ihre genetische Zusammenhörigkeit. Es kann sich bei ihnen kaum um wesentlich altersverschiedene Typen, sondern um syngenetische Differentiate ein und derselben Intrusions- und Kristallisationsablaufes handeln" (WYSS 1940, p. 414).

The granite which forms the southern slope of the Ladakh Range is older than the Indus Flysch (Late Cretaceous), which has been deposited upon its deeply weathered surface (DAINELLI, DE TERRA 1935, WYSS). DE TERRA (1932, p. 114) attributes a Variscan age to this granite and its equivalents in the Great Karakoram because of its possible connection with supposedly Variscan folding of the associated Silurian sediments at Tankse. The occurrence of granitic pebbles in conglomeratic Late Paleozoic slates at Lukong at the western end of the Pangkong lake has hardly any bearing on the age of the Ladakh granite, which crops out in the neighbourhood, as long as their identity with the latter has not been established (DE TERRA 1932, p. 90). The strong metamorphism exhibited by the sediments associated with the conglomeratic slate, *viz.* amphibolite, sericitic slates, schistose marble, and dark phyllites with brachiopods, a. o. *Productus*, suggests rather the contrary, *i. e.* a Post-Paleozoic age of the Ladakh granite, as assumed by DAINELLI (op. cit.).

The gneissose biotite-granites and granodiorites in the Great Karakoram are certainly Post-Paleozoic and probably Post-Triassic. According to LYDEKKER (1883, pp. 186), DESIO (1930, 1936), and AUDEN (1938) the Late Paleozoic and Triassic Tethys deposit in the head regions of the Shigar and the Nubra valleys, which locally are intensely metamorphosed, rest upon and are intercalated with biotite-orthogneisses. These form the fundament of the sedimentaries in the shape of huge synorogenic intrusions. The gneisses are crossed in all directions by younger granite and pegmatite.

DAINELLI (1934, p. 714) has shown, that the Pre-Senonian granite of the Ladakh Range westward about lat. 76° 30′ is succeeded by younger hornblende-granite, which usually is associated with metamorphosed basic eruptives: quartz-diorites, epidiorites, hornblende-granulites etc. This association is found from the Dras Valley in the south to the Shayok - Indus junction in the north, a zone about 80 km. wide. WADIA (1935) has shown that hornblende-granite covers a large part of the

Deosai Plateau and the region further west to Astor at the great southern bend of the Indus. In this granite, the Eocene of the Burzil Pass occurs as a floating island, proving that this granite can not be older than the Eocene.

On the northern slope of the Ladakh Range, in the Great Karakoram, and in the Aghil Range, hypabyssic and effusive acid porphyries occur remarkably frequently in close association with the granites. Thus, WYSS (1940, p. 323) found on the northern side of the Saser Pass granite-porphyry as a marginal facies of a large body of biotite-granite together with dikes of quartz-porphyry, the granite-porphyry constituting a transition between the latter and the granite. In the Ngönpo Valley, north-west of the Karakoram Pass, quartz-porphyry appears as the marginal zone of a dike of granite-porphyry intruded into limestone of Upper Dogger age (WYSS *op. cit.* p. 425).

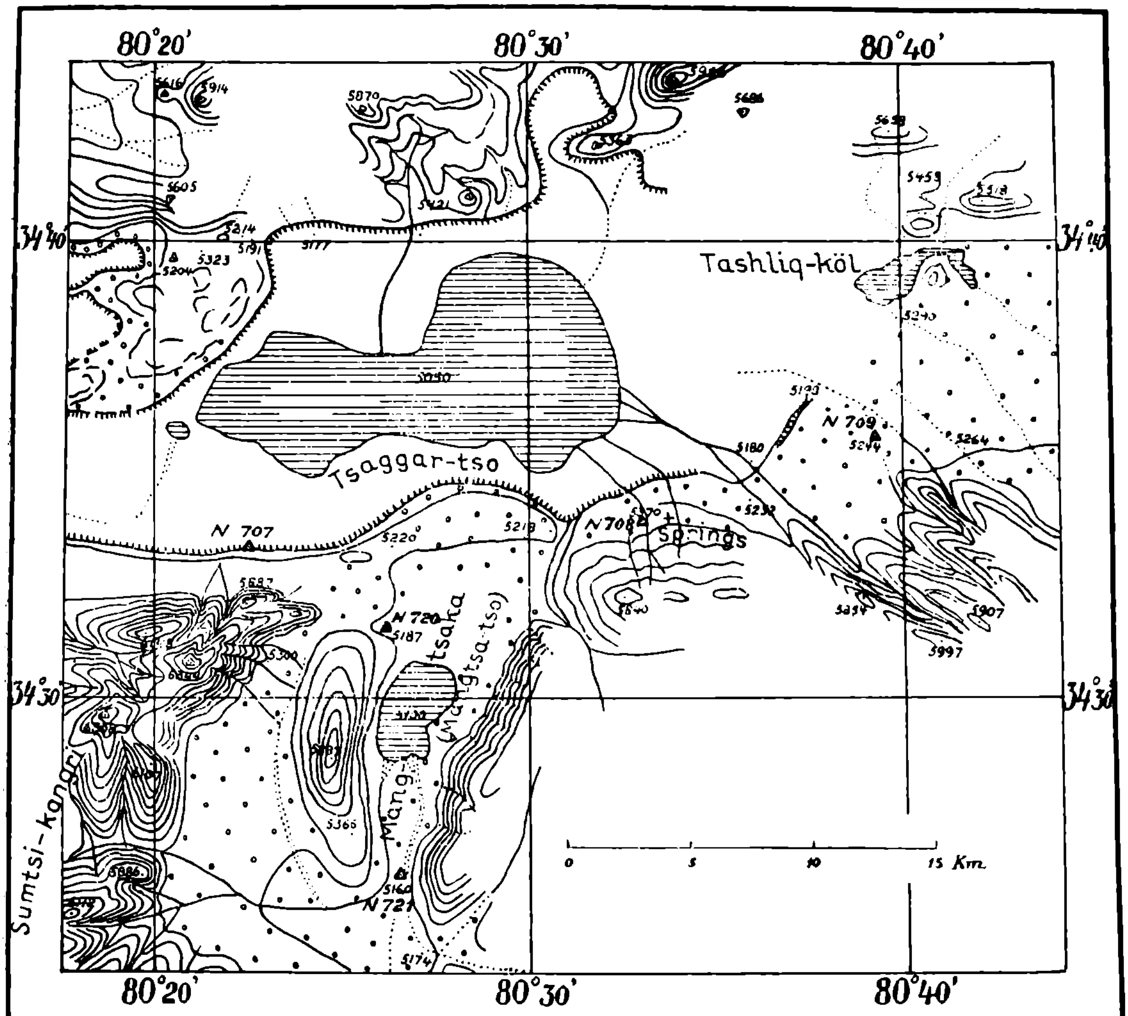


Fig. 22. The basins of Mang-tsaka and Tsaggar-tso.

Towards the south-east, the crystalline zone of the Great Karakoram and its large granitic intrusions can be traced into the Chang-chenmo Range on the southern side of the Chang-chenmo Valley, where the strike changes into easterly. Its further extension into Tibetan territory is unknown. North of the crystalline zone, however, in the Mawang-kangri, phacolithic granitic intrusions appear again on a large scale. The first of these is a large massif of strongly cataclastic, orthite-bearing biotite-hornblende-granite, discovered by DE TERRA at the western end of the range. "Die Quarzit- und Amphibolitschiefer legen sich hüllenartig um den Granitkern, der gegen W hin ein gletscherbedecktes Massiv bildet, das genau nördlich des Dyap-tso liegt" (DE TERRA 1932, pp. 96, 188).

Still further east in the basin of Mang-tsaka, a cauldron-shaped depression in the Mawang-kangri, fine sections of another large phacolithic body are exposed in the steep cliffs (Fig. 22—25). The intrusive, which consists of granodiorite and biotite-hornblende-granite is overlain by fine-grained grey quartzite, dark slates, and crystalline gray and dark bluish limestones in which discs of crinoids are sometimes visible, proving that the sediments are not older than the Paleozoic.

Behind Camp N 707, the slope of the range consists of strongly crushed crystalline limestone bordering on a coarse breccia of dark gray, phyllitic argillite. The breccia is interstratified with the same argillite partially developed as pencil slate, dipping 80° N. Then follows red brown, partially gravelly sandstone with beds of

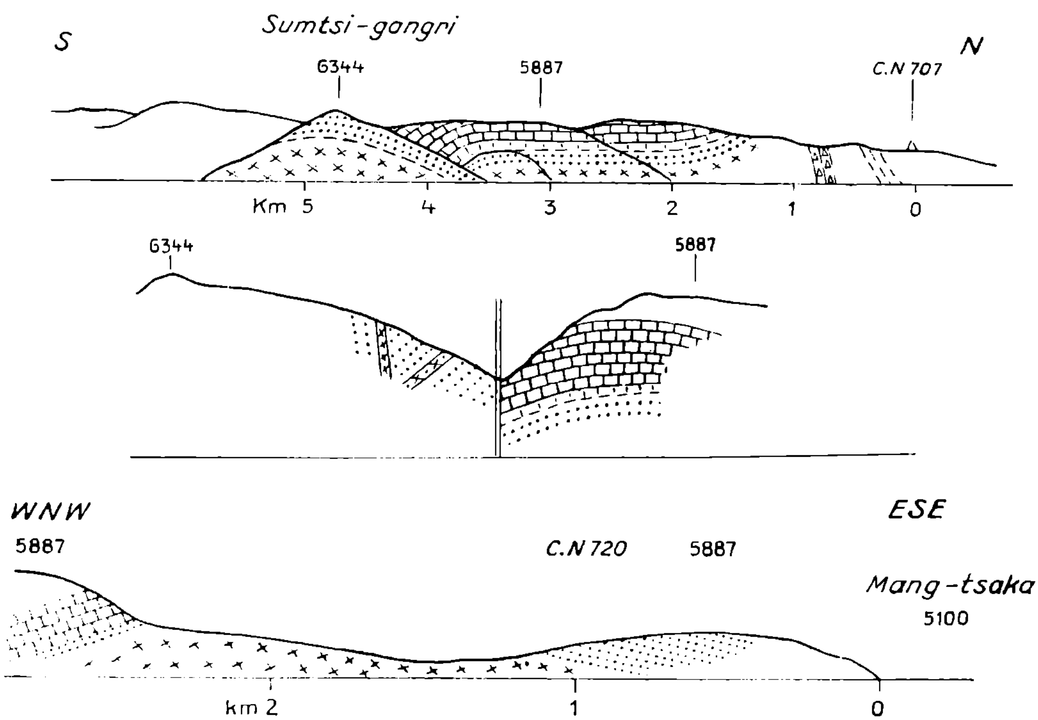


Fig. 23—25. Contacts between granodiorite and Paleozoic beds in the basin of Mang-tsaka, Mawang-kangri.

yellowish, massive shale which contains small angular fragments of the subjacent slate and dips 60—70° N. We have here probably a minor overthrust.

The sections Fig. 23—25 and the sketch map Fig. 22 elucidate the architecture of the intrusive. The massif 5887 which rises isolated in the middle of the basin, is a part of the sunken roof of the phacolite, a flat bed of quartzite sloping to the north-east and exposing the granitic fundament along the western and southern side.

The main intrusive body is a gray, medium-grained, porphyritic granodiorite (1133) with slightly gneissose structure; the mineral composition is given in Table VIII below.

TABLE VIII.

Geometrical analyses of granitic intrusives in the Mawang-kangri.

	1131 %Vol.	1133 %Vol.	1137 %Vol.	1104 %Vol.
Quartz	23.9	21.7	31.0	23.0
Potash feldspar	19.5	23.2	21.0	21.7
Plagioclase	42.2	43.8	35.2	40.6
Hornblende	—	—	—	3.1
Biotite	—	10.9	—	11.5
Chlorite	13.2		8.6	—
Ore	trace	trace	2.6	0.1
Titanite	0.4		trace	—
Orthite	0.4		0.1	—
Apatite	0.1	0.3	0.4	trace
Calcite	0.3	—	1.1	—
	100.0	100.0	100.0	100.0
mm measured	346	293	315	300
Σ slides	2	2	2	2

Spec. 1131 Granodiorite from Point 5300, eastern slope of Sumtsi-kangri.
Spec. 1133 Granodiorite from the massif 5887 near contact.
Spec. 1137 Granite from Camp N721, Mang-tsaka.
Spec. 1104 Younger granodiorite from the massif 5997, eastern Mawang-kangri.

The rock is strongly cataclastic; the quartz crystals have been crushed to fine aggregates, which are penetrated by irregular veinlets and patches of newly formed potash feldspar. But for occasional sericitic decomposition products in the plagioclase, muscovite does not occur. The plagioclase, a slightly zonary built oligoclase averaging An_{30}, also contains similar infiltrations of potash feldspar as the quartz. The primary potash feldspar forms mainly large porphyritic, cryptoperthitic individuals without quadrille structure, usually with myrmekitic reaction rim at the plagioclase contacts. The biotite is partially chloritized but the main part is fresh; the haloes around enclosed zircons are rather strong. Pale bluish apatite with minute liquid inclusions, and brownish, perfectly fresh orthite are common, as well as titanite. Ore sparsedly.

The same rock, although more strongly deformed, forms the high slope of the Sumtsi-kangri. In the specimen investigated (1131) the biotite is completely altered into pale green chlorite with much dust of leucoxene and ore. The twinning lamellae of the oligoclase are generally deformed, and quadrille structured patches appear in the potash feldspar. But for the replacement of biotite by chlorite, the quantitative mineral composition is nearly the same as in Spec. 1133 (Table VIII).

In the massif 5887, the granodiorite is associated with coarser grained muscovite-biotite-granite rich in potash feldspar (1132), probably as streaks in the former. The muscovite, which forms large independent crystals, has been subjected to deformation of the same intensity as the other primary minerals. Chlorite is absent.

In the eastern part of the intrusive body exposed around Camp N 721, the rock has the same general appearance as above, porphyritic and strongly cataclastic. In the specimen 1137, the mafic minerals are completely altered into penninite which, partially, is very rich in dusty ore and calcite, suggesting hornblende as the primary mineral. The plagioclase, mostly extensively decomposed, is mainly zonary built oligoclase (An_{34}—An_{28}), rarely andesine (An_{40}). The same bluish apatite and fresh orthite as in the granodiorite indicate close genetic affinity between these rocks. The quantitative mineral composition is given in Table VIII. The rock is probably an altered biotite-hornblende-granite. The intrusive is here separated from the limestone-quartzite series by a broad zone of micaceous schists, amphibolites, and fine-grained leptitic gneiss.

Large masses of similar granites form the glaciated, high mountains on the northern side of the basin of Changer-char, and smaller intrusions occur in the probably Permian limestone series in the southern border range.

The strong dynamic and regional metamorphism to which the older granodiorite has been subjected in the Mawang-kangri, clearly shows that the intrusives had solidified completely before the last great period of folding and magmatism during the Late Cretaceous or Early Tertiary. Their close resemblance as regards mineral composition and texture to the orthite-bearing, gneissose granites in the Karakoram and the Ladakh Range, with which the Mawang-kangri granites are also closely connected in the field, leaves little doubt that these intrusives belong to the same period of magmatic activity, and like the granite of the Ladakh Range are Pre-Senonian.

There are, on the other hand, evidences indicating a Post-Paleozoic age of these granites, *e. g.* the metamorphosed Late Paleozoic sequence in the Pangkong Valley mentioned above, and the locally strongly metamorphosed limestones of probably Permian age in the basin of Changer-char.

Younger Granodiorite and Associated Porphyries in the Western Chang-thang.

Besides these strongly cataclastic granites of granodioritic affinities, there is another younger granodiorite in the Mawang-kangri, which does not exhibit any traces of internal deformation. This rock forms the core of the snowy massif 6354 east-south-east of Tsaggar-tso, which is composed of several, parallel, high ridges (Fig. 26). The northerly consist of dark and varied coloured limestones striking E. S. E., in part strongly metamorphosed, but else lithologically very similar to the Cretaceous limestone series east of Horpa-tso of which they seem to constitute the direct extension. The limestone series contains, east and south-east of Camp N 709, several thick sills of quartz-diorite-porphyrite (1105), which evidently represent the dike accompaniments of the granodiorite.

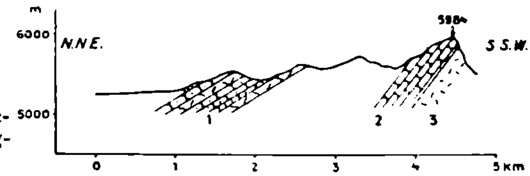


Fig. 26. Intrusions of granodiorite (3) and quartz-diorite-porphyrite (1) in the Cretaceous (?) series, Eastern Mawang-kangri.

The granodiorite, Spec. 1104, collected south of Camp N 709, is a medium-grained, equigranular rock of grayish general colour, spotted with dark minerals and irregular specks of salmon red potash feldspar. The quantitative mineral composition is given in Table VIII.

Apart from the accessories, the crystallisation began with segregation of common green hornblende ($c/\gamma = 19°$, $\gamma - \alpha = 0{,}023$; α = yellowish, β = yellowish green, γ = olive green) and some biotite, soon followed by andesine in thick strongly zoned plates, grading from An_{50} to An_{10} ($\perp \alpha : \beta/(010) = 28°$, $\perp \gamma : \alpha/(001) = -20{,}5° - +12°$). It is sometimes glassy but more often stained with sericitic and zoisitic decomposition products. The dark brown biotite is idiomorphic when bordering on or enclosed in potash feldspar or quartz; it is mostly partially altered into epidote and chlorite, and is sometimes surrounded by an aureole of later, pneumatolytic(?) negative penninite. Potash feldspar and quartz form the base, occasionally granophyric. The potash feldspar is developed as anorthoclase ($2V_{\alpha}$ about 40°, $\perp \gamma : \alpha/(001) = 8°$) and cryptoperthite. The quartz exhibits no trace of strain shadows. Zircon rather common, surrounded by a narrow halo in the biotite; apatite and ore are rare.

Although chemically very similar to the older granodiorite, this younger granodiorite differs from the latter by other accessory minerals. The older granodiorite is characterized by accessory orthite and a bluish apatite which enters abundantly. In the younger granodiorite, apatite occurs very sparingly and orthite has not been observed; instead zircon is remarkably common.

The sills of quartz-diorite-porphyrite in the limestone series on the northern side of the massif 6354, are considered as a hypabyssic facies of the granodioritic magma. The porphyrite, Spec. 1105, collected in the ridge south-east of Camp N 709 (Fig. 26), is a grayish black, dense rock with numerous small phenocrysts of white feldspar, one or two millimetres in size. Under the microscope, the rock is seen to consist of a streaky, cryptocrystalline, partly spherulitic base with phenocrysts mainly of twinned oligoclase-albite in stout prisms, plates or angular fragments, and pseudomorphs after pyroxene, hornblende, and biotite; phenocrysts of quartz are rare. The pseudomorphs after the completely altered dark minerals exhibit often perfectly the crystallographic contours of these latter. The pyroxenes have been transformed into clear, greenish antigorite, which sometimes is associated with calcite; the hornblende has been altered mainly into ore and calcite. Zircon is rather common. The rock contains also small fragments of fluxion structured, pilotaxitic andesite. No traces of internal deformation.

To this late period of volcanism I refer also beds of quartz-porphyry, which occur in the Late Cretaceous sequence on the northern shore of Yeshil-köl, at the base of the section Fig. 14. The bed, with an exposed thickness of about 10 m., is overlain conformably by reddish brown sandstone (Hor. L). The actual contact is hidden by detritus, but in levels very close to it, the sandstone exhibits, macroscopically, no evidences of metamorphism. As, on the other hand, no pyroclastic formations were noticed at the boundary, I cannot state whether the porphyry represents an effusive bed or a concordant intrusion. The rock is, in any case, of very late Cretaceous or Tertiary age.

Under the microscope the porphyry (Spec. 929) is seen to be composed of a partly cryptocrystalline, partly spherulitic, streaky base strongly impregnated with dark reddish brown ore dust, in which occur numerous large, more or less strongly corroded crystals and angular fragments of potash feldspar (26 % vol.) and likewise strongly corroded crystals of clear quartz (5,5 % vol.). Zircon is rather common. No primary mafic minerals occur except titanite embedded in ore.

The potash feldspar is partly developed as homogenous anorthoclase:

$$\alpha/(001) = 98^\circ$$
$$\beta/(001) = 9^\circ \qquad 2V_\alpha = 56^\circ$$
$$\gamma/(001) = 88^\circ$$

partly as cryptoperthite with patches of albite. A few phenocrysts are intergrown micrographically with quartz. Partial secondary replacement by calcite was noticed in one case. The quartz crystals are sometimes reduced to skeletons by resorption. They are often cracked but, as a rule, strain shadows are absent.

Beds of effusive acid porphyries and pyroclastics are piled to great thickness in the basin of Changer-char where, unfortunately, the whole Mesozoic sedimentary sequence is absent and Permian limestones form the fundament. The volcanic series is here, like the Permian beds, compressed into a broad syncline, thus proving that the extrusion of the lavas took place before the latest period of folding, and therefore cannot be younger than the Tertiary. The geology of the area has been described above pp. 65 (Sections IV a and IV b, Pl. B).

At Camp N 726, the base of the volcanic series consists of a red conglomerate with pebbles (3 to 6 cm. in size) of dark gray and bluish gray limestone. Above follows red, fine-grained (0,5—1 mm.) silicified sandstone dipping about 70° towards N. 30° W., composed of perfectly rounded grains of quartz and solitary grains of chert-like felsites; a ferrugineous cement enters sparely in the interstices. The quartz, which seems to originate from a granite, has only faint strain shadows.

At the north-western corner of the basin, the sandstone series was not seen, and here the lavas seem to rest directly upon strongly metamorphosed Paleozoic quartzite with 45° southerly dip. The lowest bed (Spec. 1150) is a brownish gray, massive rhyolite with a streaky, microfelsitic, in part nearly isotropic base containing numerous phenocrysts (0.5—1.5 mm.) of quartz, twinned acid plagioclase, potash feldspar, and more rarely phenocrysts of much paled or completely decomposed biotite. The feldspars are also extensively decomposed into micaceous or kaolinitic substances. Accessorily ore, titanite, and zircon. The abundance of phenocrysts of acid plagioclase, equal to or predominant over potash feldspar in spite of the abundance of phenocrysts of quartz, characterizes this rock as intermediate between dacite and rhyolite, comparable to the plagioclase-rhyolites described by VENDL (1927) in the Hungarian Erzgebirge. It indicates the close genetic relationship between the dacites (quartz-diorite-porphyrites) and the rhyolites in the western Chang-thang.

Above this bed follows a thick series of similar lavas together with brownish red beds, which exhibit beautifully the surface features of flows with contorted and twisted rolls of lava (1151) and agglomeratic masses. The bed Spec. 1151 is a devitrified rhyolite consisting of minute spherulites of felsitic substance soaked with quartz, and with solitary phenocrysts of feldspar completely altered into a cryptocrystalline kaolinitic mass. Rare phenocrysts of biotite are traced as accumulations of ore dust, which have preserved the crystallographic outline of the primary mineral.

Tuffaceous beds intercalated between the flows, are often very compact and hardly to be distinguished from the lavas in hand specimen. The rock, Spec. 1152, collected in the upper part of the series, is very similar to the rhyolite Spec. 1150. Under the microscope it is seen to consist of closely packed, rounded or angular fragments of rhyolites of variable texture: microfelsites with phenocrysts of quartz and / or feldspars, felsites with microspherulitic texture like Spec. 1151, and chert-like felsites, but also sparely rhyolites with holocrystalline, granophyric groundmass. The fragments are soldered together by a spare cement of jasper and quartz, which locally is miarolitic. The chemical composition of the rock is given below.

TABLE IX.

Rhyolite breccia, Spec. 1152, from the basin of Changer-char.

Analyst: S. PALMQVIST.

	%	Norm		Niggli values	
SiO_2	80.35	Q	51.21	qz	+405
TiO_2	0.38	Or	29.38	si	652
Al_2O_3	9.57	Ab	11.69	ti	2.9
Fe_2O_3	0.83	An	2.92		
FeO	0.14	C	0.85	al	45.8
MnO	trace	Sal.	96.05	fm	12.3
MgO	0.51	Hy	1.27	c	5.1
CaO	0.59	Ilm	0.30	alk	36.8
Na_2O	1.38	Hm	0.51		
K_2O	4.97	Ru	0.32	k	0.7
P_2O_5	trace	Fem	2.40	mg	0.5
H_2O+	0.82	H_2O	1.22		
H_2O-	0.40				
	99.94		99.67		—

To this volcanic complex probably also belongs a thick sill of quartz-pyroxene-diorite-porphyrite (Spec. 1153), which appears in an anticlinal vault in the Horpatso Series in the southern border range of the basin at Camp N 728 (Section IV, Pl. B). It is a light gray rock consisting of closely packed, white and yellowish plates of twinned oligoclase, 3—5 mm. in size, quartz, and pseudomorphs after pyroxene, more rarely after hornblende, in a groundmass composed in part of irregular, optically uniform patches of alkali feldspar filled with flakelets of chlorite, in part of cryptocrystalline, feathery or fibrous aggregates. The often strongly corroded quartz phenocrysts, which never show any trace of strain shadows, are always surrounded by a broad, irregular aureole of quartz with the same optical orientation as the phenocrysts, and forming a part of the groundmass. The tabular plagioclases (about An_{20}) are always much decomposed into sericite and calcite. The pyroxenes are completely altered into pale greenish, negative penninite with lamellar leucoxene and some ore, sometimes also calcite. Solitary phenocrysts with the crystallographic contour of hornblende consist of ore, calcite, and chlorite. Accessorily apatite and zircon.

Petrographically, this rock is almost identical with the quartz-diorite-porphyrite, Spec. 1105, in the Mawang-kangri. At that place, the porphyries were closely associated with the youngest granodiorite; in the Changer-char similar porphyry is associated with effusive, acid lavas. This relationship indicates a close genetic connection between the granodiorite and the effusive complex, and makes a Late Cretaceous or Tertiary age of the former very probable.

The Himalayan Granites.

Rather little is known about the geological position of the Himalayan granites and orthogneisses, the dominant magmatic element in the great crystalline zone of the Himalayas. Several granites of different petrographical character have been distinguished by the Indian geologists. The common "Himalayan Granite" is a biotite-granite, which forms the backbone of the great Himalaya Range. Younger than this is a tourmaline-bearing plagioclase-granite with accessory beryl, which often is associated with the former (HAYDEN 1934, p. 289). Contrary to the Tertiary hornblende-granites, these granites are usually more or less foliated or gneissose, do often form the core of synclines, and are apparently of synorogenic character (Mc MAHON 1887, 1897; WADIA 1926, p. 348; AUDEN 1934, p. 413; HEIM 1939). The associated sedimentary rocks are transformed into crystalline schists, the stratigraphic position of which is often doubtful. North of Mount Everest, a series of shales and limestones of Triassic and Jurassic age has been permeated with tourmaline-granite, which has metamorphosed the sediments into mica-schists and banded calc-silicate rocks. Its concordance with the foliation of the intruded rocks is specially characteristic (HERON 1922).

The Everest granite and similar synorogenic biotite-granites in Sikkim and Bhutan, are certainly Post-Jurassic. Post-Jurassic are, according to DYHRENFURTH (1932), probably also certain eyed gneisses in the Kanchenjunga. The age of the greater part of the ortho-gneisses in the Himalayas is not known.

In the north-western Himalayas, in the region of Nanga Parbat, surveys by WADIA (1932) and the German Himalaya Expedition of 1934 (MISCH 1935, 1936) have greatly elucidated the nature of the rocks of the crystalline zone. The Nanga Parbat is largely composed of foliated, intensely contorted biotite-gneiss with interstratifications of paragneisses and beds of marble, the whole finely laminated with persistent steep, northerly or north-westerly dip. The gneiss borders on both sides on large masses of dioritic and gabbroidal intrusives, the metamorphic equivalents of which also appear in the shape of sills, lenses and phacolites in the gneiss. At least part of these basic rocks probably represent the extension of the Indus volcanics. The paragneisses are, according to WADIA, largely strongly metamorphosed representatives of the Pre-Cambrian Salkhala Group of Kashmir and Hazara, permeated and injected with granitic material. A gradual transition from the gneiss into the Himalayan sedimentary series occurs. The folding is pre-crystalline. As the alteration into gneiss most probably took place during the Alpine orogeny, this part of the crystalline zone cannot represent an ancient crystalline block but is the result of a young process of metamorphism in the interior of the orogenetic zone. The granitic intrusives are of similar kind as elsewhere in the Himalayas. There is a post-tectonic, white, fine-grained tourmaline-granite; along the eastern border appears a hornblende-tonalite which intrudes the basic eruptives; north of the Burzil Pass red porphyritic hornblende-granite is recorded.

In the Lower Himalayas south-east of Simla, the Krol (Permo-Carboniferous), Tal (Cretaceous and Jurassic?), and Tertiary formations have locally been metamorphosed as a result of Tertiary orogenesis. "The effects have been such that slates in the Infra-Krol are similar to some in the Simla and Jaunsar series (Lower Paleozoic and Pre-Cambrian) . . . . It is a striking fact that, except in one rock slice of the Blaini boulder bed, no single instance has been found either in the field, or in rock slice, of any true schists or metamorphic rocks of *meso*-type being included in the pre-Tertiary conglomerates . . . . . . Not until the Dagshais, of Oligocene or Miocene age, are there found metamorphic rocks and minerals of *meso*-type" (AUDEN 1934, pp. 416). The official opinion of the Geological Survey of India as expressed in HAYDEN's great work (1934) is that the Himalayan granite is Cretaceous or Tertiary. With these statements as a background, the find of one solitary pebble of a plagioclase-granite resembling certain Himalayan granites in a breccia below the Krol Limestones in Garhwal (AUDEN 1933), can hardly be considered as a weighty argument in favour of Pre-Krol age of the Himalayan granite, because of the great similarity exhibited by granites of widely different orogenies. The same holds as regards the occurrence of granitic pebbles in the Agglomeratic Slate Series in Kashmir and in the Permian conglomerate at Spiti.

Possibly still younger than the Everest granite is the unfoliated, Late Cretaceous or Eocene plagioclase-hornblende-granite (Kyichu granite) and hornblende-diorite in the Tsangpo (Brahmaputra) Valley in Southern Tibet (HAYDEN 1907, p. 60; 1934, p. 290). This granite (granodiorite?), which is characterized by very high content of titanite, is locally associated with dacitic porphyries which are considered by HAYDEN as the dike accompaniments or an effusive facies of the granite.

MONZONITIC AND RELATED ROCKS IN THE WESTERN CHANG-THANG.

The eruptives in the investigated parts of the western Chang-thang and the Aghil Ranges are largely of monzonitic character, grading into pyroxene-diorites and gabbroic rocks on the one hand and into true nepheline-syenite on the other. Rather instructive as to the mode of intrusion of these young abyssal rocks, is the occurrence at Qizil-davan in the Western Loqzung Mountains. These outcrops were discovered by DAINELLI (1934, p. 561, 637) and described by ALOISI (1932, p. 83) as pyroxene-diorite. The outcrops were studied by the present author in 1932.

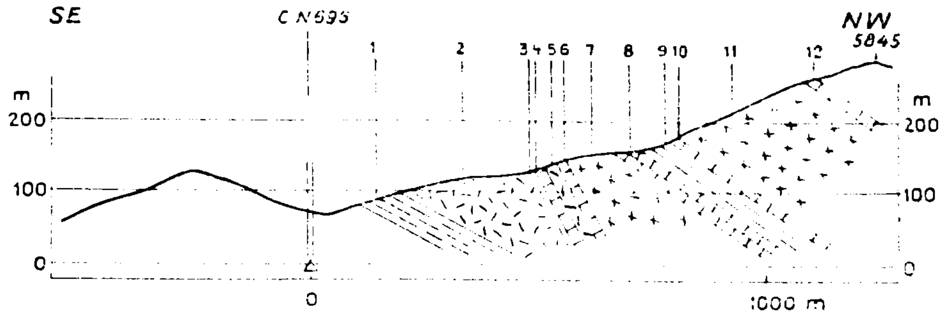


Fig. 27. Paleozoic beds with intrusions of monzonite at Qizil-davan, Western Loqzung Mountains (Legend, see the text).

At Qizil-davan, the monzonites appear in the shape of laccolithic bodies at the boundary between a series of Ordovician sediments, which form the fundament, and strongly metamorphosed crinoid limestone above, upon which, in turn, the Cretaceous complex of the "Monte della Piega" has been thrusted. On the northern side of the main pass, the following sequence of strata was noted by the author in ascending order (Fig. 27, Sketch map Fig. 18):

1) Grayish green sandy shale and argillaceous, fine-grained sandstone dipping 30° towards N. 15° W. ...... unknown thickness.
overlain conformably by

2) beds of basaltic lava (at least two); the lower, a very fine-grained, dark gray, pilotaxitic augite-basalt (1080) grades into a reddish brown, vesicular and slaggy variety (1081). Above follows another bed with similar mineral composition as the first, and grading into scoriaceous basalt at the top.

3) Brownish red, dense limestone (1083) filled with micro-fossils and fragments of shells........................ about 15 m.
This horizon is separated from the subjacent lava bed by a fault, for the dip suddenly increases here to 70° towards N. N. W. This conspicuous bed (= Horizon d of DAINELLI) can be traced in the terrain westward to the pass 5400.

4) Gray fossiliferous limestone overlying Hor. 3 conformably (Loc. N 70) .... some 10 m.
The following forms were determined by professor CH. POULSEN (Copenhagen): *Illaenus* sp., *Orthoceras* sp., *Gaurorthis* sp., and *Orthis* sp., indicating Middle or Lower Ordovician.

5) A bed (?) of strongly altered basalt .... about 10 m.

6) Gray fossiliferous limestone similar to Hor. 4 .... a few m.
7) Dark reddish gray monzonite .... about 50 m.
bordering on
8) strongly metamorphosed limestone dipping 30° towards N. 15° W., and composed almost wholly of small crinoid discs .... about 10 m.
Upon this rests conformably
9) greenish sandy shale similar to Hor. 1 .... about 20 m.
10) Light yellowish gray, very fine-grained crystalline limestone (1084) .... a few m.
11) A thick bed of dark reddish gray, fine-grained monzonite-porphyry (1085), which becomes coarser and quartz-bearing (1086) in the upper part .... about 100 m.
12) Strongly metamorphosed crinoid limestone (1087) similar to Hor. 8 .... thickness unknown.

Although the rocks exhibit very slight or no evidences of shearing, the section is probably complicated by repetition. The monzonite, Hor. 7 and 11, may possibly represent parts of the same lense-shaped intrusion capped by crinoid marble; the greenish sandy shale, Hor. 9, may be the same as Hor. 1 at the base of the section, but the absence of any trace of basaltic beds makes the connection doubtful. Anyhow, the existence of thrust planes between Hor. 8 and 9, and between Hor. 12 and the overlying Cretaceous is rather probable. Another plane of disturbance evidently separates Hor. 2 and 3.

On comparing our section with those studied by DAINELLI on the western side and north of the pass (op. cit. Fig. 52), our horizons 3, 7, 8, 10, 11, and 12 are readily recognized. DAINELLI refers the crinoid marble to the Upper Paleozoic.

The monzonite-porphyry, Spec. 1085, collected in the lower part of the large intrusive body, Hor. 11, is a dark reddish gray, strongly decomposed, fine-grained rock with solitary plates of greenish gray plagioclase as much as 1 cm. in size, in a groundmass of diverging, lath-shaped (1—2 mm.) plagioclases, xenomorphic pyroxene, antigorite, potash feldspar, ore, and various decomposition products.

The plagioclases, which usually have a thin shell of potash feldspar, exhibit besides irregular polysynthetic twinning to the albite law frequently also pericline twinning. The normative composition is An_{31}. The phenocrysts are, however, mostly completely decomposed into colourless, fibrous or spherulitic aggregates of low birefringence resembling kaolinite, together with other micaceous substances and zoisite, soaked with almost pure albite. The plagioclases of the groundmass are generally clearer but completely decalcified; part of their original content of lime remains in the shape of zoisitic dust, but much has migrated into the groundmass as zoisite and clinozoisite. The residual plagioclase has the composition An_{06}.

$$(010)/\alpha = 85^\circ \quad \perp\alpha:(010)/\beta = -16^\circ \quad n_\alpha < \text{Can. bal.}$$
$$(010)/\beta = 74^\circ \quad \perp\gamma:(001)/\alpha = +20^\circ \quad n_\beta \gtrless \text{ ,, ,,}$$
$$(010)/\gamma = 18^\circ$$

Pyroxene, a colourless augite ($2V\gamma = 50^\circ$, $c/\gamma = 40^\circ$), xenomorphic and always perfectly fresh, enters rather sparingly. More abundant is green antigorite, which possibly replaces original hypersthene. Ore enters fairly abundantly mostly in the shape of slender rods or plates 1 mm. long; apatite sparsely as thin needles; no quartz.

The chemical composition of the rock is given below

TABLE X.

Monzonite-porphyry from Qizil-davan (Spec. 1085). Analyst: S. PALMQVIST.

	Specimen 1085					Normal monzonite[1]) from Predazzo		
	%	Norm		Niggli values		%	Niggli values	
SiO_2	51.68	or	22.87	qz	−23	52.64	qz	−26
TiO_2	3.57	ab	30.77	si	145	1.10	si	140
Al_2O_3	16.44	an	17.11	ti	7.5	14.96		
Fe_2O_3	2.37	Sal.	70.75			4.44		
FeO	5.76			al	27.2	5.63	al	23.5
MnO	0.09	di	10.68	fm	37.3	0.22	fm	37.5
MgO	4.45	ol	6.36	c	18.6	3.92	c	22.4
CaO	6.20	mt	3.42	alk	16.9	7.82	alk	16.6
Na_2O	3.64	ilm	6.78			3.82		
K_2O	3.87	ap	0.10	k	0.59	3.98	k	0.41
P_2O_5	0.04	Fem.	27.34	mg	0.50	0.27	mg	0.41
H_2O+	1.62	H_2O^+	1.62	c/fm	0.50	1.17	c/fm	0.60
H_2O-	0.69							
	100.42		99.71	—		99.97	—	
Quantitative System: II:5:3:3 *Shoshonose* Niggli's System: Yogoitic magma type						Yogoitic to Normal monzonitic magma type		

[1]) Monzonite, normal type, Monte Mulatto, Predazzo (ROSENBUSCH-OSANN 1923, p. 147).

Chemically the rock has the character of a monzonite with a composition rather similar to that of the monzonite of the Monte Mulatto in Predazzo, which has been added in the table for comparison.

The upper part (Spec. 1086) of the intrusive, Hor. 11, is rather different from the lower petrographically. It is a hypidiomorphic, medium- to small-grained, red-brown, fresh-looking rock, rich in dark minerals, amongst which scintillant lists of red-brown feldspars produce a beautiful effect (Pl. XI, Fig. 2). The texture is reminiscent of that often found in hybrid rocks. The principal minerals are, in order of frequency, plagioclase, potash feldspar, antigorite, quartz, ilmenite, apatite, and titanite.

The plagioclase is developed as long, slender prisms (about 4 × 0.5 mm.) elongated along the a-axis, and always with a thick shell of potash feldspar. Polysynthetic albite twinning is rare, but almost all the crystals are twinned to the Carlsbad law. Measurements on three crystals gave in good agreement

$$(010)/\alpha = 88.7^\circ \qquad [001]/\alpha = 88.6^\circ$$
$$(010)/\beta = 73.3^\circ \qquad [001]/\beta = 17.1^\circ$$
$$(010)/\gamma = 17.0^\circ \qquad [001]/\gamma = 73.1^\circ$$

corresponding to almost pure albite. Thus, the plagioclase has been completely decalcified, but in this case the remains of the decomposed anorthite molecule is very little in evidence in the shape of secondary minerals.

The mostly reddish potash feldspar is usually perthitic. Besides as a shell around the plagioclases, it occurs also as irregular, optically uniform patches or residual skeletons in the quartz.

The pyroxene, originally probably a hypersthene, is completely altered into antigorite or bastite (α=golden yellow, γ=green), sometimes stained with leucoxene; sometimes the crystallographic contour of the primary pyroxene is preserved, showing that the pyroxene crystallized in part before, in part more or less contemporaneously with the plagioclase. The alteration into antigorite may have taken place at an early stage, probably autometamorphically.

Quartz enters rather abundantly in the interstices often with uniform optical orientation over larger areas; it exhibits only very faint strain shadows or none at all. Ilmenite fairly plentifully as slender rods, skeletons or irregular grains accompanied by leucoxene or titanite. Apatite abundantly as needles or long prisms.

The rock may be classified as a quartz-monzonite, extensively altered by late magmatic or post-magmatic, hydrothermal activity. Its consanguinity to the monzonite-porphyry is apparent by its intimate connection with the latter in the laccolite. The rocks differ, however, by the higher content of potash feldspar and apatite, the fairly high percentage of quartz, and the absence of monoclinic proxene in the quartz-monzonite. Texturally the rocks differ by the pyroxene having crystallized after the plagioclase in the monzonite-porphyry, whereas in the quartz-monzonite the relation is reversed. The very rare occurrence of polysynthetic albite twinning in the latter rock is also worthy of note. Although there can be no considerable difference in age, the rocks probably represent separate intrusions, the quartz-monzonite being the younger. The absence of any traces of deformation in the quartz in spite of the strong folding of the associated Cenomanian and Turonian strata, forces us to assume the rock to be younger than this period folding, and of Late Cretaceous or Tertiary age.

Rocks of similar character discovered by DAINELLI and described by ALOISI (1932) occur in the glaciated massifs between Qizil-davan and Sumdo, 15—30 km. south-south-west of Qizil-davan. Thus, DAINELLI found in the neighbourhood of "Campo del ghiacciaio", an iddingsite-bearing diorite associated with biotite-diorite, and in the "Valle ignota" nearer Qizil-davan, an intrusion of tephrite. The chemical composition of the latter rock is found in Table XV (D 630). A pyroxene-biotite-granite or quartz-monzonite (Table XV, D 599) with diopside and orthorhombic pyroxene was also discovered by DAINELLI in the upper Shayok Valley at lat. 34° 50′ (ALOISI 1932, p. 39), and WYSS (1940, p. 372) describes an outcrop of medium- to coarse-grained aegirine-nepheline-syenite associated with quartz-biotite-hornblende-diorite at Qara-tagh-davan near the northern border of the Aghil zone (Table XV, W 170). These intrusives exhibit only faint traces of deformation.

Lamprophyric Rocks.

Lamprophyric dikes are reported from many localities in the Aghil Ranges, the Great Karakoram, and the Ladakh Range. WYSS (1940) describes a spessartite closely associated with the quartz-biotite-hornblende-diorite at the Qara-tagh Pass, and another, cataclastic, at Leh in the Ladakh Range. Others are described by ALOISI at Skardu, Olthing-thang, Kharmang, and Shiriting in the western part of the Ladakh Range. A cataclastic kersantite was found in the upper Shayok area (WYSS *op. cit.*). Various peridotites are described by ALOISI in dioritic gneiss in the Braldo Valley, together with hornblende-diorite in the Saltoro Valley, and associated with other young ophiolites in the Indus and Dras valleys. These rocks seem to be distributed all over the Karakoram and the Aghil zones. But they occur also in the K'un-lun, outside the orogenic zone proper. Thus, near Ali-nazar-qurghan on the northern side of the K'un-lun watershed, vertical dikes of leucite-shonkinite (1050) appear in a series of isoclinally folded marbles and crystalline schists, intersecting the marble beds obliquely (cfr Section Fig. 2).

The leucite-shonkinite, Spec. 1050, is a dense, grayish black rock, scintillating by microscopic biotites, and containing solitary, light gray pellets, a mm. in size, sometimes of icositetrahedric shape, resembling leucite. Under the microscope the rock is seen to consist of small (0,3—0,5 mm.), idiomorphic prisms of pale greenish or colourless augite with hour-glass structure ($2V\gamma = 54°$, $c/\gamma = 43°$ increasing to about 49° at the margin) and chestnut brown biotite with an almost opaque margin, in a light grayish or colourless, cryptocrystalline, partially isotropic base of very low refringence, in which fibrous minerals, calcitic dust, microlites of apatite, patches of alkaline feldspar, and analcite could be distinguished with some certainty. The leucite(?) pseudomorphs, which usually are coated with biotite, consist of cryptocrystalline substances similar to those which form the base, and analcite more or less abundantly. Besides these occur a few larger phenocrysts of fresh monoclinic pyroxene and pseudomorphs of pale greenish bastite (Pl. XI, Fig. 3).

TABLE XI.

Leucite-shonkinite, Spec. 1050, collected 4 km. above Ali-nazar-qurghan, Qaraqash Valley. Analyst: S. PALMQVIST.

	%	Norm		Mode		Niggli values	
SiO_2	45.15	or	37.51	Base	50.9v%	qz	−49
TiO_2	3.54	an	11.43	Leucite	0.9	si	120
Al_2O_3	15.13	ne	10.48	Pyroxene	29.3	ti	7.1
Fe_2O_3	1.20	lc	1.31	Biotite	17.4		
FeO	5.22	Sal.	60.73	Ore	1.5	al	23.7
MnO	0.10				100.0v%	fm	38.7
MgO	6.21	di	13.43			c	20.4
CaO	9.73	ol	8.59			alk	17.2
Na_2O	2.29	ilm	6.73				
K_2O	6.63	mt	1.73			k	0.66
P_2O_5	1.11	ap	2.62			mg	0.63
H_2O+	1.77	Fem.	33.10			c/fm	0.53
H_2O-	0.13	cc	3.83				
CO_2	2.00	H_2O	1.90				
	100.21		99.56	—		—	

Quantitative System: II:6:2:2 — *Vicose*
Niggli's System: Yogoitic magma type.

The chemical composition of the rock is found in Table XI. In Washington's table of analyses (1917), rocks of similar composition are developed mainly as leucite-tephrites and kersantites. The high content of TiO_2 and P_2O_5 is remarkable.

A dike rock of related type has been described by SMITH (in WORKMAN 1917, p. 276) in the Siachen basin in the Great Karakoram. It is a pale gray rock with numerous hexagonal plates of biotite, and consisting for the rest of colourless diopside, with some aegirine and abundant apatite, all idiomorphic in a groundmass of orthoclase. The rock shows no signs of dynamic metamorphism.

As a derivative of some lamprophyric effusive rock may possibly be interpreted a peculiar tuffaceous formation in the Upper Cretaceous sedimentary sequence at

Lake Lighten, described above p. 41. It enters as distinctly sedimentary beds of pale greenish colour in the middle part of a formation of red, fine-grained sandstone (Hor. H.) about 50 m. thick. The tuffaceous sediment or chlorite-siltstone (Spec. 927) has a volcanic appearance by solitary small geods, as much as 1 cm. in size, filled with quartz and calcite. Under the microscope, the rock is seen to consist of an extremely fine-grained aggregate of fibrous chlorite and cryptocrystalline, nearly isotropic substances, together with finely disseminated calcite, leucoxene, and ore. But there also occur solitary larger individuals of the same colourless chlorite without abnormal interference colour, like that of the groundmass, $\gamma - \alpha$ = about 0,009; it resembles antigorite. The chemical composition of the rock is the following.

TABLE XII.

Chlorite-siltstone, Spec. 927, from Lake Lighten, Point 5887, Hor. H.

Analyst: S. PALMQVIST.

	%	Niggli values		Absarokite Matavuna
SiO_2	41.62	qz	−22	43.76
TiO_2	2.14	si	102	3.41
Al_2O_3	13.72	ti	4.0	11.58
Fe_2O_3	7.80	p	1.7	4.39
FeO	3.00			7.57
MnO	trace	al	19.9	—
MgO	12.63	fm	67.0	12.97
CaO	4.97	c	7.1	9.64
Na_2O	0.42	alk	6.0	3.03
K_2O	3.19			1.84
P_2O_5	1.64	k	0.83	0.45
H_2O+	6.47	mg	0.69	0.47
H_2O-	0.46	c/fm	0.11	
CO_2	1.80			
	99.86			99.11

There is a remarkable resemblance between the chemical composition of this sediment and certain lamprophyric effusive rocks *e. g.* an absarokitic lava from the Matavuna volcano on Savaii (ROSENBUSCH - OSANN 1923, p. 503), which has been added to the table for comparison. Like most potassic pikrites, the sediment is very rich in P_2O_5 and TiO_2. As far as the chemical composition is concerned, the sediment may represent a very fine-grained lamprophyric tuff or ash.

According to the chemical analysis, about 40 % of the sediment consists of chlorite. In order to ascertain the character of this chlorite, comparative thermal analysis

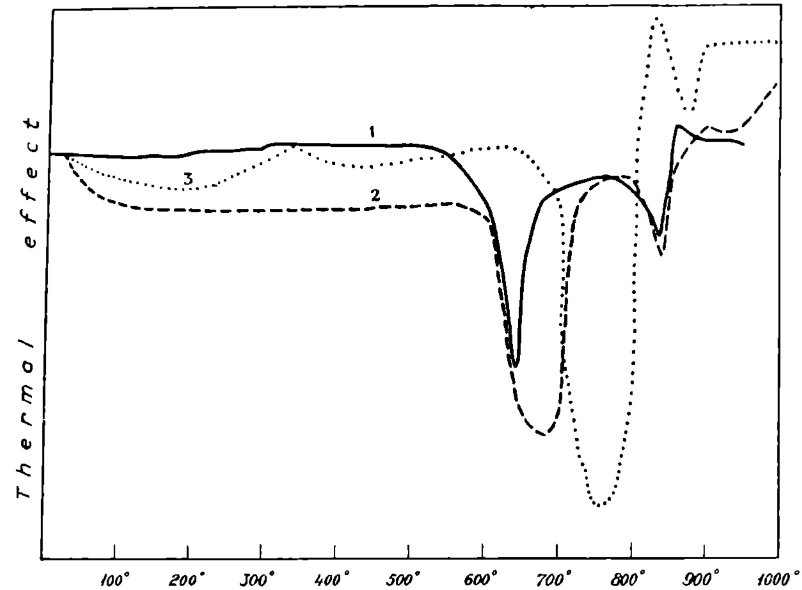


Fig. 28. Thermal analysis of 1) Upper Cretaceous tuffaceous siltstone; 2) Chlorite from the Falun Mine, Sweden; 3) Antigorite from Stubachthal, Salzburg.

was made on a sample of the sediment and on various chlorite minerals by Dr. ROLF NORIN at the ceramic laboratory at Höganäs. Dr. NORIN has communicated the following information:

"Amongst the chlorites studied, two are of interest in this connection, *viz.* pseudomorph of chlorite after anthophyllite from Falu Mine, Sweden, and antigorite from Stubachthal, Salzburg. The result of the thermal analysis is embodied in the diagram, Fig. 28. The diagram shows that the chlorite-siltstone, Graph 1, does not contain free antigorite (Graph 3), which begins to dissociate at a temperature about 100° C higher than the chlorite of the siltstone. There is, on the other hand, a remarkably close agreement between the latter and the chlorite from the Falu Mine (Graph 2), which has developed by hydration of anthophyllite, and which both begin to dissociate at 550° C. The greater width of the minimum in Graph 2 is caused by a larger amount of substance being used. Common to both graphs is also a second thermal reaction at 775—800°, and a third at 850—900° C. The agreement between the graphs is so close, that the identity of the minerals concerned becomes highly probable. The Falu chlorite, which has a greenish bronze colour in hand specimen, is colourless in thin section, $\gamma - \alpha$ = about 0.005 without abnormal interference colour, n_β = 1.602.

A chemical analysis of an anthophyllite from the Falu mine has been published by K. JOHANSSON (1930): SiO_2 .. 55.97%, Al_2O_3 .. 0.59, Fe_2O_3 .. 1.46, FeO .. 15.38, MnO .. 0.48, MgO .. 23.04, CaO .. 0.37, Na_2O .. 0.11, K_2O .. 0.03, H_2O .. 2.33, F_2 .. 0.45; Sum .. 100.21 %. A chlorite produced by hydration of this anthophyllite ought to have the composition $Ant_{70}FeAnt_{24}At_2Cr_4$, *i. e.* it ought to consist largely of antigorite. The thermal analysis shows, however, that the chlorite actually formed is not an antigorite, as also is evident by the high refringence and low birefringence of the mineral, which indicate a chlorite of the penninite series."

The above investigation leads us to classify the chlorite of the siltstone as a chlorite of the penninite series very poor in Al. It has probably developed from a pyroxene poor in Ca, *i. e.* an orthorhombic or pigeonitic pyroxene. The fact that about 40 % of the sediment consists of chlorite, indicates that the mother rock has been of lamprophyric character. The sediment may have been derived from flows of lamprophyric lavas either in shape of tuffaceous material or fluvial detritus. The channels through which these lavas erupted, may be found amongst those dikes of lamprophyric rocks, which are widely distributed over the Karakoram and the Aghil zone as well as the K'un-lun. The age of these eruptives is thus fixed to Upper Cretaceous and Post-Turonian in good agreement with the result obtained by DAINELLI concerning the age of the earlier ophiolitic volcanism in the Indus Valley, which took place during the Senonian.

The Latites.

The youngest eruptives in the northern Chang-thang are latites and andesites rich in potassium. These rocks are, in the region covered by our reconnaissance, confined to the K'un-lun Plains and the large intermontane basins in the K'un-lun in the shape of effusive beds and pyroclastics, which locally attain a thickness of hundreds of metres. The plateaus, domes, and cone-shaped mountains formed by these rocks, are a conspicuous feature in the landscape.

This broad fringe of alkaline lavas along the northern border of the Chang-thang seems to be a regional feature developed on perhaps an even more grand scale along the eastern K'un-lun or Arka-tagh, where the lavas reach still farther south into the interior of Tibet. Our present knowledge about the rocks of this latter region is due mainly to HEDIN, whose collections of specimens have been described by BÄCKSTRÖM and JOHANSSON (1900, 1907). Here, the lavas and tuffs appear as the youngest member of the geological sequence usually in the shape of horizontal beds and dissected plateaus over large areas. The lavas are described as bronzite-andesites, hornblende-biotite-andesites, and trachytoid andesite. A chemical analysis of a bronzite-andesite (Table XIII, Col. 6) shows, however, a composition of trachy-andesitic affinity, which closely corresponds to the average quartz-latite according to DALY (1933). Rocks of this character are recorded as far south as lat. 34° 35′.

The very young age of these effusives inclusive the latites in the western Chang-thang, is apparent by the fact that well preserved remains of the volcanoes from which they have emerged, have been noticed and described by many travellers (LITTLEDALE 1896, BONVALOT 1892, DUTREUIL DE RHINS 1897, ZUGMAYER 1906), and led them to suppose the existence of still active volcanoes in this region, the more so as hot springs are remarkably common here. There can be no doubt, how-

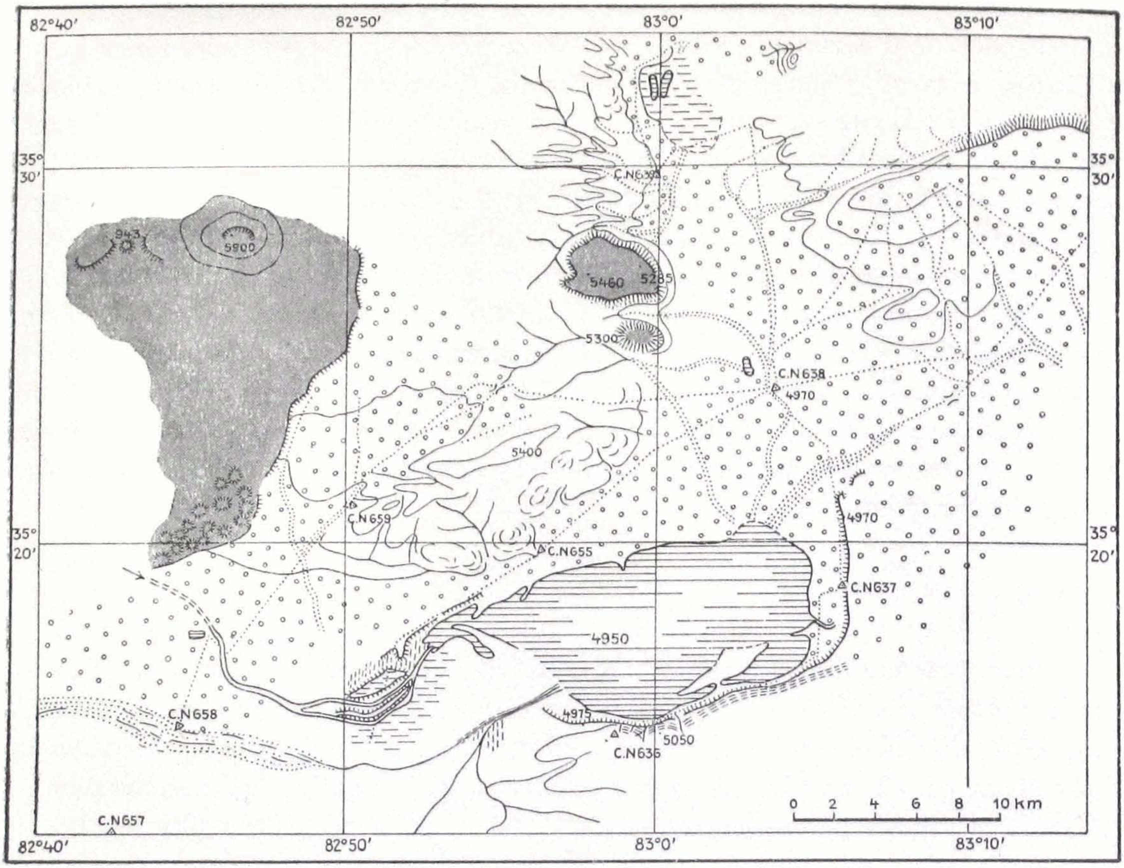


Fig. 29. The lava plateaus north of Lake Markham, K'un-lun Plains.

ever, that at least in the western Chang-thang these volcanoes are extinct since long ago, as proved by the absence of every trace of volcanic tuffaceous material in the recent alluvials. The pebbles of pumiceous andesitic lava found within a very confined area in the alluvials of the basin of Aq-sai-chin near the moraine-covered slope of the K'un-lun (cfr p. 33), have probably been derived from the moraine. In the basin of Achiq-köl, north of Lake Lighten, much dissected lava beds rest upon Pleistocene lake deposits (LEUCHS 1913) and are, thus, Post-Tertiary.

Within the extensive volcanic area at lat. 35° 30', long. 82° 45' (Map Fig. 29), the lava beds rest horizontally upon truncated, strongly folded Paleozoic formations. The lavas attain, in the plateau 5460, a thickness about 350 m. Here, the main part is vesicular (944) and exhibits locally the most beautiful flow structure with contorted layers and twisted rolls of lava. During the movement of the streams, the vesicles have sometimes become extenuated into narrow tubes, a decimetre long or even more, indicating accurately the direction of flowage. Thus, in the plateaus 5460 and 5300, the lava flowed eastward, whereas in the south-eastern part of the large western plateau, the flowage is directed towards the south, converging towards the large dome 5900 in the centre of the area, which probably represents the ancient volcano from which the lava emerged.

The augite-latite, Spec. 982, collected in the northern slope of the plateau 5460, is representative of the eastern plateau. It is a massive, grayish black rock, very dense in grain. Under the microscope (Pl. XII, Fig. 1) it is seen to consist of a pilotaxitic base of crowded, minute laths (about 0.1 × 0.02 mm.) of plagioclase amongst which are interspersed pyroxene and ore, the whole being soaked with potash feldspar. In this base occur solitary phenocrysts (about 0.5 mm.) fluidally arranged of pyroxene, biotite, and pseudomorphs probably after orthorhombic pyroxene or olivine.

The only pyroxene identified is a colourless augite ($2V\gamma = 48°$, $c/\gamma = 45°$) anhedral or roughly prismatic. The pseudomorphs above mentioned consist of some chlorite mineral probably of the bowlingite-iddingsite series. It is highly birefringent and pleochroic with α = light yellowish, γ = orange or reddish brown. The same mineral enters occasionally interstitially in the groundmass, and also as reniform masses in cavities together with calcite, quartz, and sometimes opal.

The biotite (α = pale yellowish, γ = dark red brown) is always strongly resorbed, often reduced to a skeleton of ore, or else filled with ore dust and thin needles of rutile. Apatite is abundant as long, thin needles. No spinel noticed.

Because of the small size of the crystals, the composition of the plagioclase of the groundmass could not be determined; as its n_α is considerably higher than that of canada balsam, it must be rather calcic. The potash feldspar is easily identified by its low refringence.

The rock contains occasionally inclusions of quartz and potash feldspar, probably derived from a young quartz-porphyry, which crops out in the neighbourhood of Camp N 659.

The chemical composition of the rock is given in Table XIII, Col. 4. The alkalies are the mean value of two determinations (K_2O = 4.30 and 4.87 %, Na_2O = 2.93 and 2.71 %) made by I. Lundblad-Tullström and R. Blix respectively. A determination of Rb was made spectroscopically by S. Henriksson at the Central Laboratory of the Boliden Mining Company resulting in the remarkably high value of 0.14 % Rb_2O. According to the quantitative system the rock is a *monzonose* (II : 5 : 2 : 3); according to Niggli's system it is a normal m o n z o n i t i c magma type.

Spec. 944, a vesicular variety of augite-latite collected in the eastern slope of the plateau 5300, has similar mineral composition and texture as the lava 982, but in this case the phenocrysts of biotite have disappeared almost completely under formation of ore. The rock contains similar foreign inclusions as Spec. 982.

A dark gray augite-latite, Spec. 943, of different texture and slightly coarser grain appears as dikes in the effusives of the plateau 5300. This rock has a holocrystalline, microgranular groundmass of an average coarseness about 0.1 mm. (Pl. XII, Fig. 3), consisting of anorthoclase ($\perp \gamma : \alpha/(001)$ = about 9°) and minute

	1	2	3	4	5	6
	Analyses					
	933	1050	943	982	987	H46
SiO_2	43.17	45.15	55.21	55.24	56.77	61.45
TiO_2	2.47	3.54	2.35	2.18	2.38	1.37
Al_2O_3	15.14	15.13	14.83	14.95	15.09	14.36
Fe_2O_3	10.79	1.20	5.02	4.87	3.63	2.75
FeO	2.58	5.22	2.05	1.39	4.67	4.61
MnO	0.13	0.10	0.07	0.08	0.11	—
MgO	7.35	6.21	4.25	3.55	2.46	2.73
CaO	8.64	9.73	6.24	6.18	4.97	4.34
Na_2O	2.86	2.29	2.88	2.82	2.88	3.98
K_2O	1.48	6.63	4.82	4.44	3.55	3.75
Rb_2O	—	—	—	0.14	—	—
P_2O_5	0.35	1.11	0.89	1.01	0.99	—
H_2O+	2.85	1.77	0.67	2.44	1.38	0.87
H_2O-	0.79	0.13	0.55	0.77	0.28	—
C	1.50	—	—	—	—	—
	100.10	100.21	99.83	100.06	99.16	100.21

		7	8	9	10	11	12
		Norm					
		933	1050	943	982	987	H46
Q		—	—	5.32	7.62	14.14	11.25
or		8.74	37.51	28.49	27.05	20.98	22.15
ab		23.38	—	24.38	23.85	24.38	33.66
an		24.12	11.43	13.29	14.63	17.74	10.26
ne		0.43	10.48	—	—	—	—
lc		—	1.31	—	—	—	—
	Sal	56.67	60.73	71.48	73.15	77.24	77.32
di	$CaSiO_3$	6.86	7.08	4.83	3.02	0.17	4.70
di	$MgSiO_3$	5.75	5.34	4.08	2.50	0.12	2.82
di	$FeSiO_3$	—	0.83	—	—	0.04	1.64
di	$MnSiO_3$	0.24	0.18	0.13	0.14	0.26	—
hy	$MgSiO_3$	—	—	6.50	6.34	6.00	3.97
hy	$FeSiO_3$	—	—	—	—	1.61	2.30
ol	Mg_2SiO_4	8.79	7.10	—	—	—	—
ol	Fe_2SiO_4	—	1.49	—	—	—	—
ilm		4.68	6.73	4.32	2.94	4.52	2.61
hm		10.00	—	5.01	4.87	—	—
mt		1.16	1.73	—	—	5.26	3.99
tn		—	—	0.18	1.55	—	—
ap		0.84	2.62	2.11	2.39	2.35	—
	Fem	38.32	33.10	27.16	23.75	20.33	22.03
	H_2O	3.64	1.90	1.22	3.21	1.66	0.87
	cc	—	3.83	—	—	—	—
	C	1.50	—	—	—	—	—
		100.13	99.56	99.86	100.11	99.23	100.22
		III : 5 : 3 : 4 *Camptonose*	II : 6 : 2 : 2 *Vicose*	II : 5 : 2 : 3 *Monzonose*	II : 5 : 2 : 3 *Monzonose*	II : 4 : 3 : 3 *Harzose*	II : 4 : 2 : 3 *Adamellose*

	13	14	15	16	17	18
	Niggli values					
	933	1050	943	982	987	H46
qz	−34	−49	4.8	+5	+23	+24
si	100	120	166	177	191	210
ti	4.3	7.1	5.3	5.2	6.0	3.5
p	0.4	1.2	1.1	1.4	1.4	—
al	20.6	23.7	26.3	28.2	30.0	28.8
fm	49.4	38.7	35.8	32.6	35.1	34.1
c	21.4	20.4	20.2	21.1	17.9	15.8
alk	8.6	17.2	17.7	18.1	17.0	21.3
k	0.25	0.66	0.52	0.52	0.45	0.38
mg	0.51	0.63	0.53	0.52	0.35	0.41
c/fm	0.43	0.53	0.56	0.65	0.51	0.46
$\frac{alk}{al-alk}$	0.7	2.6	2.0	1.8	1.3	2.8
	Gabbroidal to gabbroidal-theralitic	Yogoitic	Monzonitic	Monzonitic	Opdalitic	Opdalitic

Spec. 933, C r i n a n i t e from Camp N627 about 22 km. E. N. E. of Yeshil-köl. Analyst: I. LUNDBLAD-TULLSTRÖM.

Spec. 1050, L e u c i t e - s h o n k i n i t e, dike in limestone 4 km. above Ali-nazar-qurghan, Qara-qash Valley. Analyst: S. PALMQVIST.

Spec. 943, A u g i t e-l a t i t e, dike in the lava plateau Point 5460 north of Lake Markham. Analyst: I. LUNDBLAD-TULLSTRÖM.

Spec. 982, A u g i t e-l a t i t e, effusive bed in the lava plateau Point 5300 north of Lake Markham. Analyst: I. LUNDBLAD-TULLSTRÖM.

Spec. 987, H y p e r s t h e n e-l a t i t e, effusive bed in the lava plateau Point 5900 north of Lake Markham. Analyst: I. LUNDBLAD-TULLSTRÖM.

Spec. H46, H y p e r s t h e n e-l a t i t e, effusive lava on the southern side of Arka-tagh at HEDIN's camp XI (1896) about lat. 36°10′, long. 87°30′. Analyst: I. LUNDBLAD-TULLSTRÖM.

laths of plagioclase together with much ore, clinopyroxene, scaly biotite, and apatite. In this base occur scattered anhedral or roughly prismatic phenocrysts (0.5—1 mm.) of colourless augite ($2V_\gamma = 49°$, $c/\gamma = 43°$), biotite (largely resorbed under formation of ore), and sparsely, dark brownish pseudomorphs after pyroxene or olivine. It contains also occasionally agglomerations of pyroxene crystals which often are associated with an isotropic mineral with low refringence, possibly opal. The chemical composition, given in Table XIII, Col. 3, is almost identical with that of Spec. 982. According to the quantitative system the rock is a *monzonose* (II : 5 : 2 : 3); according to NIGGLI's system it is a monzonitic magma type.

The lava beds which form the large plateau around the high cone 5900, differ in some respects from the lavas of the eastern plateaus. The exposed thickness of the lava amounts to only some twenty metres along the south-eastern border but increases rapidly towards the centre.

Here, the uppermost and consequently the youngest bed consists of yet-black lava (Spec. 987), a hypersthene-latite, composed of a hyaline base of brown glass with microlites of plagioclase and large phenocrysts, several millimetres in size, of glassy andesine, hypersthene, ore, sparsely augite, spinel, and a few large prisms of pale bluish apatite, entering in the proportions shown below.

TABLE XIV.

Geometrical analysis of latite, Spec. 987.

	% Vol.	% Weight.
Groundmass	77.8	72.5
Andesine (An_{37})	11.9	11.9
Hypersthene	6.1	7.9
Augite	0.2	0.3
Ore	3.8	7.2
Spinel	0.1	0.1
Apatite	0.1	0.1
	100.0	100.0

The spec. gravity of the rock is 2.65; for the plagioclase has been assumed 2.67, pyroxene 3.4, and ore 5.0, from which the spec. gravity of the groundmass has been calculated to be 2.47.

The usually idiomorphic andesine is slightly zonary built grading from An_{40} to An_{34}. Besides ordinary polysynthetic twinning to the albite law, twinning to the manebach and pericline laws is rather common. The crystals are, along the margin, almost always impregnated with minute drops of brown glass giving them a cellular or spongeous appearance (Pl. XI, Fig. 4), but even then the margin is usually perfectly sharp and rectilinear. In some cases, however, the crystals are reduced to a skeleton, being all but completely resorbed and replaced by brown glass. Similar inclusions of glass are described by BACKLUND (1923, p. 221) in phenocrysts of andesine in hypersthene-augite-andesite in the Andes.

The hypersthene is usually prismatic without terminal faces, often tapering off at the ends, and sometimes swallow-tailed, the hollow being filled with glass, thus indicating considerable corrosion. $2V_{\alpha} = 60.5°$, $\gamma - \alpha = 0.015$, corresponding to 29 mol. % $FeSiO_3$ according to HESS 1940 (42 mol. % according to WINCHELL 1927). It is often enclosed in the plagioclases and encloses itself ore and spinel, the latter then sometimes with adhering traces of biotite. Clinopyroxene occurs only very sparingly. The ore appears as crystal plates of hexagonal outline or as long rods as much as 1×0.1 mm. Remarkably common is dark violet blue or greenish blue spinel (as much as 0.3 mm. in size) sometimes with a rim of plagioclase when occurring in the groundmass.

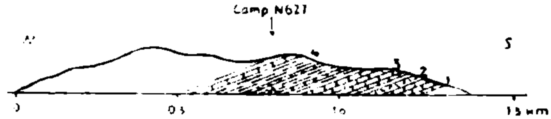
Because of the small size of the crystals, the plagioclases of the groundmass could not be more closely determined; as its refringence is distinctly higher than that of canada balsam, it must be rather calcic. There enter also abundantly minute prisms and granules of a yellowish or brown, non-pleochroic (?) primary mineral with positive elongation, high birefringence, and parallel extinction (basaltic hornblende ?).

Chemically, this rock (Table XIII, Col. 5) differs from the more basic members of the series by lower Mg and Ca, and higher Fe mainly in the ferro state, whereas in the latter ferri-iron predominates. The rock is a *harzose* (II : 4 : 3 : 3) according to the C.I.P.W. system, and represents an opdalitic magma type according to NIGGLI.

Below this bed comes another of lighter brownish gray, miarolitic tuff (Spec. 988) which is exposed to a thickness of some ten metres in a ravine west of Camp N659. This rock contains similar phenocrysts of spongeous andesine, hypersthene ($2V_{\alpha} = 61°$), clinopyroxene, ore, and spinel as the hyaline latite; the colourless, very fine-grained groundmass is holocrystalline and composed of alkali feldspar, plagioclase, ore, finely disseminated biotite, some pyroxene, and apatite. There are also larger agglomerations of ore associated with green spinel, sillimannite, and dendritically distributed biotite as well as a few large fragments of quartz and garnet, the latter surrounded by a broad aureole of some opaque substance.

Another representative of this group, more mafic and of crinanitic character, was encountered in the shape of a sill, a few metres thick, in a series of dark limestones at Camp N 627, which is situated 22 km. E. N. E. of Yeshil-köl (Fig. 30). The dark grayish black, aphanitic rock, Spec. 933, has a basaltic appearance. Under the microscope (Pl. XII, Fig. 2) it is very similar to the augite-latites Spec. 982 and 944, but contains solitary, large phenocrysts of olivine and, more rarely, augite. The

Fig. 30. Sill of crinanite in the Upper Cretaceous sequence at Camp N 627, E. N. E. of Yeshil-köl.
1 and 3, bluish gray limestone,
4, red brown calcareous shale,
2, crinanite.



holocrystalline, fluxion-textured groundmass consists of minute laths (0.2—0.3 × 0.02 mm.) of calcic plagioclase (n_α > canada balsam), interstitial potash feldspar which occasionally also appears as allotriomorphic, larger individuals with flamy extinction, clinopyroxene abundantly together with yellowish and reddish brown pseudomorphs of iddingsite, a little calcite, and numerous grains of black, opaque minerals. Apatite is rather common. The texture is mostly doleritic (in the sense of KROKSTRÖM 1932), but ophitically textured patches occur also.

The colourless, glassy olivine appears as large sub-idiomorphic crystals, 1—2 mm. in size. Its axial angle $2V_\alpha = 86°$ corresponds to 24 mol. % Fe_2SiO_4 (WINCHELL 1927). Pale yellowish and green antigorite has sometimes developed along cracks but very little ore. Some crystals are surrounded by a broad aureole of antigorite fringed by a narrow, opaque rim towards the groundmass. There are also a few fine pseudomorphs of brownish red iddingsite. The phenocrysts of clinopyroxene attain similar large size as the olivine. They have a slightly violet tinge, $2V_\gamma$ = about 48°, c/γ = about 43°.

The chemical composition of the rock is given in Table XIII, Col. 1. According to the C.I.P.W. system the rock is a *camptonose* (III : 5 : 3 : 4) with a small content of normative nepheline. According to NIGGLI's system it represents a theralitic-gabbroidal to normal gabbroidal magma type, differing from the average normal gabbroidal magmas by remarkably high *alk*. But for the rather high content of K_2O, its chemical composition agrees rather closely with the average crinanite as given by DALY (1933, p. 22). Petrographically, the rock differs from the typical crinanite by the absence or very rare occurrence of analcite and zeolites (cfr WALKER 1934).

A very curious feature in the chemical composition of this rock is its very high content of coal or hydrocarbons amounting to 1.50 % C. The character of this substance is not known. It must enter amongst the opaque, ore-like masses which occur abundantly in the rock.

Not far to the west, near the western shore of Yeshil-köl, a similar intrusion was discovered by HEDIN in Upper Cretaceous strata. The specimen (H83), which was described by HENNIG (1916) as a vitrophyric hornblende-olivine-basalt, contains phenocrysts of augite, basaltic hornblende, olivine, andesine (An_{36}), and ore. The plagioclase, which is rather sodic for a normal basalt, suggests that also this rock is of latitic character.

In Table XV and XVI the available analyses of intrusive rocks in the Karakoram, the Aghil zone, and the K'un-lun Plains have been collected. The number of analyses is still too small as compared to the very large extension of the area, to allow any conclusions concerning the consanguinity and distribution of the various magma types. The youngest granitic rocks, which are a very important element in the orogene, are represented only by some analyses of their effusive equivalents. An attempt to represent the chemical data in variation diagrams cannot present any adequate picture of the processes of differentiation because of the impossibility to distinguish at this stage the eruptives of the various magmatic cycles.

But apart from the age relation, the eruptives exhibit some distinctive chemical features in the Karakoram on the one hand, and in the Aghil—K'un-lun zone on the other. Thus, the eruptives of the latter zone are generally poorer in lime feldspar than the corresponding rocks in the Karakoram, and cluster in the III sextant of the Osann diagram, Fig. 31. In the *k-mg* diagram Fig. 32, the *k*-values of the Alpidic eruptives of the Aghil--K'un-lun zone have a tendency to increase with increasing *mg*, being distributed over a field elongated towards the N. N. E., whereas amongst the eruptives of the Karakoram zone the relation is reversed. In the rocks of the former area, which cover a rather narrow interval of *si*-variation ($100 < si < 210$), $k > 0.2$ with maximum 0.66. In the rocks of the latter area, which cover a much wider interval ($76 < si < 506$), $k < 0.3$ in all rocks the *si* of which is < 200.

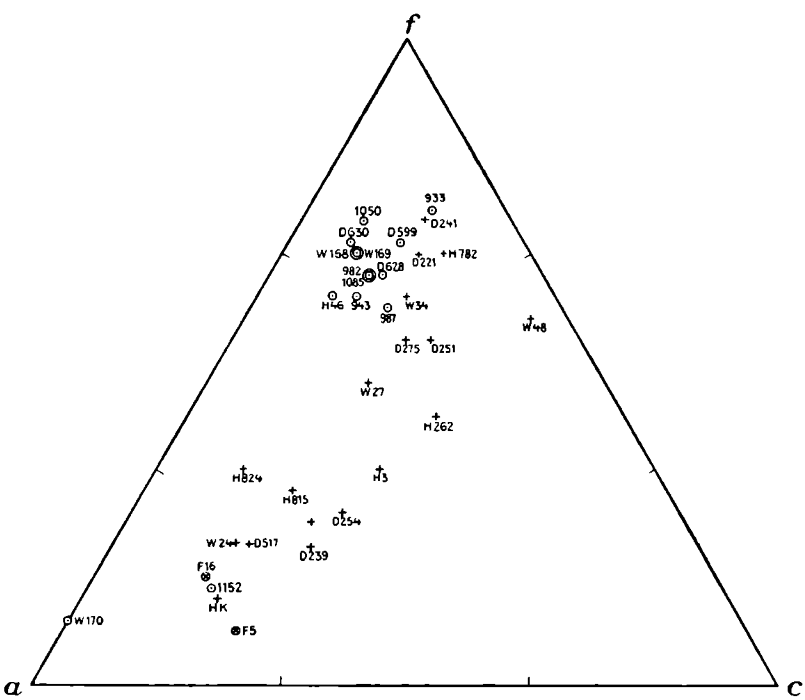


Fig. 31. Osann values of Karakoram and Chang-thang eruptives. Crosses = eruptives in the Karakoram zone; Circles = eruptives in the Aghil—K'un-lun zone.

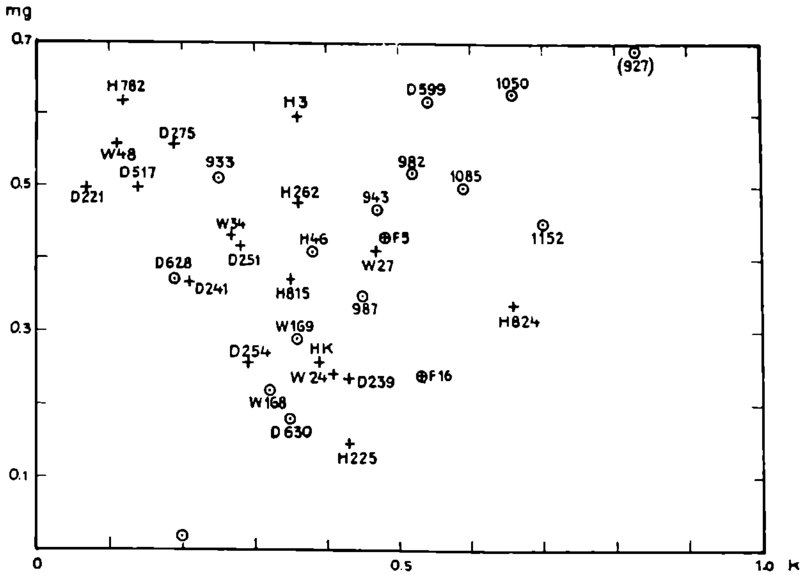


Fig. 32. k-mg diagram of Karakoram and Chang-thang eruptives (Symbols, see Fig. 31).

It is, as yet, not possible to state, to what extent this distribution is incidental, due to the magnitude of the denudation in the contrasted zones and thus reflects a vertical distribution of the various magmas, or if there is actually a change into more alkaline magmas towards the margin of the orogene. The second alternative is favoured by the apparently zonal distribution of the Late Cretaceous or Tertiary acid porphyries on the one hand, and the Late Tertiary or Pleistocene latites on the other. The significance of this alkaline element in the orogene from the magma tectonic point of view was realized by WYSS (1940, p. 411); "Wie in den Alpen die wahren Alkaliprovinzen sich erst im Verlauf der alpinen Hauptgebirgsbildung, und nur in den Schollengebieten der Vorländer und der Innensenken einstellten, so scheint auch hier im zentralasiatischen Gebirgssystem die atlantische Sippe sich in der Innensenke lokalisiert zu haben". We will return to this problem later.

A conspicuous feature of the magmatism in the Karakoram—Aghil zones is the repeated alternation of periods of simatic and sialic volcanism. Thus, the Pre-Senonian period furnished the Panjal Traps (Late Paleozoic and Triassic) and, later, the greater part of those graniticrocks in the Ladakh Range and in the Mawang-kangri, which have become more or less strongly gneissified by folding and regional metamorphism. To this group probably belong also certain gneissose granites in the Karakoram. During the Upper Cretaceous, when these intrusives had already solidified and had been laid bare by denudation, erupted in the flysch belt of the Dras, upper Indus, and the Brahmaputra valleys, huge masses of mainly basic lavas, followed by ophiolitic intrusives. Similar eruptives are also an important element in the allochtonous flysch regions with exotic blocks in southern Tibet and the Tethys-Himalaya. HEIM and GANSSER have shown (1939, pp. 184) that here the largely andesitic extrusives are older than the flysch (Upper Cretaceous), while the more basic peridotitic rocks are younger than the flysch,

TABLE XV.

Analysed Rocks from the Aghil Zone and Western Chang-thang.

	Niggli values								Osann values			Locality
Spec.	si	al	fm	c	alk	k	mg	c/fm	a	c	f	
933	100	20.6	49.4	21.4	8.6	0.25	0.51	0.43	3	5	22	Crinanite, Camp N 627.
1050	120	23.7	38.7	20.4	17.2	0.66	0.63	0.53	6	2.5	21.5	Leucite-shonkinite, Ali-nazar-qurghan, Qara-qash Valley.
D630	128	23.7	41.9	17.0	17.4	0.35	0.18	0.40	7	2.5	20.5	Tephrite, "Valle ignota", Upper Qara-qash. (ALOISI 1932).
1085	145	27.2	37.3	18.6	16.9	0.59	0.50	0.50	7	4	19	Monzonite-porphyry, Qizil-davan, Upper Qara-qash.
D628	143	26.5	39.0	18.6	15.9	0.19	0.37	0.47	6.5	4.5	19	Augite-porphyrite, "Valle ignota", Upper Qara-qash (ALOISI 1932).
W 168	169	24.6	40.2	17.3	17.9	0.32	0.22	—	7	3	20	Quartz-biotite-hornblende-diorite, N. E. of the Karakoram Pass (WYSS 1940).
W 169	176	24.9	40.8	17.0	17.3	0.36	0.29	0.40	7	3	20	Quartz-biotite-hornblende-diorite, Qara-tagh Pass (WYSS 1940).
W 170	172	36.5	16.2	2.1	45.2	0.2	0.02	0.12	27	0	3	Nepheline-syenite, Qara-tagh Pass (WYSS 1940).
943	166	26.3	35.8	20.2	17.7	0.52	0.53	0.56	8	4	18	Augite-latite, lat. 35° 25', long. 83° 0'.
982	177	28.2	32.6	21.1	18.1	0.52	0.52	0.65	7	4	19	Augite-latite, „ „
987	191	30.0	35.1	17.9	17.0	0.45	0.35	0.51	7	5.5	17.5	Hypersthene-latite, lat. 35° 21', long. 82° 47'.
D599	178	23.9	44.5	18.9	12.7	0.54	0.62	0.42	5	4.5	20.5	Pyroxene-biotite-granite, Upper Shayok (ALOISI 1932).
H46	210	28.8	34.1	15.8	21.3	0.38	0.41	0.46	9	3	18	Hypersthene-latite, lat. 36° 10', long. 87° 30'. (BÄCKSTRÖM 1900).

though not younger than the thrusting. To this period of magmatism belong also certain alkalilamprophyric rocks in the Aghil—K'un-lun zone, the tuffaceous deposits of which are embedded in the Upper Cretaceous sedimentary sequence.

At Amlang-la, south-west of Raksas-tal, the ophiolites are, according to HEIM (1939, p. 178), associated with syenodiorites, which appear as sheets several hundred metres thick in the flysch series, and thus are younger than the flysch. The syenodiorites evidently belong to the same magmatic cycle as the ophiolites, and are considered by HEIM as a pre-phase of these latter. Chemically these syenodiorites differ from the otherwise rather similar monzonitic rocks in the Loqzung Mountains mainly by the strong predominance of sodium over potassium.

In the Late Cretaceous or Early Tertiary followed wide-spread intrusions of granodiorites and hornblende-granites, accompanied by intense surface volcanism with dacitic and rhyolitic lavas. In the western Chang-thang, these lavas attained their greatest development in the south. They constitute the western extension of the

TABLE XVI.

Analysed Rocks from the Karakoram Zone.

	Niggli values								Osann values			Locality
Spec.	si	al	fm	c	alk	k	mg	c/fm	a	c	f	
W48	76	26.6	32.6	38.3	2.5	0.11	0.56	1.17	1.5	11.5	17	Gabbro, Khardung-la, Ladakh Range (Wyss 1940).
H782	113	24.3	43.4	23.8	8.5	0.12	0.62	0.55	3.5	6.5	20	Dike of basalt, Transhimalaya (Hennig 1916).
D241	141	22.2	43.0	26.1	8.7	0.21	0.37	0.60	3.5	5	21.5	Quartz-diorite, Tolti, Indus Valley (Aloisi 1932).
W34	157	26.6	39.4	20.7	13.3	0.27	0.43	0.52	6	6	18	Quartz-biotite-hornblende-diorite, Leh (Wyss 1940).
D221	150	24.6	36.5	27.6	11.3	0.07	0.50	0.75	4.5	5.5	20	Quartz-diorite, Skiriting, Indus Valley (Aloisi 1932).
D251	171	32.1	28.5	25.4	14.0	0.28	0.42	0.89	6	8	16	Quartz-diorite, Tolti, Indus Valley (Aloisi 1932).
D275	198	31.8	30.6	21.1	16.5	0.19	0.56	0.68	7	7	16	Quartz-porphyrite, Burgi-la, Skardu (Aloisi 1932).
H262	252	39.6	27.2	18.9	14.3	0.36	0.48	0.69	7.5	10	12.5	Quartz-biotite-diorite, Rung-tal, Transhimalaya (Hennig 1916).
W27	265	36.7	31.2	12.9	19.2	0.47	0.41	0.40	9.5	6.5	14	Biotite-hornblende-granite, Te-Rong Glacier (Wyss 1940).
D254	270	42.3	15.5	16.5	25.7	0.29	0.26	1.05	13.5	8.5	8	Porphyrite, Zendu, Indus Valley (Aloisi 1932).
H815	322	42.0	14.9	13.2	29.9	0.35	0.37	0.88	15	6	9	Dacit, Hlagar, Upper Indus, Transhimalaya (Hennig 1916).
H3	332	49.4	19.3	14.1	17.2	0.36	0.60	0.73	11	9	10	Gneissose biotite-granite, Tankse, Ladakh Range (Hennig 1916).
D239	354	44.2	11.2	15.3	29.3	0.43	0.24	1.37	15.5	8	6.5	Granite, Tolti, Indus Valley (Aloisi 1932).
HK	374	46	10.5	6.5	37	0.39	0.36	—	20.5	5.5	4	Hornblende-biotite-granite, Kailas, Transhimalaya (Heim 1939).
F16	378	45.3	11.4	5.9	37.4	0.53	0.24	0.51	20.5	4.5	5	Gneissose granite, Siachen Glacier (Comucci 1933).
H225	384	41.8	16.6	13.6	28.0	0.43	0.15	0.82	15	7.5	7.5	Quartz-dacite, Ngantse-tso, Transhimalaya (Hennig 1916).
W24	398	43.6	12.1	10.4	33.9	0.41	0.24	0.86	18.5	5	6.5	Biotite-hornblende-granite, Nubra Valley (Wyss 1940).
H824	409	53.2	17.9	5.4	23.5	0.66	0.34	0.30	16.5	3.5	10	Dacite, Camp H 247, Upper Indus, Transhimalaya (Hennig 1916).
D517	448	43.6	19.5	3.6	33.3	0.14	0.50	0.18	18	5.5	6.5	Quartz-keratophyre, Shu-shol, Ladakh Range (Aloisi 1932).
F5	506	48.8	5.4	9.5	36.3	0.48	0.43	1.87	20.5	7	2.5	Granitite, Siachen Glacier (Comucci 1933).

broad belt of young acid effusives, which accompanies the Transhimalaya and its northern foreland. Based on the rather large material of rock specimens collected by HEDIN, HENNIG (1916, p. 163) arrived at the conclusion that "die Dacite an die höchsten Strecken des eigentlichen Transhimalaya gebunden sind". Similar is, according to the same author (p. 155), also the distribution of the rhyolites. Although, as we have seen in the foregoing, the young acid effusives are not confined to the Transhimalaya as Hennig was led to suppose, but also occur in the Aghil zone and, sporadically, even on the K'un-lun Plains, they undoubtedly attain their greatest development within the southerly parts of the Chang-thang. Similar porphyries do, however, occur also in the Brahmaputra Valley (HAYDEN 1907, p. 63) and may be expected to appear elsewhere, where the offshoots of the youngest granites have penetrated to the surface.

The young granodiorite in the Mawang-kangri with its dike accompaniments of dacitic porphyries is evidently equivalent to the Late Cretaceous or Tertiary Kyichu granite in southern Tibet. To the same period of sialic magmatism can be referred the Tertiary hornblende-granite in the Burzil-Astor area, in Gilgit (Mc MAHON 1900), and Hindukush (GRIESBACH 1887) indicating this to be a really regional magmatic feature of the orogene. Although these intrusives often exhibit only faint traces of internal deformation or none at all, the fact that their effusives have been involved in the folding, which has deformed the latest Cretaceous formations in the western Chang-thang, proves that the effusives are older or at most contemporaneous with this period of diastrophism.

Together with the acid lavas in the Transhimalaya, typical basalts (Table XVI) are recorded at several localities by HENNIG (1916). The age of these rocks is not known.

A fairly lengthy interval of time elapsed before the next period of intense volcanism began in the western Chang-thang and continued into the Pleistocene. Like the Upper Cretaceous, so are also the Pleistocene magmas in this region of mediterranean affinity, being represented by large extrusions of latites, i. e. monzonitic and quartz-monzonitic magmas. These lavas attain their greatest development in the K'un-lun and its southern foreland and are probably widely distributed over northern Tibet. In southern Tibet, however, rocks of this type are known from one place only, *viz.* from the pass of Abuk-la (lat. 31° 17', long. 82° 42') in the Transhimalaya. As the author could ascertain on the specimen, the rock described by HENNIG (1916, p. 139) as an orthoclase-bearing basalt, is a typical augite-latite, consisting of a microgranular, very fine-grained groundmass rich in alkali feldspar, clinopyroxene, biotite, and ore, with numerous phenocrysts of augite ($2V_\gamma = 51°$, $c/\gamma = 40°$).

It is a significant fact that basaltic rocks are, as yet, unknown in northern Chang-thang, the rocks classified as basalts by earlier travellers having proved to be lati-

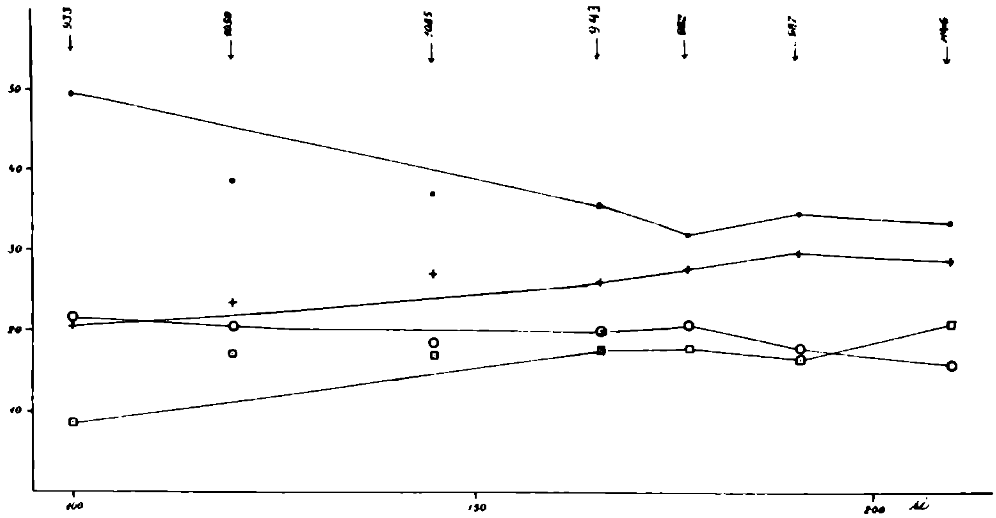


Fig. 33. Variation diagram of monzonitic eruptives in the Aghil—K'un-lun zone.

tes in all cases, when it has been possible to check the statements. Lamprophyres of kersantitic, spessartitic, and camptonitic types are, on the other hand, rather common. The latites therefore probably belong to a sequence of differentiation containing as other members lamprophyres, diorites, and monzonites which all are well represented within our region.

All these Late Cretaceous and Pleistocene rocks of mediterranean facies are closely related chemically, ranging from gabbroidal to opdalitic within an interval of *si*-variation between 100 and 210 (Table XIII and Fig. 33). The hypersthene-latite Spec. H 46, which seems to be of wide occurrence in the eastern Chang-thang, fits perfectly into the series with a chemical composition rather similar to that of the youngest and most acid member, Spec. 987, of the series in the western Chang-thang, an indication that the same petrographic province reigns also in the east and is a truly regional feature of the K'un-lun foreland. The monzonite-porphyry (Spec. 1085) and the leucite-shonkinite (Spec. 1050), entered into the diagram for comparison, are not strictly comparable to the other rocks of the potassic series because their geological position is not known; the monzonite-porphyry may belong to an earlier period of magmatism, whereas the leucite-shonkinite, because of its position in the K'un-lun proper, is more likely to belong to the younger eruptives. It differs, however, from the latites and associated rocks by its remarkably high content of K_2O (6.63 %).

A conspicuous feature in the variation diagram Fig. 33 is the small amplitude of variation of *fm*, *c*, and *alk* throughout the series whereas *al* slowly increases with

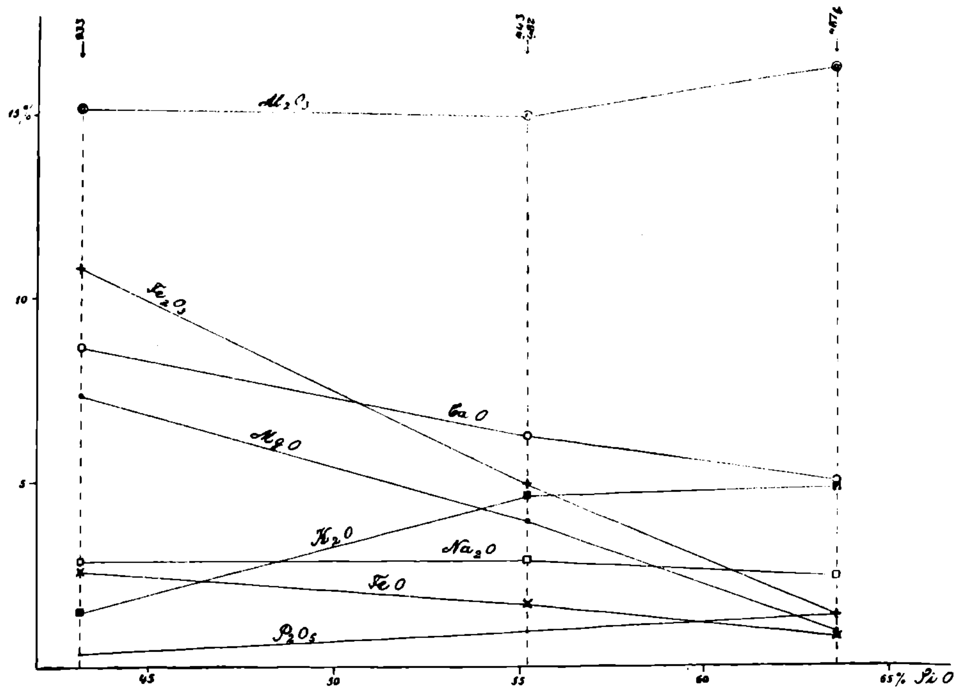


Fig. 34. Variation diagram of the latite series, K'un-lun Plains.

increasing *si*. Only the most mafic member, the crinanite, exhibits a strong increase in *fm* and decrease in *alk*. But if we restrict ourselves to consider only those members of the suite which are distinctly associated in the field and evidently are products of differentiation of the same magmatic body, the relation depictured in the diagram Fig. 34 is revealed. We have here included only the specimens 933, 943, 982, and the groundmass of 987, rocks the chemical composition of which because of their fine grain and the sparseness or absence of phenocrysts should not differ considerably from the corresponding magmatic liquids. Because of the very close agreement between the analyses 943 and 982, and the fact that the former rock represents merely a hypabyssal facies of the effusive 943, the mean value of these two analyses has been used. The lava 987 is not directly comparable to the other rocks of the series because its phenocrysts of andesine, hypersthene, ore, and spinel clearly are instable in their present setting and are the relicts of an earlier magmatic stage. But eliminating this element according to the geometrical analysis Table XIV, the remaining hyalopilitic base, which constitutes 72 % of the rock, should represent a stage on the liquid line of descent. The composition of the groundmass thus obtained is given in the first column of Table XVII, whereby the composition of the plagioclase and the hypersthene has been taken from Tröger's tables (1935) and the ore is assumed to consist of equal parts of ilmenite and magnetite.

TABLE XVII.

Actual and calculated composition of the groundmass of the hypersthene-latite, Spec. 987.

	987 (base)	
	Actual comp.	Calc. comp.
SiO_2	63.5	63.5
TiO_2	0.7	2.1
Al_2O_3	16.2	14.7
Fe_2O_3	1.4	0.9
FeO	0.8	1.1
MgO	0.9	1.5
CaO	5.0	4.5
Na_2O	2.4	2.8
K_2O	4.8	6.8
P_2O_5	1.4	1.4
H_2O+	1.9	
	99.1	99.3

The hypersthene-latite Spec. H 46 contains, according to the description of Bäckström (1900), scattered large phenocrysts of orthorhombic pyroxene and plagioclase in an abundant, hyalopilitic base, *i. e.* it is an effusive of similar inhomogenous type as the hypersthene-latite 987, and therefore not directly comparable to the aphanitic members of the series. In this case, the quantitative mineral composition of the phenocryst fraction is not given and the composition of the groundmass cannot be calculated. The analysis could therefore not be used in this connection.

The analysis 933, the mean values of 943 and 982, and the groundmass of 987 exhibit a very simple additive relation to each others in the diagram Fig. 34. It has the form of an ordinary addition and subtraction diagram in which the composition of one member of the series is determined by the composition of the others. Thus, based on the primary analyses 933 and 943/982, the composition of a magma with the ordinate 63.5 % SiO_2 turns out as shown in the second column of Table XVII. Apart from the lower amount of Al_2O_3 and higher K_2O, the composition of this magma corresponds tolerably well to the composition of the groundmass of the hypersthene-latite. A magma of this composition may therefore originate by subtracting from the augite-latite material of the composition of analysis 933 to an amount of 42 %, *i. e.* 42 % of the augite-latite has to crystallize, the separated crystal fractions having the composition of analysis 933. The fact that such a rock, a crinanite, is actually present in the rock association, is in favour of a magmatic development of the nature outlined above.

But it is also evident from the very fine-grained texture of the crinanite, which contains only scattered larger phenocrysts of olivine and pyroxene, that this rock cannot represent an agglomeration of crystals settled during a process of crystallization. The crystals once separated must have largely melted during a later stage, and finally the melt has been subjected to rapid cooling during the process of intrusion.

The Late Cretaceous simatic magmatism in the Karakoram and the western Chang-thang was accompanied by upheaval, regression of the sea, and considerable denudation, as shown by the large conglomerates in the Upper Cretaceous sequence in the latter region. During the later part of the Upper Cretaceous, several transgressions are registered on the K'un-lun Plains, indicating resumed discontinuous subsidence which ended with the deposition of the very thick, littoral and fluviatile upper flysch. In this stage we must place the youngest granitic magmatism with its large extrusions of acid lavas especially along the Transhimalaya. Then followed upheaval of that great part of the crust which is enclosed between the Transhimalayan foredeep in the south and the Paleocene parageosyncline along the northern side of the K'un-lun, an upheaval amounting to some 6,000 m. since the last marine regression at the end of the Eocene or slightly later. This tectogenesis released disjunctive forces and resulted in the formation of ruptures and horsts discordant to the ancient tectonic trend lines. To its later stage are ascribed the large outbursts of young monzonitic magmas along the northern border of the orogene.

The Post-Paleozoic magmatic development of the Karakoram and the western Chang-thang reminds in some respects of the Post-Paleozoic magmatism in the southern Andes (BACKLUND 1923) and in the North American Cordilleras. During the Upper Triassic, the Cordilleran geosyncline was divided into two sequent geosynclines: the Rocky Mountains and the Pacific (CRICKMAY 1931, p. 72). In the Pacific or Nevadian geosyncline (STILLE 1940), mainly basic lavas (basalts, gabbros, serpentines) began to emerge at the end of Lower Jurassic time and accumulated intermittently to great thickness during the Middle and Upper Jurassic. Then followed, at the end of the Jurassic, the Nevadian folding with its enormous intrusions of granodioritic magmas. A second paroxysm followed during the Middle Cretaceous and, later, others in the Canadian and Alaskan Cordilleras.

In the Rocky Mountains, on the other hand, these periods of folding and magmatism are only slightly in evidence or non-existent; here, the first and dominant alpinotypic folding, the Laramide Revolution, took place at the end of the Cretaceous, culminated at the beginning of the Tertiary, and was followed, locally, by strong magmatism. These eruptives were, according to STILLE (1940, p. 264) generally not synorogenic, but represent allochtonous magmas coming from the west. They consist to a considerable part of monzonites, quartz-monzonites, and alkaline rocks; the occurrence also of diorites and granodiorites of similar type as those of the pacific zone, point, however, at a close genetic relationship to these latter. According to LINDGREN (1933) and STILLE, the magmatic activity migrated eastward from the Pacific zone as large subcrustal currents, reaching the eastern border of the Cordilleran system at the end of the Cretaceous.

APPENDICES

APPENDIX A

JUNGPALÄOZOISCHE KORALLEN VON SVEN HEDINS ZENTRALASIEN-EXPEDITION 1932

von FRANZ HERITSCH, Graz.

Herr Dozent Dr. ERIK NORIN übersandte mir aus dem bei der letzten Expedition SVEN HEDINS aufgesammelten Materiale paläozoischen Alters eine Reihe von Gesteinsstücken, welche Korallen, Bryozoen und Fusuliniden enthalten. Die Fusuliniden hat Dr. FRANZ KAHLER (Klagenfurt), die Bryozoen Dr. KARL METZ (Leoben) zur Bearbeitung übernommen. Das Ergebnis meiner Bearbeitung der Korallen lege ich hiemit vor.

Es ist mir eine ausserordentliche Ehre, für das grosse Werk, SVEN HEDINS letzte grosse Zentralasien-Expedition wiederum darstellt, ein kleines Bausteinchen beitragen zu dürfen.

Ich gebe in den nächsten Zeilen die Übersicht des mir übersandten Materiales der verschiedenen Fundpunkte:

A) Lokal. 77, 12. Oktober 1932. Chutgar; geograph. Breite = 34° 34^{m}, geograph. Länge = 80° 32^{m}. Ein niedriger Hügel, ohne festes Gestein, aber mit Kalkschutt bestreut. Von hier stammen nur Fusuliniden und Bryozoen.

B) Lokal. 83, 5. November 1932. 17 Kilometer östlich des Sees Dyap-tso; geograph. Breite = 34° 11^{m}, geograph. Länge = 79° 58^{m}. Dieselbe Kalksteinformation wie Lokal. 80, von welcher mir keine Proben vorliegen, auch hier mit Quarziten verbunden. Von hier stammen Bryozoen und Fusuliniden.

C) Lokal. 79, 24. Oktober 1932. nördlich von Tashliq-Köl. Es liegen Bryozoen vor.

D) Lokal. 78, 24. Oktober 1932. südlich von Tashliq-Köl; geograph. Breite = 34° 38^{m}, geograph. Länge = 80° 39^{m}. Zwischen Kuen-Lun im Norden und Karakorum-Hedin-Gebirge im Süden. Von hier stammen Bryozoen und Korallen *(Protomichelinia microstoma* YABE et HAYASAKA, *Amplexus sp., Palæosmilia sp.)*.

E) Probe 1124, 21. Oktober 1932. 5 Kilometer östlich vom Nordende des Horpa-tso. Grauer Kalk mit sehr dicken (bis zu 15 mm im Durchmesser haltenden) Krinoidenstielen. Im Permkalk des zentralen Mittelmeeres sind solche dicke Krinoidenstielglieder sehr verbreitet, besonders im unteren und mittleren Perm.

F) Probe 1115. 20 Kilometer östlich von Horpa-tso; geograph. Breite = 34 ° 36^{m}, geograph. Länge = 81 ° 18^{m}. Nach Mitteilung Dr. NORINS ist es wahrscheinlich ein mesozoischer Kalkstein. Der graue Kalk enthält ausser Krinoidenstielgliedern keine Versteinerungen. Er kann mesozoisch sein, doch ist ein paläozoisches Alter durchaus nicht ausgeschlossen.

G) Probe 1065, 16. November 1932. Maliq-shah, Karakorum; geograph. Breite = 35° 58^{m}, geograph. Länge = 78° 0^{m}. Hieher gehört ein grauer Kalk mit Bryozoen und ein grauer Kalk mit Krinoidenstielgliedern und mit losen Täfelchen von Krinoidenkelchen. Es handelt sich wohl um sicheres Palaeozoikum.

H) Probe 854. Nordgehänge des Chili-tagh im Tian-schan, etwa südlich von Utsch-Turfan; geograph. Breite = 40° 30^{m}, geograph. Länge = 79° 10^{m}. Geröll von Kalkstein, der die Kuruk-üssüm Schichten Gröbers überlagert. In dem hellen Kalk liegt die Koralle *Wentzelella subtimorica* HUANG.

I) Probe 858. Geröll aus dem Flussbett von Zizran-bulaq, südl. Tien-shan, Breite = 40° 23^{m}, geogr. Länge = 78° 19^{m}; heller Kalk mit *Stylidophyllum denticulatum*, HUANG.

K) Probe 1092, 3. Oktober 1932. Aus dem Loqzung Gebirge beim Lager N 701 geograph. Breite 34° 50^{m}, geograph. Länge 79° 40^{m}. Es liegt die Koralle *Tetrapora halysitiformis* YOH vor.

Stylidophyllum denticulatum HUANG.

Tfl. XIII, Fig. 1, 2, 7. — Tfl. XIV, Fig. 1, 4, 5. — Tfl. XV, Fig. 1—17.

Stylidophyllum denticulatum HUANG, 1932, S. 73, Tfl. VII, Fig. 1a—c.

Die Koralle trägt die Bezeichnung: Spec. 858, Geröll aus dem Flussbett von Zizran-bulaq beim Lager N 565.

„Der Fundort liegt am Nordfusse der Kette, welche die Ebene von Chong-talas im Süden begrenzt. Eine weitverbreitete, mächtige Formation von roten, spätkarbonischen Sandsteinen wird bei der Quelle von Zizran-bulaq von einem weissen Kalkstein mit Horizonten, die fast ausschliesslich von Crinoiden-fragmenten und Kalktrümmern bestehen, konkordant überlagert (Känkerin-Kalkstein von GRÖBER). Von hier stammt wahrscheinlich der weisse Kalkgeröll, Spec. 858. Darüber folgt eine Reihe von schwarzen und dunkelgrauen Kalksteinen und Kalkschiefern (Die Baliklіq Reihe)." (NORIN).

Mir liegt ein fabelhaft schön erhaltener, fast vollständiger Korallenstock vor. Er stammt wohl aus einem etwas tonigen Sediment, vielleicht aus einem tonigen Kalk. Der Stock hat eine bräulich-gelbe Farbe. Wie die Abbildung Fig. 1 auf Tafel XIV zeigt, ist der Querschnitt dickpilzförmig. Der Stiel des Pilzes ist sehr kurz. Die Grössenmasse des abgebildeten Längsschnittes sind folgende:

grösste Breite = 98 mm,
grösste Höhe = 60 mm.

In der Abbildung bedeuten die gestrichelten Linien die Lage der Columellen.

Der Stock ist mit Ausnahme der Oberseite von einer Epithek umgeben, welche eine andere Masse ist und eine andere Stellung im Bau der Koralle hat als die Mauern, welche die einzelnen Koralliten von einander trennen. Es ist leider nicht gelungen die Epithek in einem Dünnschliff zu erfassen, weil ja der Anfertigung von Dünnschliffen auch durch die Notwendigkeit, möglichst grosse Teile der Koralle zu erhalten, eine enge Grenze gesetzt war.

Von oben gesehen hat der Stock einen polygonalen Umriss, mit folgenden Grössenverhältnissen:

grösste Länge = 13 mm,
grösste Breite = 9.5 mm,
grösste Höhe = 6.0 mm.

Auf der Unterseite misst man:

grösste Länge = 13.5 mm,
grösste Breite = 10.0 mm.

Man vergleiche dazu die Abbildungen auf Tafel XIV, Fig. 1.

Der massive Korallenstock besteht aus prismatischen, recht unregelmässig polygonalen Koralliten, deren Durchmesser um 10 mm liegt. Die Oberseite und, weniger schön, die nur unbedeutend entwickelten seitlichen Flächen zeigen die K e l c h e der Koralliten (Tfl. XIII, Fig. 1). Jeder Kelch zeigt eine randlich flach geneigte und dann steil in die Tiefe sinkende Bodenfläche; im Zentrum ist der Kelchboden wiederum ganz flach und weist im Mittelpunkt selbst den schmalen, steil aufragenden Knopf der Columella auf. Zahlenmässig gliedert sich der Kelchboden in folgender Weise:

bei 9.8 mm Gesamtdurchmesser — 3.1 mm breite, randliche flache Neigung — dann der steile Abstieg und der flache Boden im Zentrum von 3.6 mm Durchmesser und dann wieder der flache randliche Teil von 3.1 mm Breite;

bei 12.1 mm Gesamtdurchmesser sind die entsprechenden Zahlen 3.4 : 5.3 : 3.4 mm.

Auf den steilen Gehängen der Kelchböden treten meist die Septen als scharf markierte Rippen hervor. Das ist nicht oder nicht so scharf der Fall auf den flach geneigten Partien der Kelchböden. Die Kelche sind von einander durch Mauern getrennt, deren Verlauf auf der Oberfläche des Stockes nicht immer im ganzen Umkreis jedes Koralliten zu verfolgen ist. Wo die Mauern deutlich sind, bilden sie zwischen den Koralliten recht gut markierte Kämme. An vielen Stellen ist auf der Oberfläche des Stockes in der Nähe der Mauern das Blasengewebe zu sehen.

Die U n t e r s e i t e d e s S t o c k e s (Tfl. XIV, Fig. 1) ist recht flach. Annähernd erhebt sich der Kegel des Stieles des „Pilzes". Dieser Teil ist, wenn er auch nicht das Zentrum der Unterseite darstellt, doch der Mittelpunkt für die Skulptur der Unterseite. Es sind hier zwei Arten von Skulpturelementen vorhanden:

a) Über die Unterseite verlaufen annähernd konzentrische Runzeln runzelartige, meist flache Falten, welche beide nur eine geringe Höhe haben. Sie sind 1 bis 2 mm, selten mehr als 3 mm breit. Die einzelnen Runzeln oder Falten lassen sich nicht über längere Strecken durchverfolgen, da sie oft in einander übergehen. Es liegt daher nicht volle Parallelität sondern nur ein im grossen und ganzen konzentrischer Verlauf der Runzeln und Falten vor.

b) Das zweite Skulpturelement der Unterseite ist eine radiale Streifung, deren Zentrum der Stiel ist. Von der Spitze des Stieles läuft die Streifung herab und verbreitet sich, im Allgemeinen radial, im Detail aber vielfach gewunden, über die ganze Fläche der Unterseite bis zu deren äussersten Rand. Leider sind alle Randteile so stark abgewetzt, dass man nicht sagen kann, wie die feine Streifung gegen die Region der Kelche endet. — Die radiale Streifung ist sehr fein; es kommen 3 bis 4 feine Streifen auf 1 mm Breite. Jeder Streifen ist flach und auf beiden Seiten durch eine scharfe, sehr steile und daher sehr schmale Furche begrenzt. Die infolge des radialen Ausstrahlens der Streifen nötige Vermehrung der Streifen geschieht durch Teilung.

Über die beiden einander etwa unter einem rechten Winkel kreuzenden Skulpturen der Unterseite erheben sich die „Kratere der Dornen". Über ein ebenes Stück der Unterseiten oder über deren flache Runzeln oder Falten erheben sich Formen, welche man am besten mit einem Maar vergleichen kann; oder es könnte bei steileren Formen der Vergleich mit dem Muschelkrebs *Balanus pictus* aus dem Miozän herangezogen werden. Ein äusserer scharf markierter Wall — wo er gut erhalten ist, immer sehr deutlich von der Umgebung abgetrennt, obwohl die Radialstreifung über ihn hinaufsteigt — umgibt eine zentrale Senkung, welche durch ihre Tiefe immer die Senkung des Walles übertrifft. HUANG hat diese Erhebungen auf der Unterseite Dornen („spines") genannt. Der Name scheint mir sehr unzutreffend zu sein; man könnte eher Pustel sagen. Die Absenkung vom Oberrande des Walles zum „Kraterboden" der Pustel geschieht sehr steil, sie kann sogar überhängend sein. Die Pusteln haben folgende Durchmesser: meist 1 bis 1.5 mm, selten 2 mm, sehr selten grösser als 2 mm; meist sind sie annähernd kreisförmig, seltener länglich; bei einem Exemplar konnte 4 mm Länge und 1 bis 1.5 mm Breite gemessen werden. Wenn die Pusteln in einer den Runzeln parallelen Reihe stehen, sind sie 5 bis 6 mm von einander entfernt — diese Anordnung auf einer Runzelreihe ist aber nicht häufig. Wenn die Pusteln nicht reihenmässig angeordnet sind, kann ihre Entfernung von einander auch mehr als 12 mm betragen. — Die Kratere der Pusteln sind fast immer hohl. Sehr vereinzelt sieht man sie von einer dichten, krystallinen Kalzitmasse erfüllt, welche bei der Betrachtung mit der Lupe keine deutliche Struktur zeigt — leider war die Untersuchung dieser Kalzitkolben u. d. M. nicht möglich, da die Herstellung eines Dünnschliffes nicht gelang.

Unterseiten von ähnlicher Beschaffenheit sind bei lonsdaleiden Korallen schon bekannt gemacht worden. Die Unterseite der *Polythecalis frechi,* welche VOLZ als

Lonsdaleia frechi aus dem Perm von Sumatra beschrieben hat, ist mit einer derben, radial gestreiften „Epithek" bedeckt, welche nach unten zahlreiche dünne, lange und hohle Stacheln entsendet. Nach HUANG (1932) hat *Polythecalis chinensis* GIRTY aus dem Chihsia-Kalk von China eine dicke „Epithek". *Polythecalis multicystosis,* ebenfalls aus dem Chihsia-Kalk von China, hat auf der flachen Unterseite eine dicke „Epithek", welche zahlreiche hohle Dornen (spines) trägt (dazu HUANG, 1932, Tfl. X, Fig. 8. YOH und HUANG, 1932, Tfl. VII, Fig. 1).

Ich habe versucht, der Frage der „Dornen" näher zu treten, doch haben die Schliffe kein sicheres Ergebnis gezeitigt, da sie nie mit Sicherheit die richtigen Stellen getroffen haben — es mussten ja Schliffe parallel zur Mauer und zwar in deren obersten Lagen sein.

Die Frage konnte aber auf einem anderen Wege gelöst werden. Der Korallenstock wurde in zwei annähernd gleich grosse Trümmer zerschnitten; es entstanden so zwei grosse Flächen mit Längsschnitten der Koralliten (Tfl. XIII, Fig. 2). An der Kante dieser Fläche zur Unterseite wurde an einer Stelle ein kleiner „Dorn" ausgezeichnet angeschnitten. Man sieht dort mit aller Klarheit, dass sich über der Einstülpung des „Dornes" die Columella erhebt, welche im ersten Anfang eine dicke Beschaffenheit (etwa wie bei *Lithostrotion*) hat. Auf diese Beschaffenheit des untersten Teiles der Columella werde ich bei der Besprechung des Querschnittes des Stieles des Pilzes noch zurückkommen.

Bezüglich des W a c h s t u m e s d e s K o r a l l e n s t o c k e s sei auf die Fig. 1 auf Tfl. XIV verwiesen. In dieser Figur ist die Fläche dargestellt, welche durch die Zerschneidung des Stockes in zwei grosse Trümmer geschaffen wurde. In der Figur ist die Lage der Columellen durch kleine Striche markiert. Man sieht wie die Koralliten von der Unterseite ausgehen und aufwärts streben.

Die M a u e r, mit welcher die einzelnen Koralliten an einander grenzen (das ist die Epithek bei HUANG) scheint in sehr charakteristischer Weise dick gezähnt zu sein. Sie kann scheinbar stellenweise verschwinden — das ist wenigstens der Eindruck, den die Betrachtung der Oberfläche des Stockes gibt. Diese Verhältnisse wurden in Dünnschliffen untersucht, welche in der Struktur der Mauer und deren Zähnung sehr interessante Strukturen aufzeigen.

a) Die Mauer erscheint zweiteilig (Tfl. XV, Fig. 1—4). Im Inneren ist eine Reihe von kreisförmigen oder unregelmässig krummlinig begrenzten oder ganz unregelmässig gestalteten oder eckigen Körpern zu sehen, welche im gewöhnlichen Lichte dunkler als die andere Mauer sind und im polarisierten Lichte sich auch sehr deutlich von dem anderen Bestande der Mauer abheben; diese Körper hängen entweder mit einander durch dünne oder dicke Verbindungsbalken zusammen oder sie haben keine Verbindung mit einander. Die kleinen Körperchen haben innerlich kein Gefüge — wenigstens ist ein solches auch bei starken Vergrösserungen des Polarisationsmikroskopes nicht erkennbar. Die Körperchen sind vielmehr gleichmässig dicht aus Kalzit aufgebaut.

b) An diese zentralen Körperchen legt sich (Tfl. XV, Fig. 1—4) kalzitische Substanz von heller Farbe. Die lichten Teile der Mauer sind immer ganz scharf vom dunklen Kern abgesetzt. Die lichte Substanz bildet auch die Zähnchen (denticles bei HUANG).

Die dunklen Kerne innerhalb der lichteren Substanz entsprechen den Verkalkungszentren von OGILVIE-GORDON.

HUANG beschreibt von *Stylidophyllum denticulatum,* dass die gezähnte Mauer gelegentlich verschwinden kann. Diesbezüglich habe ich folgende Feststellungen machen können:

1) Die Abbildung Tfl. XV, Fig. 7 zeigt fast vollständig das für *Stylidophyllum* bezeichnende, das normale Verhältnis. Es stossen drei Koralliten an einander. Im Treffgebiete der drei Mauern findet eine teilweise Auflockerung oder Auflösung der Mauern statt, während sie sonst ganz dicht sind. Es treten Hohlräume in den Mauern auf, welche mit Sediment gefüllt werden, also während des Lebens offen gewesen sein mussten. An die Mauer lehnt sich als äusserste Zone des Aufbaues die Region der Blasen an.

2) Auch in der Abbildung Tfl. XV, Fig. 6 stossen drei Koralliten an einander. Die drei Mauern sind nicht nur im Treffpunkte aufgelöst, sondern es herrscht auch auf der Strecke zwischen zwei Treffregionen dieselbe Auflockerung. Es sind mehrere Züge von Mauern vorhanden, aber jeder Zug hat seine eigenen Verkalkungszentren und jede einzelne Mauer ist von der nächsten durch Hohlräume getrennt.

3) In der Abbildung Tfl. XV, Fig. 8 berühren sich fünf Koralliten. Die Mauern sind nicht nur in den Regionen der Eckpunkte aufgelockert, sondern dasselbe ist der Fall auf den Strecken der Verbindungsstränge; hier aber spriesst ein junger Korallit (an der einen Längsseite der Abbildung, mit dem kleinen Durchmesser) auf.

4) Die Abbildung Tfl. XV, Fig. 9 zeigt dieselben Verhältnisse mit dem Beginn der Auflösung der Mauer dort, wo ein junger Korallit aus dem Blasengewebe eines grossen Koralliten aufspriesst.

5) Die Abbildung Tfl. XV, Fig. 5 zeigt die Auflösung der Mauer neben einem aufspriessenden jungen Koralliten. Die Mauer ist hier ersetzt durch ein der normalen Ausbildung gegenüber dickeres Blasengewebe; dieses Gewebe ist in der Richtung entgegengesetzt dem kleinen Koralliten mit kleinen Dornen auf der Konvexseite der Blasen ausgezeichnet.

Die obigen Beobachtungen sind an zwei über einander von einem Stück herabgeschnittenen Querschnitten gemacht, welche etwa 8 mm von einander entfernt sind. Im Allgemeinen gilt die Gesetzmässigkeit, dass die Auflösung oder Auflockerung der Mauern nur dort eintritt, wo drei Koralliten an einander stossen oder wo ein neuer Korallit aufspriesst. Wenn die Koralliten die Grösse der erwachsenen

Formen erlangt haben, sind die Mauern ganz einheitlich und es gibt dann keine Lücken in der Auflockerung in der Umrandung der Koralliten.

Leider sind die Verhältnisse der lonsdaleiden Korallen noch viel zu wenig bekannt, um diese Eigenschaft der ontogenetischen Entwicklung phylogenetisch auswerten zu können.

Die transversalen Dünnschliffe zeigen vier Zonen des Aufbaues (Tfl. XIII, Fig. 7, Tfl. XIV, Fig. 4):

a) die Columella,

b) die intermediäre Area zwischen der Columella und den inneren Enden der Septen erster Ordnung,

c) die Zone der Septen = die Zone des Dissepimentes,

d) die Blasenzone als Randzone, das ist also die periphere Zone.

Die Columella ist dünn; ihre durchschnittliche Breite liegt um 2 mm, geht aber auch unter diesen Betrag herab (Zahlen später!). Die Columella besteht aus becherförmigen Tabellæ und einer kleinen Zahl von radial gestellten Lamellen.

Der Bau der Columella ist im Mikroskop recht verschiedenartig. Das drückt sich z. B. in der Medianlamelle aus, denn diese kann sehr deutlich entwickelt sein (Tfl. XV, Fig. 11, 14); die Medianlamelle kann etwas unklar im Detailbild der Columella sein (Tfl. XV, Fig. 10, 13, 15; von diesen hat Fig. 13 keine stereoplasmatische Verdickung); die Medianplatte kann fehlen, obwohl der Bau der Columella symmetrisch ist (Tfl. XV, Fig. 16); in einem Falle (Tfl. XV, Fig. 17) ist die Columella ganz unsymmetrisch und die Lage der Medianplatte ist ganz unsicher. Bei fast allen Columellen ist die stereoplasmatische Verdickung sehr bedeutend. Meist ist sie so entwickelt, dass sie das Bild des lonsdaleiden Säulchens stört. Im polarisierten Lichte stellt sich die stereoplasmatische Verdickung als Anlagerung an die dunkleren Tabellæ und Lamellen dar, welche beide immer dunkle, feine Linien im Dünnschliff sind. Der stereoplasmatische Kalzit liegt immer mit der c-Achse senkrecht oder annähernd senkrecht auf den Tabellæ und Lamellen. Das ist derselbe Bau, wie er die Septen beherrscht.

Die bei den lonsdaleiden Korallen so häufige Verbindung des Gegenseptums mit der Columella ist hier nur einmal zu sehen (Tfl. XV, Fig. 12).

Die Septen sind mässig dick und gewöhnlich in zwei Ordnungen entwickelt. Die Septen zweiter Ordnung sind durchaus nicht überall vorhanden. Häufig liegt der Fall vor, dass sie zwischen zwei Septen erster Ordnung entwickelt sind und daneben aber fehlen. Der Unterschied in der Länge der Septen erster und zweiter Ordnung ist nicht gross.

Häufig sind die Septen nicht gerade sondern gebogen oder auch geknickt. Die Septen bestehen immer aus einem dunklen Innenfaden — das entspricht dem sogenannten primären Mauerblatt — und einer ebenso dünnen Umhüllung aus einer hellen, kalzitischen Substanz.

Die Zahl der Septen erster Ordnung wird von HUANG mit 16 bis 22 angegeben. Ich machte folgende Beobachtungen:

Durchmesser des Koralliten	Durchmesser der Septenzone	Durchmesser der Columella	Zahl der Septen erster Ordnung
10.4 mm	7.8 mm	1.0 : 1.7 mm	17
9.8 : 11.6 mm	6.3 mm	1.6 : 1.8 mm	16
8.1 : 14.2 mm	8.1 : 8.2 mm	1.7 : 2.0 mm	16
8.6 : 12.1 mm	6.1 : 6.8 mm	1.7 : 2.0 mm	18
8.1 : 9.9 mm	6.1 : 6.2 mm	1.5 : 1.9 mm	17

Die Septen erster Ordnung enden fast immer, bevor sie die Columella erreichen. Zwischen der Columella und den inneren Enden der Septen besteht daher fast immer eine Respektdistanz; nur ein Septum, das Gegenseptum, kann in die Columella fortsetzen, wenn die Koralle erwachsen ist.

Wenn die Septen zweiter Ordnung überhaupt entwickelt sind, so messen sie die Hälfte oder zwei Drittel der länge der Septen erster Ordnung.

Ziemlich häufig sind sehr kurze Septen — eigentlich mehr Septaldornen als Septen dritter Ordnung — entwickelt, welche sich zwischen die anderen Septen mehr oder weniger regelmässig einschalten. Diese Septen „dritter Ordnung" sind kaum von den Dornen zu unterscheiden, welche auf den konvex nach Innen gerichteten Bögen des Blasengewebes liegen.

D i s s e p i m e n t ist zwischen den Septen zahlreich vorhanden. Es ist im äusseren Teil der Septenzone dichter angeordnet. HUANG meint, dass das Dissepiment als Aussenrand der Septenzone und als deren Abschluss eine falsche (innere) Mauer bilden könne. Ich habe ganz selten beobachtet, dass dort durch die Anlagerung von ganz wenig stereoplasmatischer Substanz eine leichte Verdickung entstehen kann, welche im Dünnschliffbild nur wie ein Schatten an der Grenze erscheint. Aber mit den schönen inneren Mauern, welche manche *Lonsdaleidæ* oder besonders die typischen Arten von *Caninia* zeigen, kann sich die Erscheinung bei dem mir vorliegenden *Stylidophyllum* nicht vergleichen.

Die B l a s e n z o n e ist in sehr hervorragender Art entwickelt. Sie nimmt beiläufig ein Drittel des gesamten Durchmessers des Koralliten ein; nie erreicht sie die Hälfte des Durchmessers. Sie wird von zahlreichen regelmässigen Blasen gebildet, welche konvex nach Innen angeordnet sind. An der Konvexseite von vielen Blasen — nicht aber von allen, wie HUANG schreibt — sind dornartige Zähnchen vorhanden. Diese Zähnchen mögen in den Jugendzuständen der Koralle einmal Septen gewesen sein; doch spricht gegen diese Deutung der Umstand, dass sie viel zahlreicher als die Septen sind und durchaus nicht immer deren Lage im Querschliff entsprechen.

Durch den halben Stiel des „Pilzes" (durch die andere Hälfte, als in Tfl. XIII, Fig. 2, Längsschnitt, abgebildet wurde) wurde ein Querschliff gelegt (Tfl. XV, Fig. 17). Der Durchmesser des einzigen, in diesem Dünnschliff fast vollständig erhaltenen Koralliten ist 8.0 mm, der grössere Durchmesser der Columella beträgt 1.6 mm. Die Zahl der Septen, welche in der Nähe der Columella enden, beträgt 17; die meisten dieser Septen erster Ordnung erreichen die Mauer. Die Septen zweiter Ordnung sind sehr kurz. Es ist nur sehr wenig Blasengewebe vorhanden. Die Mauer ist scharf ausgeprägt.

Es ist nicht nur das fast vollständige Fehlen des Blasengewebes, das den Querschliff fremdartig dem Bilde der Koralle gegenüber erscheinen lässt. Der zweite Hauptunterschied liegt im Bau der Columella. Diese ist nach der Art der Säulchen von *Lithostrotion* fast massig gebaut. Das mag den noch zu erbringenden Hinweis an die Nähe zukünftiger Studien rücken, dass von *Lithostrotion* zu *Lonsdaleia* eine Brücke führt.

Der Längsschliff (Tfl. XIV, Fig. 5) ist nicht günstig getroffen worden. Die Columella erscheint in ihm aufgebaut aus becherförmigen Tabellæ und einigen nicht durchgehenden Lamellen, ohne dass dabei die Medianlamelle deutlich zu erkennen wäre. — Sonst ist im Längsschliff nichts Bemerkenswertes zu sehen. Sehr häufig sind den konvexen Seiten der Blasen kleine Dornen aufgesetzt.

Ich führe in den folgenden Zeilen den Vergleich mit den aus dem Perm beschriebenen Arten von *Stylidophyllum* durch.

Stylidophyllum arminiæ Felser, 1937, aus dem oberen Schwagerinenkalk der Karnischen Alpen, hat eine geringere Zahl von Septen und eine Columella ohne Medianlamelle.

Stylidophyllum chaoi Huang, 1932, hat folgende Unterschiede: Der Durchmesser ist viel bedeutender, die Columella aber kleiner; die Dentikulierung der Mauer ist viel weniger ausgebildet, denn den Zähnen fehlt die Regelmässigkeit und die starke Ausbildung. Die Trennung von Columella und Septen ist nicht sehr scharf. Die randliche Blasenzone nimmt über die Hälfte des Durchmessers ein.

Stylidophyllum floriformis Martin *var. carinthiaca* Heritsch, 1936, hat eine etwas zu hohe Zahl von Septen.

Stylidophyllum gnomeiense Huang, 1932, dazu Heritsch, 1939. In Grösse und Zahl der Septen herrscht Übereinstimmung, nicht aber im Bilde der Septenzone. Unterschiede liegen ferner in der Mauer, welcher die Zähnchen fehlen, dann darin, dass viele Septen die Mauer erreichen.

Stylidophyllum intermedium Huang, 1932. Durchmesser und Columella sind zu klein, die Zahl der Septen ist zu gering.

Stylidophyllum japonicum Yabe et Hayasaka, 1915. Die Zahl der Septen ist viel zu gross und die Columella ist sehr breit.

Stylidophyllum jenningsi DOUGLAS, 1936. Diese Art könnte in den Grössenverhältnissen, in der Zahl der Septen und der Dicke der Columella mit der mir vorliegenden Form in Übereinstimmung gebracht werden, aber die Zähnung der Mauer fehlt und der Bau der Columella ist wesentlich verschieden.

Stylidophyllum kueichowense HUANG, 1932, dazu DOUGLAS, 1936. Die Zähnung der Mauer stimmt mit meiner Form überein. Die Unterschiede liegen darin, dass *Stylidophyllum kueichowense* einen viel zu grossen Durchmesser, eine viel zu dicke Columella und eine zu breite Blasenzone (die Hälfte und mehr des Gesamtdurchmessers) hat.

Stylidophyllum orientalis DOUGLAS, 1936. Die Zahl der Septen ist zu gross, die Columella ist zu dick und die Dentikulierung ist nicht ausgeprägt.

Stylidophyllum simplex DOBROLJUBOVA, 1936 (Trudy). Der Durchmesser ist zu gross. Im Verhältnis zur Grösse des Durchmessers ist die Zahl der Septen relativ gering.

Stylidophyllum volzi YABE et HAYASAKA, 1915; dazu HUANG, 1932, DOBROLJUBOVA, 1936 (Akademia, Trudy), FELSER, 1937, HERITSCH, 1939. Der Durchmesser ist viel zu gross und die Columella ist sehr dick.

Stylidophyllum variabile GERTH, 1938. Die Zahl der Septen ist viel zu gering. Die Mauern sind viel dicker. Die Dentikulierung ist prächtig.

Stylidophyllum yokohamai OZAWA, 1924; dazu DOBROLJUBOVA, 1936 (Transactions). Keine Übereinstimmung mit der mir vorliegenden Form.

Vorkommen des *Stylidophyllum denticulatum:* In Südchina zusammen mit *Tetrapora elegantula.*

Tetrapora elegantula ist Zonenfossil und gehört in die Permsedimente der gleichnamigen Zone. Diese Zone entspricht dem tieferen Teil des Trogkofelkalkes, dann beiläufig der Artinsk-Stufe (mit Ausnahme des obersten Artinsk); weiterhin ist die Zone der *Tetrapora elegantula* ein Äquivalent der *Perrinites*-Zone (mit Ausnahme des obersten Teiles) und der Leonard-Hess-formation (mit Ausnahme des obersten Teiles).

Wentzelella subtimorica HUANG.

Tfl. XIII, Fig. 3, 4, 6. — Tfl. XV, Fig. 24.

Lonsdaleia (Waagenophyllum) timorica OZAWA (non GERTH!). OZAWA, 1925, S. 182. Tfl. XIII, Fig. 7—9.
Wentzelella subtimorica HUANG, 1932. S. 59, Tfl. IV, Fig. 1.
Wentz. subtimorica HUANG. DOUGLAS, 1936. S. 23. Tfl. II, Fig. 2.
Wentz. subtimorica HUANG. HERITSCH, 1939. S. 173. Tfl. I, Fig. 2, 3; Tfl. II, Fig. 7, 8, 15—17.

Die Koralle trägt die Bezeichnung: Probe 854, 26. Jänner 1932. Geröll aus einem Kalk, welcher die Kuruk-üssüm-Schichten GRÖBERS überlagert. Nordhang des Chili-tagh (im Tian-schan, etwa südlich von Utsch-Turfan); geograph. Breite = 40° 30^m, geograph, Länge = 79° 10^m.

Mir liegt das Bruchstück eines Stockes von folgender Grösse vor:

Oberfläche des Stockes mit gut ausgewitterten Kelchen — 51 : 53 mm.

Grösste Länge: grösste Breite des Stockes = 77 : 80 mm.

Grösste Höhe der Koralliten = 54 mm.

Der Stock liegt in einem sehr hellen, weisslich-gelben Kalk, der sehr rein ist. Die Herstellung der Dünnschliffe war dadurch ganz besonders erschwert, dass die Koralliten sich sehr leicht von einander trennen lassen. In der Mitte des Stockes wachsen die Koralliten ganz gerade aufwärts. In den äusseren Teilen des Stockes aber wachsen sie etwas nach Aussen geneigt, also bogenförmig.

Im Längsbruch sieht man die verschiedene Grösse der Durchmesser der Koralliten (Tfl. XIII, Fig. 3): von 3 mm bis 7 mm. Der Längsanbruch ergibt, weil der Kalk eine ziemliche Krystallinität besitzt, keinen richtigen Einblick in den Bau der Koralle.

Die Oberfläche zeigt (Tfl. XIII, Fig. 4) die prachtvoll ausgewitterten Kelche. Die Mauern, welche die Kelche von einander trennen, sind mehr als 1 mm dick. Die Kelchwände senken sich sehr steil bis senkrecht in die Tiefe, zu dem ebenen Kelchboden, in dessen Mitte sich der Knopf des Säulchens erhebt. Die Septen, welche über die steilen Kelchwände als Schienen absteigen, sind nur bei guter Erhaltung des betreffenden Kelches zu sehen.

Wie die Dünnschliffe zeigen, ist der Erhaltungszustand der Koralle bei weitem nicht erstklassig, aber doch noch recht gut. Leider hat das Sediment fast dieselbe Farbe wie das Gerüst der Koralle — daher kann der Erhaltungszustand nicht erstklassig sein.

Die Koralle ist aus prismatischen, hexagonalen, pentagonalen, selten tetragonalen Koralliten aufgebaut. Der Durchmesser der Koralliten schwankt nach HUANG um 8 mm. DOUGLAS gibt 6 bis 7 mm an. Ich fand bei den Exemplaren aus dem Taurus 9 mm als maximalen Durchmesser. Die kleinsten Koralliten sind vierseitig. Die erwachsenen Koralliten sind recht regelmässig sechsseitig, doch können diese Polypen, wenn neue Koralliten aufspriessen, auch sieben Seiten bekommen.

Die Mauern sind scharf begrenzt (Tfl. XIII, Fig 6) und umgeben die Koralliten vollständig; nur dort, wo mehrere junge Polypen erscheinen, kann es Störungen geben. Die Mauern entbehren der echten Zähnchen, wie sie beim Genus *Polythecalis* sehr häufig sind und auch beim Genus *Stylidophyllum* vorkommen. Der mir vorliegenden Form fehlen wenigstens deutliche Zähnchen. Wenn man aber den transversalen Dünnschliff im Mikroskop betrachtet, dann könnte man bei nicht allzu genauer Besichtigung den Eindruck erhalten, dass Zähnchen vorhanden sind. Das ist aber in dem Sinne eine Täuschung, weil echte Dentikel immer keilförmige, dick und kurz in das Innere vorspringende Vorragungen sind. Hier aber, bei dem zentralasiatischen Exemplar liegen echte, ganz kurze Septen vor, nämlich schmale Septaldornen, welche immer eine recht ansehnliche Länge haben. Es sind dieselben Bildungen, wie sie auf den randlichen Blasen sehr häufig sind.

Die Columella ist nur klein. Ihr Durchmesser misst nur ein Viertel oder noch weniger als der gesamte Durchmesser des Koralliten. Der Umriss ist länglich-oval. Der innere Bau kann sehr verschieden sein. HUANG beobachtete einen Aufbau aus wenigen unregelmässigen Tabellæ und drei bis vier transversalen Lamellen. Die Medianplatte ist im Querschliff undeutlich. — DOUGLAS gibt den Aufbau aus vielen Tabellæ und vielen radialen Lamellen an. Die Medianplatte ist mehr oder weniger abgegrenzt, aber nicht bedeutend verdickt. DOUGLAS bildet auch recht typische lonsdaleide Columellen ab. — Bei den Vertretern der Art aus dem Taurus fand ich Columellen mit dem prinzipiellen Bauplan der lonsdaleiden Säulchen, obwohl die exakte Regelmässigkeit des Baues diesen Columellen fehlt. Die Medianlamelle ist meist recht gut entwickelt. — Bei den Koralliten aus Zentralasien (Tfl. XV, Fig. 24) sind die Columellen länglich, meist länglich-oval. Oft sind sie von einem Bruchnetz umgeben, welches sie scharf gegen den anderen Bau der Koralle abtrennt. Die Columellen sind ziemlich einheitlich gebaut, denn sie bestehen immer nur aus einigen Tabellæ und wenigen Radiallamellen. Bei einem sehr jungen Koralliten ist ein sehr einfacher Bau zu sehen; denn die Columella besteht da nur aus einem Dreieck und alles Andere fehlt! HUANG bildet auch solche Formen der Columellen ab.

Im Längsschliff sieht man den Aufbau, den HUANG abgebildet hat: Die Tabellæ sitzen wie Dachreiter eng über einander; sie sind am Aussenrande mit einander verwachsen, so dass das Säulchen durch eine senkrechte Linie nach Aussen abgegrenzt wird. Diese einheitliche Abgrenzung, welche gleichsam eine Röhre darstellt, ist von HUANG mit einer „inneren Mauer" verglichen worden.

Die Zahl der Septen erster Ordnung wird von HUANG mit 13 bis 19 angegeben. DOUGLAS beobachtete 20 und ich konnte bei den Exemplaren aus dem Taurus 16 bis 20 Septen erster Ordnung feststellen. Die Zahl der Septen erster Ordnung und die Durchmesser der zugehörigen Koralliten stehen in folgender zahlenmässiger Verbindung:

Exemplare aus Zentralasien		Exemplare aus dem Taurus	
Durchmesser	Zahl der Septen erster Ordnung	Durchmesser	Zahl der Septen erster Ordnung
6.0 : 7.0	18	8.0 : 9.0	20
6.0 : 6.5	18	5.0 : 7 2	16
7.9 : 8.5	19	6.0 : 7.3	16

Die Zahl der Septen zweiter Ordnung ist gleich gross jener der ersten Ordnung. Die Septen der zweiten Ordnung sind nur um einen geringen Betrag kürzer als jene der ersten Ordnung; DOUGLAS gibt drei Viertel jener der ersten Ordnung an. Vielfach sind an der Mauer noch ganz kurze Septen dritter Ordnung entwickelt, deren schon bei der Zähnung der Mauer gedacht wurde. Die Septen erster und zweiter Ordnung sind mässig dick und leicht gebogen.

Nach HUANG erreichen die Septen erster Ordnung die Columella. Aber seine Abbildung (1932, Tfl. IV, Fig. 1a) zeigt, dass das durchaus nicht richtig ist, denn nur ganz selten erreicht wirklich ein Septum die Columella. Die Abbildungen von DOUGLAS zeigen dieselben Verhältnisse und ich habe bei der Beschreibung der Exemplare aus dem Taurus darauf hingewiesen, dass zwischen den inneren Enden der Septen erster Ordnung und der Columella ein allerdings sehr kleiner Zwischenraum vorhanden ist.

Die Mehrzahl der Septen erreicht die Mauer. Aber in einigen der hier abgebildeten Querschnitte (Tfl. XIII, Fig. 6) sind die Septen vor der Erreichung der Mauer scharf abgeschnitten und von ihr durch Blasen getrennt. Selten kommt es zur Entwicklung einer förmlichen Blasenzone. Bei den von HUANG (1932, Tfl. IV, Fig. 1a) abgebildeten Querschnitten gibt es nur ganz schwache Andeutungen einer Blasenzone. In dem von DOUGLAS (1936, Tfl. II, Fig. 2) abgebildeten Querschnitt ist diese Erscheinung bereits wesentlich besser ausgeprägt. Ich selbst habe bei der Beschreibung der *Wentzelella subtimorica* aus dem Taurus sehr bestimmt auf die randlichen Blasen hingewiesen: Wenn die Koralliten annähernd gleichlange Seiten in ihren polygonalen Umrissen haben, reichen die Septen fast immer bis zur Mauer; es kommt aber auch da vor, dass einzelne randliche Blasen vorhanden sind, welche die äusseren Enden der Septen von der Mauer trennen. Bei sehr lang gestreckten polygonalen Umrissen der Koralliten sind in den am weitesten von einander getrennten Endräumen Blasen entwickelt, welche sogar kleine Flächen von Geweben bilden können. Diese Verhältnisse habe ich (1939, Tfl. I, Fig. 3) abgebildet.

Der hier abgebildete Querschnitt aus dem zentralasiatischen Material (Tfl. XIII, Fig. 6) zeigt an verschiedenen Stellen meist nur vereinzelte oder wenige Blasen an der Mauer, besonders dort, wo in der Nachbarschaft neue Koralliten aufspriessen. Der Querschliff wird aber auch von einer recht breiten Zone von Blasen durchzogen; dort spriessen vier junge Polypen auf. Es ist, wie der Querschliff zeigt, eine ungewöhnlich lange Zone von grossen Blasen vorhanden. Die Blasen gehören zum angrenzenden grösseren Koralliten und sind mit Dornen, welche in das Innere dieses Koralliten gerichtet sind, ausgestattet.

Ich möchte nur kurz darauf hinweisen, dass das Vorhandensein von Blasen mit der Fassung des Genus *Wentzelella* nicht übereinstimmt, denn dieses gehört nach HUANG (1932, S. 45/6) in die Gruppe B der *Lonsdaleidæ:* „Genera, bei welchen die Septen die Mauer erreichen". In der Charakteristik des Genus wird eigens das Fehlen einer randlichen Blasenzone betont. Mir scheint, dass eine Revision der lonsdaleiden Korallen des Perm ein erstrebenswertes Ziel wäre und dass die kritischen Bemerkungen von GERTH (1938, S. 231) sehr bemerkenswert sind.

Das Dissepiment ist in der Septenzone sehr zahlreich. Es bildet, verschieden je nach dem Durchmesser, drei bis sechs Blasenreihen.

Die Tabulæ sind wohl entwickelt. Sie sind zum Teil etwas blasig und bilden eine deutliche Zone um die Columella. Leider sind die drei angefertigten Längsschnitte nicht gut geworden, aber aus allen dreien zusammengenommen ergibt sich das Bild, das HUANG (1932, Tfl. IV, Fig. 1 b) in einem Schliff darstellen konnte.

Wentzelella subtimorica hat nahe Beziehungen zu *Wentzelella timorica* (GERTH). *Wentzelella subtimorica* hat eine kleinere und meist wesentlich einfacher gebaute Columella; ferner zeigt sie zum Unterschied von *Wentzelella timorica* im Längsschnitt eine Bodenzone; schliesslich besteht bei *Wentzelella subtimorica* die Neigung zur Bildung einer randlichen Blasenzone.

Wentzelella subtimorica ist in Südchina aus der Zone der *Wentzelella timorica* durch HUANG beschrieben worden. DOUGLAS führt sie von Darreh-Duzdan in Persien an. Im Taurus kommt die Art zusammen mit *Polythecalis rosiformis* YOH et HUANG in der Zone der *Wentzelella timorica* vor.

Palaeosmilia sp.

Tfl. XV, Fig. 23.

Die Koralle trägt folgende Bezeichnung: D/2. Lokal N 78, 24. Oktober 1932. Tashliq-Köl; geograph. Breite = 34° 38^{m}; geograph. Länge = 80° 39^{m}. Der Fundort liegt zwischen dem Kuen-Lun im Norden und dem Karakorum — Hedin Gebirge im Süden. Von demselben Fundort stammen die Korallen *Amplexus sp.* und *Protomichelinia microstoma.*

In einem sehr festen, hellen Kalk stecken mehrere Exemplare der Koralle, die recht mässig erhalten sind. Die Untersuchung im Dünnschliff ergab Folgendes: Der Durchmesser des Querschliffes beträgt 14.0(?): 18.0 mm. Auf der einen Seite ist der Dünnschliff unvollständig, weil die Koralle ganz am Rande des Gesteinsstückes liegt. Auf der anderen, ganz vom Gestein umgegebenen Seite des Schliffes sieht man eine Verletzung des Tieres, welche, wie die ganze Art der Störung des Baues zeigt, schon zu Lebenszeiten des Tieres eingetreten sein musste; das Tier hat die Störung durch einen unregelmässigen Bau der neugebildeten Hartteile auszugleichen versucht.

Die Zahl der Septen erster Ordnung ist wegen der erwähnten Verletzung nicht sicher feststellbar. Tatsächlich sind 24 Septen erster Ordnung zu zählen. Wenn die Verletzung nicht eingetreten wäre, so müsste sich ihre Zahl auf 30 bis 32 belaufen. Die Septen erster Ordnung erreichen wenigstens zum Teil das Zentrum, sie drehen sich dort um einander, aber sie winden sich dort nicht um einander.

Die Septen zweiter Ordnung sind verschieden entwickelt: Sie sind entweder sehr lang (bis zu zwei Drittel der Länge der Septen erster Ordnung). Oder es sind nur keilförmige Ansätze an der Mauer vorhanden, worauf nach einer Lücke die Septen auf eine kürzere oder längere Strecke wieder einsetzten. Oder die Septen erstrecken sich von dem keilförmigen Ansatz nur für eine sehr kurze Strecke in das Innere fort. Oder die Septen zweiter Ordnung fehlen vollständig.

Wo die Septen erster und zweiter Ordnung an die Mauer herantreten, erhebt sich auf dieser ein breiter, keilförmiger Vorbau, der als Ansatzstelle der Septen fungiert. Die Mauer selbst ist sehr dünn.

Das Blasengewebe lässt nur einen zentralen Raum frei, welcher ein Viertel des Durchmessers des Querschnittes als Breite misst. Das Gewebe ist ziemlich dicht und geht vom inneren Rande bis an die Mauer in der gleichen Dichte und der gleichen Form durch.

Ich glaube mit Sicherheit annehmen zu können, dass die mir vorliegende zentralasiatische Form in die Gruppe jener Palæosmilien gehört, welche ich vor kurzer Zeit aus dem tieferen Perm namhaft gemacht habe (1936, S. 134). Es sind das *Palæosmilia ampfereri* aus dem unteren Schwagerinenkalk der Karnischen Alpen, *Palæosmilia hammeri* aus dem Trogkofelkalk der Südalpen und *Palæosmilia schucherti* aus dem Saddle Creek-Kalk an der Basis des Perms von Texas.

Chi (1939, S. 167) beschreibt aus dem Maping-Kalk von China (= unterstes Perm) eine „*Caninia sp.* (aff. *Palæosmilia hammeri* Heritsch)". Er meint, dass *Palæosmilia schucherti* und *Palæosmilia ampfereri* eng an *Lophophyllum (Koninckophyllum)* anzuschliessen seien. Wenn ich die Charakteristiken von *Koninckophyllum* bei Nicholson, jene des *Lophophyllum* bei Carruthers lese, so sehe ich, dass die beiden Paläosmilien sehr weit von diesen Genera entfernt sind. Chi meint fernerhin, dass *Palæosmilia hammeri* zu *Caninia* zu stellen sei. Ich halte mich bezüglich des Genus *Caninia* an die Auseinandersetzungen von Salée und kann nur feststellen, dass *Palæosmilia hammeri* nichts dort zu tun hat.

Die von Chi (1938, S. 167, Tfl. I, Fig. 6 a-c) beschriebene Form hat leichte caninoide Züge; aber eine deutliche innere Mauer fehlt ebenso wie die Verdünnung der Septen gegen die äussere Mauer hin. Die Charakteristik des Genus *Caninia* bei Salée zeigt deutlich, dass *Caninia sp.* bei Chi nicht zu diesem Genus gehören kann.

Ich gebe allerdings Chi gegenüber gerne zu, dass das Genus *Caninia* durch die Einstellung der doch mit recht verschiedenen Eigenschaften ausgestatteten unterkarbonischen, oberkarbonischen und permischen Art zu einer Art von Sammelbegriff wird, dessen Auflösung in der Zukunft gemacht werden muss.

Amplexus sp.

Tfl. XIV, Fig. 6, 7, 8. — Tfl. XV, Fig. 21, 22.

Die Koralle trägt dieselbe Bezeichnung und stammt von demselben Fundort wie *Palæosmilia sp.* und *Protomichelinia microstoma.*

Es liegt eine ganze Reihe von Exemplaren vor. Alle stammen aus einem sehr hellen, reinen Kalk. Der Umschluss durch den Kalk ist so vollkommen, dass nirgends eine Spur der äusseren Skulptur zu sehen ist. Die Querschnitte wittern derart aus, dass am Rande die Septenzone sehr scharf hervortritt. Die Betrachtung des angewitterten Querschnittes von oben her zeigt, dass die schmale Septenzone nach Innen zu an der Erhebung endet, welche von den aufgewölbten Böden gemacht wird.

Es wurden eine Reihe von Exemplaren im Anrieb und zwei Dünnschliffe untersucht. Wenn die Koralle als *Amplexus* bezeichnet wird, so ist sie damit in die Reihe jener unangenehmen permischen Korallen gestellt, welche man vorläufig — bis nämlich einmal dieses Genus von den unterkarbonischen Arten angefangen bis zu den permischen Vertretern zusammenhängend untersucht sein wird — eben nicht anders bezeichnen kann. Über die Unzweckmässigkeit des Namens *Amplexus* habe ich schon an anderer Stelle Klage geführt. Es ist mir natürlich sehr wohl bekannt, dass das Genus *Amplexus* in der Fassung von SOWERBY keine Dissepimente hat. Aber es haben sich so viele Autoren über diese alte Festsetzung des Genus hinweggesetzt und es ist — offen gesagt — ein heilloses Durcheinander entstanden, dass ich es nicht als einen allzu schweren Fehler ansehen kann, wenn jetzt noch Formen mit einem oder zwei Blasenzügen als *Amplexus* bezeichnet werden.

Die Untersuchung der beiden transversalen Dünnschliffe ergab folgende Zahlen:

Nummer	Durchmesser	Zahl der Septen	Länge der S. I. O.	Länge der S. II. O.	Durchmesser des freien Raumes im Zentrum.
D/5	7.2 : 8.6 mm	19 + 19 = 38	3.0 — 3.3	1.6 — 2.2	2.5 — 2.9
D/2	6.5 : 6.8 mm	17 + 17 = 34	1.8 — 2.2	1.0 — 1.3	2.7 — 2.9

Diese Zahlen werden durch die Messungen an den Anrieben ergänzt: Der kleinste Durchmesser ist 6.5 mm, mit 17 + 17 = 34 Septen. Der grösste Durchmesser liegt bei fast kreisrundem Umfang über 8 mm, mit 20 + 20 = 40 Septen. Der freie zentrale Raum misst 3.5 mm Breite.

Die Septen sind mit einem sehr deutlichen primären Mauerblatt ausgezeichnet; ebenso hat die sehr dünne, bei einzelnen Schnitten auch fehlende Mauer den dunklen Strich des primären Mauerblattes. Die inneren Enden der Septen erster Ordnung sind gelegentlich etwas verdickt, so dass sie fast keilartig aussehen. Innerhalb der Zone der Septen zweiter Ordnung sind zwei Züge von Blasen entwickelt. Unter den Septen erster Ordnung ist — nicht in allen Schnitten! — gelegentlich eines wesentlich kürzer als die anderen; das ist das Haupt- oder das Gegenseptum, was leider nicht zu unterscheiden ist.

Eine Artbestimmung wage ich nicht vorzunehmen. Der im *Productus*-Kalk des Salt Range, des zentralen Himalaya, von Tibet, von Djoulfa und von Balia Maden vorkommende *Amplexus abichi* WAAGEN et WENTZEL (dazu Literatur bei HERITSCH, 1937) ist durch das Fehlen der Septen zweiter Ordnung ausgezeichnet und kommt daher und wegen der Grösse des Durchmessers, der hohen Zahl der Septen zum Vergleich nicht in Betracht. — Über den sogenannten *Amplexus arundinaceus* LONSDALE, der aus dem Perm von Neu-Süd-Wales und von Timor beschrieben wurde, werde ich mich an anderer Stelle äussern; hier kommt er zum Vergleich nicht in Betracht. — Der von HUANG (1932) aus dem mittleren Perm von Süd-China beschriebene *Amplexus cf. arundinaceus* könnte im allgemeinen Habitus mit der mir vorliegenden zentralasiatischen Form wohl verglichen werden, doch ist die Zahl der Septen und der Durchmesser zu gross und es fehlen auch die Blasen. — Der aus Timor und Djoulfa bekannte *Amplexus beyrichi* K. MARTIN (dazu Literatur bei HERITSCH, 1937) kann noch am ehesten mit der mir vorliegenden Form verglichen werden, denn die Zahl der Septen ist nicht allzu viel grösser und die Übereinstimmung bezieht sich sowohl auf den Besitz von Septen zweiter Ordnung als auch auf das Vorhandensein von etwas Blasengewebe.

Amplexus coralloides wird leider noch immer aus dem Perm angeführt. Eine Untersuchung aller unter diesem Namen gehenden Formen ist eine sehr dringende Angelegenheit. Im Übrigen kommen alle diese permischen Formen des *Amplexus coralloides* für den Vergleich mit der beschriebenen zentralasiatischen Form nicht in Betracht, weil alle „*Amplexus coralloides*" nur Septen einer Länge haben. — *Amplexus grabaui* HERITSCH (1937) ist aus Timor, Djoulfa und der Mongolei bekannt. Die Art hat Septen erster und zweiter Ordnung, aber keine Blasenzüge. Die Zahl der Septen ist grösser als bei meiner zentralasiatischen Form. — *Amplexus pustulosus* HUDLESTON, aus West-Australien und Timor beschrieben, hat keine Blasen und viel zu viele Septen, so dass sie zum Vergleich nicht in Betracht kommen kann.

Protomichelinia microstoma YABE et HAYASAKA.

Tfl. XIII, Fig. 5, 8. — Tfl. XV, Fig. 18, 19, 20.

Michelinia favositoidea GIRTY, 1913. S. 312. Tfl. 29, Fig. 1, 2 (Non! *Michelinia favositoidea* BILLINGS, Report Progr. Canad. Geol. Survey, S. 175).
Michelinia (Protomichelinia) microstoma YABE et HAYASAKA, 1915. S. 61
Michelinia (Protomichelinia) microstoma YABE et HAYASAKA, 1920. Tfl. IX, Fig. 8a, b.
Michelinia mansuyi COWPER REED, 1925. Tfl. I, Fig. 16—20
Michelinia microstoma YABE et HAYASAKA. HUANG, 1932. S. 92. Tfl. XI, Fig. 3.

Die Koralle trägt dieselbe Bezeichnung und stammt von demselben Fundort wie *Amplexus sp.* und *Palæosmilia sp.*

Das Genus *Michelinia* wurde von DE KONINCK auf Grund der prachtvoll erhaltenen Korallen des Unterkarbons von Belgien aufgestellt. Aus der Charakteristik des Genus ist besonders hervorzuheben, dass die zahlreichen Mauerporen keine regelmässige Anordnung in ihrer Position zu den Kanten der Wände erkennen lassen. Weiters ist wichtig, dass die Kelche der prismatischen oder subcylindrischen Koralliten, die über ihre ganze Länge mit einander in Verbindung stehen, immer polygonal sind und nie durch verdickte Ränder gerundet werden. Die Tabulæ sind zahlreich und mehr oder minder derart gebogen, dass sie nach oben konvexe Böden bilden. Die Böden anastomosieren gewöhnlich mit einander auf grössere oder kleinere Strecken hin, so dass sogar eine Art von losem, offenem Gewebe entstehen kann. Die Böden tragen oft zahlreiche, vertikale Dornen, welche man als Fortsetzung der Septen gedeutet hat. Die Septen werden durch zahlreiche, vertikal angeordnete Streifen oder vertikale Reihen von Tuberkeln vertreten. Das Äussere von *Michelinia* gleicht dem von *Favosites;* aber die Koralliten von *Michelinia* haben meist viel grössere Durchmesser, als es bei *Favosites* üblich ist (zu dieser Charakteristik vergleiche man NICHOLSON, 1879, S. 139).

Das charakteristische Merkmal von *Michelinia* ist die Beschaffenheit der Böden; diese erstrecken sich selten gerade durch den Visceralraum, da sie sich — wenigstens bei den typischen unterkarbonischen Arten des Genus — in der Nähe der Mauer mit den benachbarten Böden vereinigen und sogar eine Art von Blasengewebe bilden können. Es ist gar keine Frage, dass die Michelinien mit den Favositen nahe verwandt sind. Der grösste Unterschied von *Michelinia* gegenüber *Favosites* besteht einmal in der Beschaffenheit der Böden und weiters in der ungleichmässigen Zahl und der ungleichmässigen Lage der Mauerporen.

YABE und HAYASAKA (1915) haben die *Michelinia multitabulata* aus dem Perm von Japan beschrieben, welche so kleine Mauerporen hat, dass man sie kaum zu erkennen vermag.

Die beiden japanischen Autoren werden durch diese Art an das Genus *Beaumontia* erinnert. Dieses Genus — man vergleiche hiezu MILNE EDWARDS und HAIME'S grundlegendes Werk, 1852, S. 276, und NICHOLSON, 1879, S. 329 — hat mit *Michelinia* die blasigen Böden gemeinsam. Weiters hat *Beaumontia* unregelmässige, gelegentlich auf der Oberfläche vorhandene Septalstreifen. Während MILNE EDWARDS und HAIME das Vorhandensein von Mauerporen erwähnen, hat NICHOLSON es bezweifelt. — Das Genus *Beaumontia* ist eine unsichere Angelegenheit und YABE-HAYASAKA haben wohl recht, wenn sie es wegen der unklaren Definition des Genus ablehnen, es zur Bezeichnung der von ihnen beschriebenen Koralle zu verwenden.

ROEMER (S. 462) erwähnt bei der Charakteristik des Genus die blasigen, unregelmässigen Böden, nichts aber von den Mauerporen; doch hält er es für möglich, dass die Wandporen nur übersehen worden seien. Wenn ROEMERS Meinung von den Wandporen richtig sein sollte, dann wäre LINDSTRÖM im Recht, dass er *Beaumontia* bei den *Favositidae* einstellt.

STUCKENBERG (1895, S. 226) hat zwei Arten von *Beaumontia* aus dem Jungpaläozoikum des Urals beschrieben, von welchen die Eine sehr feine, nur von Innen zu sehende Mauerporen hat. Die beiden Arten sind so ungenügend beschrieben und auch so wenig gut abgebildet, dass man sich von ihnen keine sichere Vorstellung machen kann. Man wird die beiden Arten bei einer Diskussion der Beziehungen von *Michelinia* und *Beaumontia* ausschalten müssen.

YABE und HAYASAKA führen die unveröffentlichte, ihnen als Manuskript vorliegende Abhandlung von JIMBO an, welche die Beschreibung einer *Beaumontia* aus den Kitakami-Bergen enthält. YABE und HAYASAKA sagen, dass es sich bei dieser Form um keine *Beaumontia* handeln könne, weil sie mit unregelmässigen Reihen von Mauerporen ausgestattet ist. Es liegt vielmehr eine *Michelinia* vor. Die beiden Forscher entschliessen sich also in der Frage des Genus *Beaumontia* dazu, dass Formen mit Mauerporen und blasigen Böden zu *Michelinia* zu stellen seien.

Dagegen nimmt SIBLY (1904, S. 70) bei der Beschreibung unterkarbonischer Korallen einen anderen Standpunkt ein. Er stellt die *Beaumontia aff. egertoni* M. E. H. aus dem hohen Visé von England zur *Beaumontia*-Sektion des Genus *Michelinia;* allerdings erwähnt er die Mauerporen nicht.

Über das Genus *Beaumontia* sind daher die Akten keineswegs geschlossen. Erst nach Untersuchung des Originalmateriales kann festgestellt werden, ob das Genus aufrecht zu erhalten ist oder nicht. Vielleicht ist *Beaumontia* mit dem zu erörternden Genus *Michelinopora* identisch.

YABE und HAYASAKA haben 1915 den Vorschlag gemacht, das Genus *Michelinia* in drei Subgenera, *Eumichelinia, Protomichelinia, Michelinopora,* aufzuteilen. Ich glaube, es wäre besser, dem Genus *Michelinia* DE KONINCK die beiden Subgenera *Protomichelinia* und *Michelinopora* anzuschliessen. Der Name *Eumichelinia* ist deswegen überflüssig, weil die Charakteristik mit jener von *Michelinia* DE KONINCK zusammenfällt.

Das Genus *Michelinia* DE KONINCK (= *Eumichelinia* YABE et HAYASAKA) umfasst die typischen unterkarbonischen Formen und einige aus dem Devon, dem Oberkarbon, vielleicht auch aus dem Perm. Die Koralliten sind relativ kurz, was auch die Form des Stockes bedingt. Die Koralliten haben konvexe Tabulæ und infolge der Verschmelzung der Böden die charakteristische „Blasenbildung". Die ältesten Formen von *Michelinia* haben keine sehr weiten Zellröhren (im Devon besonders von Amerika!). Die ältesten Formen haben niedrige Septalkämme, was bei den karbonischen Arten nicht mehr der Fall ist. Es ist klar ersichtlich, dass die früher gegebene Definition des Genus hier zur Anwendung kommen muss.

Die beiden Subgenera sind hauptsächlich auf ost- und südasiatischem Material aufgebaut. Sie stellen die permischen Vertreter des alten Begriffes *Michelinia* vor. Sie unterscheiden sich eigentlich recht erheblich von den karbonischen Formen:

1) Durch die flacheren Böden, welche dem Genus *Favosites* ähnlich sind.

2) Durch die andere Art des Stockes, welcher aus sehr langen, säulenartigen Koralliten aufgebaut ist. Sie erinnern daher gewissermassen an die devonischen Vertreter von *Michelinia,* aber auch an *Favosites.*

Das Subgenus *Protomichelinia* YABE et HAYASAKA zeigt grosse, halbkugelförmige oder birnförmige Stöcke. Die Koralliten sind lang, prismatisch oder subzylindrisch und stehen in engem Kontakt mit einander. Die Mauern sind dünn und tragen zahlreiche niedrige, dornige Septalkämme. Die Mauerporen stehen unregelmässig verteilt und sind recht gross. Die Böden sind konvex, sehr eng gestellt und mit einander im Kontakt, so dass jenes erwähnte „blasige Gewebe" entsteht, welches manche Autoren als „blasige Endothek" bezeichnen.

Der Unterschied gegenüber von *Michelinia* liegt in der Länge der Koralliten. Gegen das folgende Subgenus *Michelinopora* liegen die Unterschiede in der Grösse der Mauerporen, in den dornigen Septalkämmen und der häufigen Vereinigung der Böden.

Das Subgenus *Michelinopora* YABE et HAYASAKA hat als Typ die *Mich. multitabulata* YABE et HAYASAKA. Diese Art bildet grosse Korallenstöcke, bestehend aus langen, prismatischen, mit einander auf die ganze Länge in vollem Kontakt stehenden Koralliten, welche gerade sind und in radialer Ordnung stehen. Die Mauern sind dünn und lamellar gebaut, denn sie bestehen aus zwei Blättern. Die Septalkämme sind zahlreich, sehr niedrig, aber doch deutlich. Es sind weder Septallamellen noch Septaldornen entwickelt. Die Mauerporen sind zahlreich und unregelmässig verteilt, aber sehr klein. Die Böden sind zahlreich, eng gestellt und leicht nach aufwärts gebogen. Sie sind mehr oder weniger unregelmässig angeordnet; die einen sind kurz, die anderen verwachsen mit den benachbarten Böden, woraus sich eine „halb-blasige Struktur" ergibt.

Gegenüber *Michelinia* liegt der Unterschied in den langen Koralliten, den kleinen Poren und dem schwach entwickelten Septalapparat. Von *Protomichelinia* unterscheidet sich das Genus *Michelinopora* durch das Fehlen der Septaldornen, die kleinen Mauerporen und die unregelmässig angeordneten Böden.

Es werden, wie aus den bisherigen Erörterungen hervorgeht, dem Genus *Michelinia* Formen zugerechnet, welche in der Art der Septen sehr wesentlich von den typischen Formen DE KONINCKS abweichen. Ich denke da zum Beispiel an *Michelinia abnormis* HUANG (1932, Tfl. XI, Fig. 4), welche im Bau des Querschliffes eigentlich rein dem Typus *Favosites* entspricht. *Favosites relictus* GERTH aus Timor hat ganz gerade und von einander vollständig gesonderte Böden. Ist das wirklich ein *Favosites* oder gehört er zu *Michelinia?* Diese Frage ist durchaus berechtigt, denn GERTH selbst (1921) gibt an, dass die Poren unregelmässig verteilt zu sein scheinen — auf seiner Abbildung (Tfl. 149, Fig. 4, des Timor-Werkes, 1921) ist es so dargestellt. —

Mir liegt von dem früher genannten Fundort das Bruchstück eines grossen Stockes vor (Tfl. XIII, Fig. 5); das Stück hat 111 mm Breite, 102 mm Tiefe und 73 mm Höhe. Von einer zentralen Partie, welche aber keineswegs der tiefsten Stelle des Stockes entspricht, strahlen radial sehr lange Zellröhren aus. Sie liegen eng an einander und sind nur so wenig gebogen, dass das Breitenwachstum des Stockes ermöglicht wird. In den Anbrüchen der Zellröhren sieht man die sehr eng gestellten Böden. Sehr häufig sind Poren zu sehen — daraus wird man schon schliessen können, dass sie einen bedeutenden Durchmesser haben. Die Poren sind unregelmässig gestaltet; man kann nur gelegentlich von reihenartiger Anordnung sprechen. Meist stehen die Poren in zwei Reihen, doch liegen mitten in den zweireihigen Porenscharen Poren in dreireihiger Anordnung.

Die Gesamtheit der Erscheinungen spricht auf den ersten Blick für *Favosites*, doch weicht die unregelmässige Anordnung der Mauerporen von der strengen Fassung dieses Genus ab. In der Literatur sind Formen mit unregelmässigen Poren bei *Favosites* eingestellt worden, wie die früheren Auseinandersetzungen aufzeigen.

Der mir vorliegende zentralasiatische Stock ist gelb gefärbt; die Diagenese des Kalkes ist relativ gering, etwa so wie bei dem früher beschriebenen *Stylidophyllum denticulatum.*

Der transversale Dünnschliff zeigt ebenfalls eine sehr bedeutende Ähnlichkeit mit *Favosites*. Er zeigt den engen Kontakt der prismatischen Koralliten. Die Zellröhren sind polygonal. Kleine Koralliten sind vierseitig (Durchmesser bis 1.8 mm); diese kleinen Röhren sind selten. Die fünfseitigen Koralliten sind schon wesentlich grösser. Im erwachsenen Zustande, bei normaler Grösse sind die Koralliten sechs- bis siebenseitig. An Durchmessern wurden auf einem kleinen Fleck des Dünnschliffes gemessen (in Millimetern):

1.4 : 1.8	2.4 : 2.6	2.2 : 2.8	2.6 : 2.7
2.2 : 2.5	2.2 : 2.7	2.5 : 2.8	2.8 : 3.0

Die Mauern sind sehr dünn (0.1—0.2 mm). Sie bestehen aus drei Blättern: In der Mitte das schwarze Band des sogenannten primären Mauerblattes; an diese im Dünnschliff sehr gut sichtbare, dunkle, sehr schmale Mittellinie schliessen sich in wenigstens zehnfacher Breite zwei Blätter von hellerer Farbe an — das sind die aus feinsten Kalzitkryställchen aufgebauten Lagen, in welchen die c-Achsen der Kryställchen beiläufig senkrecht zur Mittellinie stehen. Ziemlich selten sind Septalkämme vorhanden, welche sehr kurz sind und im Schnitt breite Dreiecke auf den Mauern bilden; gelegentlich sieht man zwei von ihnen neben einander liegen.

Die Mauerporen sind ziemlich gross. Ich vermag keine durchgreifende Regelmässigkeit in ihrer Anordnung zu erkennen. Meist ist im Querschliff auf einer Seite des polygonalen Schnittes eines Koralliten nur eine Pore zu erkennen, welche den Schnitt einer Zellröhre darstellt; sehr häufig liegt e i n e gute Pore randlich auf einer solchen Seite, so dass es wohl möglich ist, dass zwei Reihen von nicht horizontal neben einander liegenden Poren vorhanden sind; oder es könnten diese beiden Reihen in der Höhe unregelmässig angeordnet sein. — Wo die Poren durch den Dünnschliff nicht genau getroffen worden sind, wo aber der Schliff in der nächsten Nähe der Poren durchgeht, haben die Mauern dunkle Flecken. Auch die vom Dünnschliff getroffenen Poren haben schwarze Umrandungen — hier scheint also die Substanz des primären Mauerblattes mächtiger zu sein und die ursprüngliche Anlage der Poren zu bilden; die ursprüngliche Anlage der Poren müsste dann eine kragenförmige Verbreiterung des primären Mauerblattes sein.

Der Längsschnitt zeigt die eng an einander stehenden Tabulæ (Tfl. XV, Fig. 18, 19), welche sehr zahlreich, aber nicht so zahlreich sind, wie YABE—HAYASAKA und HUANG angeben; ich habe nämlich nur 18 bis 20 Böden auf 10 mm Höhe gezählt, während die genannten Forscher 23 bis 25 angeben. Die Böden sind meist vollständig, in geringem Masse unregelmässig, meist aber horizontal oder manchmal etwas nach aufwärts gebogen; sie anastomosieren sehr selten. Erst bei starker Vergrösserung und Durchleuchtung des Dünnschliffes unter dem Mikroskop zeigen sich die Böden am Rande etwas herabgebogen.

Im Längsschliff ist Mauersprossung zu sehen. Die unter der Sprossungsstelle etwas dickere Mauer gabelt sich. Dadurch entsteht der schlanke Trichter der neuen Zellröhre mit Böden von *Michelinia*-Charakter; das heisst, die Böden sind nach aufwärts gewölbt und zwar so, dass in der Mitte Teile des Bodens horizontal sind und die Ränder sich scharf nach abwärts biegen. Der Trichter erhält sehr rasch die normale Breite der Zellröhren und die beiden Mauern gehen dann parallel weiter nach oben.

YABE—HAYASAKA beschrieben die Art aus dem hohen Perm; HUANG führt sie aus dem Chihsia-Kalk und zwar aus der Zone der *Polythecalis yangtzeensis* an. YABE—HAYASAKA führen als Begleiter der *Protomichelinia microstoma* eine Reihe von Brachiopoden an, welche auf das Niveau des indischen *Productus*-Kalkes und auf Djoulfa verweisen: *Orthothetes armenianus, Dalmanella indica, Productus sumatrensis var. palliatus* u. s. w.

Tetrapora halysitiformis YOH.

Tfl. XIV, Fig. 2, 3.

Tetrapora halysitiformis YOH, YOH und HUANG, 1932, S. 17. Tfl. III, Fig. 1, 2.

Die Koralle trägt folgende Bezeichnung: Probe 1092. Aus dem Loqzung Gebirge beim lager N 701; geogr. Breite = 34° 50^m, geogr. Länge = 79° 40^m.

Mir liegt ein abgerolltes Stück von im angewitterten Zustande dunkelblauen, im frischen Bruch aber graublauen Kalkes vor, in welchen der Korallenstock eingelagert ist. Die Oberfläche des Stockes misst in der Fläche der ausgewitterten Querschnitte der Koralle 93:82 mm. An den Seitenflächen ist die Höhe des Stockes mit maximal 38 mm festzulegen. Die Hartteile des Stockes sind als weisser Kalzit erhalten. Der Erhaltungszustand ist ungünstig, denn die Details des Aufbaues sind nur stellenweise zu sehen und zwar besser auf den angewitterten Flächen als im Dünnschliff.

Die Koralliten sind, wie auch die Dünnschliffe zeigen, in unregelmässig kettenartiger Weise an einander gereiht. Die einzelnen Koralliten stehen neben einander, kommen aber meist nicht in einen direkten Kontakt. Sie sind vielmehr seitlich mit einander durch kurze Röhren verbunden; die durchschnittliche Entfernung der Zellröhren von einander beträgt meist weniger als der halbe Durchmesser der Koralliten. Der Durchmesser der Koralliten beträgt meist etwas über 2 mm, liegt aber sehr häufig bei 2.5 mm, kann aber auch 3.0 mm übersteigen. Über das innere Gefüge kann wegen des ungünstigen Erhaltungszustandes kaum etwas gesagt werden. — Im Längsbruch des Stockes sieht man die eng gestellten Böden.

Die Koralle ist von Süd-China aus der Zone der *Tetrapora elegantula* beschrieben worden.

Hinsichtlich der stratigraphischen Stellung der beschriebenen Korallen kann ich mich kurz fassen. Ich verweise zuerst auf die Übersicht der Vorkommen des Perms in Zentralasien, welche sich bei MERLA (1934) findet, ferner auf die wenige neuere Literatur. Zur Erleichterung der stratigraphischen Übersicht sei auf die folgende Tabelle verwiesen, welche neben den allgemeinen Gliederungen mit Hilfe der Korallen und Ammonoideen eine kurze Darstellung der Einteilung der Permformation in einigen wichtigen Gebieten bringt.

		Südalpen	Korallen	Ammonoideen	Süd-China	
Oberes Perm	Salt Range-Stufe	Bellerophon-Stufe	Fauna von Djoulfa und Likodra	Otoceras	Lopingian	Chansing-Kalk
			Sinophyllum kayseri	Timorites		Choutang-Kalk
Mittleres Perm	Sosio-Stufe	Grödener-Schichten Tarvisen Brekzie	Wentzelella timorica	Waagenoceras	Yangsinian	Maokou-Kalk
	Trogkofel-Stufe	Trogkofel-Kalk	Polythecalis yangtzeensis	Perrinites		Chihsia-Kalk
			Tetrapora elegantula			
Unteres Perm	Rattendorfer-Stufe	Oberer Schwagerinen-Kalk	Stylidophyllum volzi	Properrinites	Chuanshan-Kalk	
		Grenzlandbänke	Caninia (Siphonophyllia) sophiae		?	
		Unterer Schwagerinen-Kalk	Stylidophyllum stillei		Schichten mit Schwagerina fusulinoides	

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APPENDIX B

PERMISCHE BRYOZOEN AUS NORDTIBET

von Dr. KARL METZ, Leoben.

Als mir Anfang 1940 eine Serie von jungpaläozoischen Bryozoen, die auf der letzten grossen Expedition Dr. SVEN HEDINS in Nordtibet durch Dr. E. NORIN aufgesammelt worden waren, von Prof. HERITSCH in Graz übergeben wurde, hoffte ich reichliches Vergleichsmaterial und die gesamte entsprechende Literatur mir beschaffen zu können, insbesondere erhoffte ich vollständige Einsichtnahme in die in den letzten Jahren reichlich erschienenen russischen Arbeiten über oberpaläozoische Bryozoen.

Die äusseren Umstände erschwerten eine Anschaffung der gesamten Literatur, besonders der Krieg machte die Beschaffung von Vergleichsmaterialien unmöglich. Ich musste daher auf wertvolle Behelfe verzichten. Durch diese Umstände, sowie durch die Unkenntnis von Begleitversteinerungen ergab sich auch eine allgemeine Unsicherheit in der Alterseinstellung der behandelten Arten, die nur einigermassen durch das Entgegenkommen von Herrn Dozent Dr. E. NORIN in Lund und die freundschaftliche Hilfsbereitschaft von Dr. F. KAHLER in Klagenfurt behoben werden konnte.

Wenn trotzdem diese mehr paläontologische Zusammenstellung ohne die wünschenswerte stratigraphische Unterbauung, wie sie aus der modernen Literatur über das Perm erwartet werden könnte, vorgelegt wird, so hat das seinen Grund darin, dass in absehbarer Zeit keine wesentliche Änderung der herrschenden Schwierigkeiten zu erwarten ist. Eine Verbesserung liesse sich nur auf breiter Grundlage liefern, wie es die Bearbeitung oder Einsichtnahme der Vergleichsmaterialien bieten würde. Die Inangriffnahme solcher Studien wurde aus den schon genannten Gründen vorläufig ebenfalls zurückgestellt.

Das Material ist z. T. ausgezeichnet erhalten und erlaubte die Herstellung aufschlussreicher und gut messbarer Präparate. Die einzelnen Proben wurden an verschiedenen Fundpunkten gesammelt und zeigen dementsprechend auch verschiedene Erhaltungszustände. In der folgenden Tabelle wird eine Zusammenstellung der Fundpunkte, ihrer Lage, des Versteinerungsmaterials und der vermutlichen stratigraphischen Einstellung gegeben.

TABELLE I.

Handstück	Fundort	Gestein	bestimmte Bryozoen	Alter	Begleitversteinerungen
A 2	Lok 77 lat 34°34' long 80°32' Chutzar	grauer, fossilreicher, etwas toniger Kalk	*Ramipora hochstetteri* Toula *Dichotrypa inflata* n. sp. » *clavaeformis* n. sp. *Cystodictya sphenoides* n. sp.	Unteres Perm = unteres Mittelperm (wahrscheinl. = unterer Trogkofelkalk der Alpen) [1]	Fusuliniden, schlecht erhaltene fenestellide Bryozoen
A 5	» »	dunkelgrauer, körnig kristalliner Krinoidenkalk	*Batostomella spinigera* Bassler *var. nov. acanthostellata*		Kleine Brachiopoden-Bruchstücke
A 6	» »	» »	*Batostomella* sp.		Kleine Brachiopoden-Bruchstücke
A 8	» »	» »	*Polypora* sp. indet. (nicht beschrieben)		Kleine Brachiopoden-Bruchstücke, Krinoiden
A 12	» »	» »	*Polypora* sp. ex gr. *orbicribata* Keys		Fusuliniden, Brachiopoden-Bruchstücke, Algen
B 1	Lok 83 lat 34°11' long 79°58' 17 km östl. d. Sees Dyaptzo	eisenschüssiger ziegelroter, toniger Kalk	*Polypora goldfussi* Eichw. » sp. ex gr. *tripliseriata* Bassl. » *tibetana* n. sp. *Fenestella* aff. *pulchradorsalis* Bassler » *permiana* Stuck. var. nov. *pentagona*	= Lok 77	
B 2	» »	grauer, etwas toniger Kalk	*Dichotrypa inflata* n. sp.	»	
B 3	» »	eisenschüssiger ziegelroter, toniger splitteriger Kalk	*Ramipora hochstetteri* Toula *Fenestella* cf. *kolymaensis* Nekhoroshev.	»	
B 4	» »	grauer Kalk	*Polypora* sp.	»	Fusuliniden
B 5	» »	» » etwas kristallin	unbestimmbare Reste	»	Krinoiden, kleine Brachiopoden
C 1	Lok 79 Tashliq-köl	grauer, splittriger Kalk	unbestimmbare Reste	Liegend zu Lok 78	Krinoiden, Algen
C 4	» »	fast weisser Kalk	*Cyclotrypa megastoma* n. sp.		
C 5	» »	» »	Reste von *Ascopora*?		Algen
D 8	Lok 78 lat 34°38' long 80°39.8' Tashliq-köl	weisser kristalliner Krinoidenkalk	*Fistulipora* sp.	höheres Perm = Productuskalk von Djoulfa [2]	
G 2	Lok 79 A lat 35°58' long 78°0' Maliq shah Karakoram	dunkelgrauer toniger, etwas eisenschüssiger Kalk	*Polypora macrops* Bassler	unbestimmter Horizont des Perm	Kleine Brachiopoden Reste von fenestelliden Bryozoen

[1]) Nach einer brieflichen Mitteilung von Dr. Kahler entspricht der Entwicklungszustand der Fusuliniden etwa dieser Alterseinstellung. (Es sind Übergangsformen zu *Parafusulina*).

[2]) Zu dieser Altersbestimmung kommt Prof. Heritsch auf Grund der Korallen: *Protomichelinia microstoma* Yabe-Hayasaka, Amplexus sp., Paläosmilia sp.

Wie aus der Übersicht deutlich wird, stellen die Bryozoen aus der Gruppe der Fenestelliden, wie zu erwarten, die Hauptmasse der Formen dar. Ihre Bestimmung wurde durch zweierlei Umstände sehr erschwert.

Die genannte Gruppe zeitigte im Karbon und Perm eine unübersehbare Fülle von Arten, die heute wesentlich in russischer und amerikanischer Literatur aufscheint. Die Russen bauten in den letzten Jahren die Bearbeitungsmethoden von Bryozoen zu einem komplizierten und bis in die letzten Einzelheiten des inneren Feinbaues gehenden Schema aus, welches bei den fenestelliden Bryozoen in übersichtlicher Tabellenform zum Ausdruck kommt. Im Gegensatz dazu arbeiten die Amerikaner viel mehr nach äusseren Merkmalen (Skulptur etc.). Die Angaben innerer Merkmale sind im Vergleich zu russischen Autoren überaus lückenhaft, woraus sich die schwierige Vergleichbarkeit der beiderseitigen Literaturangaben ergibt. Wenn ich bei der Beschreibung fenestellider Bryozoen mehr der Methode der Russen folgte, so hat das seinen Grund darin, dass mir ihre Beschreibung erschöpfender schien und auch dem Erhaltungszustand des mir vorliegenden Materials mehr angepasst war. Ich hoffte dadurch einen späteren Vergleich der hier beschriebenen Arten wesentlich zu erleichtern, zumal bei der anerkannten Notwendigkeit von vergleichenden und absoluten Messungen der Wert auch guter Abbildungen geringer ist, als bei anderen Tiergruppen.

Ich betone jedoch, dass mir der Bestimmungswert mancher in der Tabelle angeführten Messungen als noch sehr unsicher erscheint, wie überhaupt die zur Artabgrenzung oder sogar Gattungsabgrenzung verwendeten Kriterien noch nicht mit genügender Sicherheit festzustehen scheinen. Darin mag auch der Unterschied in der Methodik beider genannter Literaturzweige begründet liegen.

Für die meisten übrigen Gattungen treten die genannten Schwierigkeiten mehr in den Hintergrund gegenüber der Unsicherheit, die durch die noch mangelnde Kenntnis ihrer Verbreitung und Formenfülle bei der Bestimmung gegeben ist.

Ich bin für die Überlassung des wertvollen und lehrreichen Materials zu grösstem Dank verpflichtet und gebe der Überzeugung Ausdruck, dass seine Kenntnis bei der Bearbeitung späterer Aufsammlungen von entscheidendem Nutzen sein wird.

UNTERORDNUNG: *CYCLOSTOMATA.*

Fistulipora Mc. Coy.

Zoarium massiv, flach, verzweigt, parasitisch oder freiwachsend, unter der Oberfläche mit gefalteter Epithek. Zoözien zylindrisch oder oval eiförmig, im Querschnitt dünnwandig bis nahe der Oberfläche. Sie sind durch Diaphragmen unterteilt und umschlossen durch ein ein- oder mehrreihiges Blasengewebe. Lunarien in stärkerer oder schwächerer Ausbildung immer entwickelt.

Fistulipora sp.

In einem weissen Kalkstück liegt ein strauchförmiges Zellenbündel in unvollständiger Erhaltung. Das zwischen den Zellröhren liegende Blasengewebe ist zerstört. Die Röhren zeigen einen Durchmesser von 0,42 mm, der zwischen ihnen liegende Raum misst durchschnittlich 0,40 mm. In ziemlich regelmässigen Abständen liegen in den Tuben Diaphragmen ohne Perforation, 3—4 auf 2 mm Längserstreckung der Zoözialtuben.

Im Querschnitt sind die Röhren unregelmässig rund, auf einer Seite kräftig gerundet, auf der Gegenseite stark abgeflacht, vereinzelt mit einer kleinen lippenartigen Einstülpung. Die stark gerundete Seite trägt ein Lunarium, welches halbmondförmig regelmässig gekrümmt oder annähernd rechtwinkelig abgeknickt ist. Die Zellröhren sind allseitig gleichmässig gestellt, ohne dass eine besondere reihenweise Ordnung zum Ausdruck käme. Auf zwei Millimeter in jeder Richtung des Zoariums liegen 2—2,5 Zellenquerschnitte.

Cyclotrypa Ulrich.

Im Bau entsprechend *Fistulipora,* doch fehlen die Lunarien und die Zoözialröhren sind im Querschnitt rund.

Cyclotrypa megastoma n. sp.

Taf. XVI, Fig. 1—5.

Ein auffallend grosses und erstklassig erhaltenes Stück weist einen Durchmesser der Zoözialtuben von 1—1,14 mm (nahe der Basis auch 0,72 mm) auf. Auf 5 mm beliebiger Erstreckung des Zoariums liegen 2,5—3 Öffnungen, die auf der Anwitterungsfläche leicht über der zwischenliegenden Blasengewebszone erhaben sind. Das Blasengewebe zeigt 3—4 Gewebslagen zwischen zwei Zoözialröhren. In annähernd regelmässigem Abstand voneinander liegen in den Zoözialröhren auf 2 mm Länge 7 Diaphragmen, die stellenweise auffallend unregelmässige Wölbungen und Knitterungen aufweisen können. Die Zoözialwände sind gleichmässig 0,07—0,08 mm dick.

Im Querschnitt erweisen sich die Zoözien als vollkommen rund, ohne Spur eines Lunariums. Die zwischen den runden Öffnungen liegenden Zellen des Blasengewebes sind gleichmässig polygonal gebaut und erweisen sich auch im Längsschnitt als regelmässig.

Die beschriebene Art wächst unregelmässig radialstrahlig um einen Fremdkörper und erreicht die beachtenswerte Dicke von maximal 8 mm.

Ein zweites kleineres Exemplar im gleichen Gesteinstück zeigt die selben Eigenschaften und wird der gleichen Art zugezählt. (Taf. XVI, Fig. 1).

Da von dem Fundort der vorliegenden Art keine begleitenden Versteinerungen vorliegen und auch die Fazies des beherbergenden Kalkes sich von der der übrigen Fundorte unterscheidet, ist eine direkte Einstufung nicht möglich.

Das Genus Cyclotrypa hat seine Hauptverbreitung im Devon, geht jedoch im Ural (*C. waageni* STUCK. bei NIKIFOROVA 1938 pag. 47, 216, = *Dybovskiella waageni* STUCKENBERG 1895, pag. 23, 24, Taf. XII, Fig. 3) in das Oberkarbon hinauf. Die von CONDRA 1902 beschriebene Art *C.? barberi* würde für die gleiche Verbreitung in Nordamerika (Nebraska) sprechen.

UNTERORDNUNG: *TREPOSTOMATA.*

Batostomella ULRICH.

Zoarium aus dichotomierenden schlanken Zweigen bestehend. In den Zoözien sind wenige Diaphragmen entwickelt. Zoözialöffnungen sind klein, rund oder oval, Acanthoporen zahlreich entwickelt und klein, die kleinen Mesoporen mit runden Öffnungen.

Batostomella spinigera BASSLER *var. nov. acanthostellata.*

Taf. XVIII, Fig. 2, 4—6.

Vergl. 1929 BASSLER, pag. 61, Taf. 12, Fig. 5—11.

Ein einzelnes Exemplar zeigt mehrere von einer gemeinsamen dünnen und löcherigen Basis ausgehende Zweige, die sich auch gabeln.

Der durchschnittliche Durchmesser dieser Zweige ist 3,3—4,3 mm. Ein vom Hauptexemplar getrennter, jedoch im gleichen Präparat liegender etwas schiefer Querschnitt mag einen Durchmesser von 7 mm erreichen.

Tangentialschnitte zeigen auf 2 mm Zweiglänge 6 Zoözialöffnungen, die oval geformt und ziemlich unregelmässig angeordnet sind. Ihre Durchmesser schwanken zwischen 0,19—0,30 mm. Vereinzelt kommen auch auffallend kleine Öffnungen von 0,12—0,15 mm vor. Die Zoözialtuben zeigen im Querschnitt stets polygonale (4—7-eckige) Umrisse von 0,25—0,30 mm Durchmesser.

Die regelmässig gebauten Wandverdickungen beginnen erst ziemlich weit an der Peripherie der Zweige, so dass der Axialteil einen verhältnismässig breiten Raum einnimmt. Die Zoözialtuben gehen in regelmässiger Krümmung in den peripheren Teil über und weisen in den meisten Fällen im Übergangsraum 1 bis höchstens 2 nicht perforierte Diaphragmen auf.

Mesoporen treten auffallend stark zurück und verschwinden in Tangentialschnitten, die knapp unter der Oberfläche liegen, vollständig. Ihre Durchmesser schwanken zwischen 0,07 und 0,1 mm. Dagegen sind Acanthoporen reichlich in unregelmässiger Streuung und stark veränderlicher Grösse vorhanden, ihre Durchmesser schwanken zwischen 0,06 und 0,1 mm. Sie erwiesen sich in den meisten Fällen als sternförmig im Querschnitt.

Das starke Zurücktreten von Mesoporen gegenüber den häufigen Acanthoporen sowie die Entwicklung der Diaphragmen in den Zoözialtuben weisen auf enge Verwandtschaft mit der von BASSLER aus Timor beschriebenen Art *B. spinigera.* Die von NIKIFOROVA 1933 aus Djoulfa beschriebene *var. araxensis* unterscheidet sich von unserer Art weniger durch die Grösse als durch die vergleichsweise stärkeren Mesoporen und durch runde Acanthoporen.

Batostomella sp.

Taf. XVIII, Fig. 3, 7.

Ein auffallend kräftiges unvollständig erhaltenes Exemplar mit dem Durchmesser von 10,7 mm zeigt auf 2 mm Länge des Zoariums 5—6 Öffnungen. Diese sind im Tangentialschnitt oval bis kreisrund und messen 0,25—0,30 mm im Durchmesser. Im Querschnitt erweisen sich die Zoözialtuben als polygonal mit einem Durchmesser von durchschnittlich 0,30 mm. Diaphragmen sind selten im Grenzgebiet zwischen Axialteil und Peripherie entwickelt.

Mesoporen sind zwischen den dicht gestellten Zoözialöffnungen überaus selten, dagegen treten reichlich Acanthoporen auf. Diese sind rund und zeigen eine zentrale Öffnung inmitten eines konzentrischen fibrösen Gewebes. Ihre Durchmesser schwanken zwischen 0,08—0,11 mm. Zahlreiche, wesentlich kleinere Acanthoporen zeigen polygonalen Umriss. Alle Acanthoporen schliessen sich, zu Reihen geordnet, in Polygonen um die Zoözialöffnungen zusammen.

UNTERORDNUNG: *CRYPTOSTOMATA.*

Fenestella LONSDALE.

Zoarium trichter- oder fächerförmig, nur an der Innenseite zellentragend, Zweige gewöhnlich gerade, vereinzelt gekrümmt in regelmässigen Abständen durch Querbrücken miteinander verbunden. Zellöffnungen zweireihig angeordnet, durch einen einfachen oder höckerigen Mediankiel voneinander getrennt.

Fenestella parviuscula BASSLER.

Taf. XIX, Fig. 1.

1929 BASSLER pag. 76, Taf. 17, Fig. 8—13.

Das Bruchstück eines sehr feinen Netzes stimmt in seinen Ausmassen vollständig mit den von BASSLER angegebenen wenigen Massen überein. Charakteristisch sind die quadratischen Fensterchen mit abgerundeten Ecken und dünnen, gleichmässig geraden Querbrücken zwischen den Zweigen.

TABELLE II.

	Zahl der Zweige auf 10 mm Breite des Zoariums	Zahl der Maschen auf 10 mm Länge des Zoariums	Zahl der Zoözien auf 5 mm Länge der Zweige	Querschnittformen der Zoözien	Zahl der nebeneinander liegenden Zoözialreihen im Zweig	Breite der Zweige	Länge der Fensterchen	Breite der Fensterchen	Breite der Dissepimente
Fenestella parviuscula BASSLER	22	19	21	pentagonal-dreieckig		0.19—0.26	0.38—0.41	0.26—0.30	0.11—0.15
Fenestella permiana STUCK. *var. nov. pentagona*	12 (14)	7 (9)	11 (12)	regelmässig pentagonal		0.42—0.53 (0.35—0.50)	1.06—1.29 (0.95)	0.40—0.61 (0.38)	0.38—0.50 (0.30)
Fenestella cf colymaensis NEKH.	ca 15	ca 10	ca 10	z. T. pentagonal		0.38—0.45	0.68—0.76	0.34—0.45	0.34—0.38
Fenestella sp. aff. pulchradorsalis BASSLER	13	19	15—16	pentagonal		0.31—0.45	0.96—1.07	0.45—0.53	0.19-0.27
Polypora timorensis BASSLER *var. nov. regularis*	9	7	13—14	pentagonal	3—4 (5)	0.57—0.75 extrem 0,90	1.10—1.21	0.57—0.70	0.38—0.49
Polypora goldfußi EICHW.	5—(6)	2.5—(3)	11.5—12	rhomb. selten pentagonal	5	0.98—1.12	2.9—3.8 extrem 4.2	0.98—1.54 extrem 1.96	0.42—0.70 extrem 0.98
Polypora sp. ex. gr. tripliseriata BASSLER	9—11	8	13	pentagonal	3	0.55—0.60	0.75—0.95	0.40—0.53	0.40—0.53
Polypora tibetana n. sp.	5—7	6	12	rhomboidal selten pentagonal	4	0.8—1.1	1.4—1.82	0.8—1.1	0.45—0.7
Polypora macrops BASSLER	10	10	16	hexagonal	4 (5)	0.57—0.80	0.57—0.68	0.38—0.45	0.38—0.53
Polypora sp.	12	11	18—19		4	0.45—0.64	0.45—0.67	0.38—0.40	0.54—0.60
Polypora sp. ex. gr. orbicribata KEYS	6	5—6(?)	ca 13	?	6	1.42—1.52	1.14—1.21 (1.33—1.50)	0.40—0.80	0.72—0.90 (0.60)

Die Zoözien sind undeutlich dreieckig, die Zweige tragen auf der Oberseite einen deutlichen Kiel, während die nicht zellentragenden Rückseiten mässig gerundet sind. Eine Längsstreifung ist auf den Zweigen, wie auf den Querbrücken vorhanden. Durch kräftigen Gewebeansatz an der Rückseite der Zweige und Dissepimente erhält das Netz mitsamt dem Kiel der Oberseite eine Dicke von 0,42 mm.

Die Massverhältnisse der Art sind der Tabelle zu entnehmen.

Fenestella permiana STUCK.
Var. nov. pentagona.

Taf. XIX, Fig. 3.

Vergl. 1895 STUCKENBERG, pag. 149, Taf. XXI, Fig. 5.

Zwei ausgezeichnet, wenn auch nur in Bruchstücken erhaltene Netze unterscheiden sich untereinander in ihren Ausmassen nur unwesentlich, lassen jedoch in den Grössenverhältnissen unverkennbare Beziehungen zu *Fen. permiana* erkennen. Die Masse beider Exemplare sind der Tabelle zu entnehmen.

Von der typischen *Fenestella permiana* unterscheiden sich die Stücke aus Nordtibet darin, dass die Zoözien regelmässige Pentagone bilden, die zackig ineinandergreifen. Erst dort, wo sie sich voneinander lösen, erhalten sie unregelmässig viereckige bis tropfenförmige Umrisse. Auch ist die die beiden Zellreihen trennende Linie knapp unter der Oberfläche nicht mehr gezackt oder wellig, sondern verläuft gerade, wie die Kiellinie der Oberfläche. Zwischen den runden Zoözialöffnungen sind zahlreiche feinste Poren zu beobachten.

Fenestella cf. kolymaensis NEKHOROSHEV.

Taf. XIX, Fig. 2.

NEKHOROSHEV, Kolyma Region, Taf. I, Fig. 3. Textfig. 1.

Mir liegt ein Exemplar einer ziemlich feinmaschigen Art mit vergleichsweise breiten, undeutlich sechseckigen bis tropfenförmigen Zoözialschnitten im Längsschliff vor. Die Art hat einen deutlichen Kiel, der im Längsschliff zwischen den Zoözialreihen als schwach gekrümmtes Band erscheint. Auf 10 mm Breite des Zoariums kommen 15 Zweige, auf die gleiche Länge 10 Maschen. In 5 mm Länge liegen in einer Reihe c:a 17 Zoözien. Die Breite der Zweige ist 0,38—0,45 mm, die Fensterchen sind 0,68—0,76 mm lang und 0,34—0,45 mm breit. Die Dissepimente sind bei unserer Art 0,32—0,36 mm breit, während NEKHOROSHEV bei seiner Art nur 0,16—0,20 mm angibt. Äusserlich sind auf dem Kiel feine Tuberkeln feststellbar, die Rückseite ist gestreift.

Das mir vorliegende Exemplar hat auch gewisse Ähnlichkeiten mit *Fen. basleoensis* BASSLER 1929, unterscheidet sich von dieser jedoch durch die länglicheren Zoözien im Tangentialschnitt.

Nach den Angaben NEKHOROSHEVS wurde *Fenestella kolymaensis* in Schichten des hohen Oberkarbons bis unteren Perms gefunden.

Fenestella sp. aff. pulchradorsalis BASSLER.

Taf. XIX, Fig. 4, 5.

Vergl. 1929 BASSLER, pag. 74, Taf. 16, Fig. 10—13, Taf. 18, Fig. 1—4.

Mehrere Exemplare eines regelmässig gebauten Netzes lassen immer wieder die gleichen Grössenverhältnisse erkennen. Die Zoözien sind wechselständig, pentagonal bis tropfenförmig und in günstigen Präparaten lässt sich das Vorhandensein eines Kieles erkennen.

Die Rückseite zeigt bei den Exemplaren von Timor nach der Beschreibung BASSLERS Verdickungen der Zweige und Dissepimente, ferner eine Granulierung, die in Streifen angeordnet ist. Die Verdickungen scheinen bei meinen Exemplaren zu fehlen, auch ist die Ornamentation unzureichend erhalten. Ein weiterer Unterschied gegenüber der Originalart BASSLERS liegt darin, dass die Exemplare aus Tibet mit grosser Regelmässigkeit 9 Maschen auf 5 mm zeigen, während die von Timor 10 Maschen aufweisen.

Polypora MC. COY.

Zoarium wie bei *Fenestella,* aber die Zellen zwei-achtreihig ohne Mediankiel, dagegen vereinzelt Reihen von Knötchen zwischen den Zellen.

Polypora timorensis BASSLER *var. nov. regularis.*

Taf. XIX, Fig. 8.

Vergl. 1929 BASSLER, pag. 79, Taf. 19, Fig. 1—4.

Es liegt das Bruchstück eines Exemplares vor, das in seinen Ausmassen am meisten der von BASSLER beschriebenen Art *P. timorensis* entspricht. Die Masszahlen mögen der Tabelle entnommen werden. Von der Variation *darashamensis,* die von NIKIFOROVA aus Djoulfa beschrieben wurde, ist unser Exemplar durch die grössere Anzahl der Maschen auf 10 mm getrennt. Dementsprechend sind auch die Fensterchen in dem mir vorliegenden Bruchstück etwas kürzer (Länge 1,10—1,21 gegenüber 1,28—1,61 mm bei der Art aus Djoulfa).

Die Zoözien sind regelmässig 4 reihig geordnet, liegen jedoch unmittelbar vor einer Dichotomie in 5 und unmittelbar nachher in 3 Reihen. Die Zellöffnungen sind rund, in tiefen Schnitten zeigen die Zoözien rhombische bis sechseckige Umrisse. Sie sind in oberflächen-nahen Schnitten durch leicht geschwungene Längslinien getrennt.

Die Rückseite ist gestreift und wie es scheint ohne Granulierung.

Polypora goldfussi EICHWALD.

Taf. XIX, Fig. 9.

1895 STUCKENBERG, pag. 155, Taf. XXII, Fig. 3.

1938 NIKIFOROVA, pag. 133, Taf. XXVII, Fig. 6, 7. XXXI, Fig. 1—4.

Es liegen mehrere Bruchstücke grösserer Netze vor, welche erst bei der Präparation eines Handstückes gefunden wurden, deren natürliche Oberflächen also nicht erhalten sind.

Die Zweige (0,98—1,12 mm breit) sind gerade oder schwach gekrümmt und vermehren sich durch Dichotomie oder Einschaltung neuer Zweige. Auf 10 mm Breite des Zoariums sind 5, seltener 6 Zweige zu zählen, auf die gleiche Länge des Zoariums 2,5—3 (selten) Maschen. 11, 5—12 Zoözien liegen in einer Reihe auf 5 mm Zweiglänge. Die Zoözien sind gewöhnlich in 5 Reihen angeordnet, doch findet man vor einer Verzweigung auch 6—7 Reihen und hinter einer solchen 4 Reihen. In Schnittlagen, in denen die Zoözien rund erscheinen, sind sie von zahlreichen, in Reihen geordneten feinen Poren umgeben. Die von den Zweigen sich scharf abhebenden Dissepimente wechseln in ihrer Breite stark (0,42—0,70 mm, extrem bis 0,98 mm). Die Fensterchen zeigen Längen von 2,6—4,2 mm und Breiten von 0,98—1,54 mm (extrem 1,96 mm).

Polypora sp. ex. gr. tripliseriata BASSLER.

Taf. XX, Fig. 6.

Mir liegen aus einem Handstück zwei Exemplare einer schlanken *Polypora* vor. Der Bau des Netzes ist sehr regelmässig mit geraden und nicht oft dichotomierenden Zweigen. Die Art zeigt folgende Masse:

Zahl der Zweige auf 10 mm Breite des Zoariums: 9—11.
„ „ Fensterchen „ Länge „ „ : 8.
Zahl der Zoözien in 5 mm Länge des Zweiges: 13.
Breite der Zweige: 0,55—0,60 mm.
Länge der Fensterchen: 0,75—0,95 mm.
Breite „ „ : 0,40—0,60 „
Breite der Dissepimente: 0,40—0,45 mm (Extrem 0,38—0,53 mm).

Die Zoözien sind in 3 Reihen angeordnet, an Verzweigungen beobachtet man auch 2 und 4 Reihen. Die Rückseite der Zweige ist längsgestreift. In einigen Schnitten sieht man zwischen den Zoözialreihen geschwungene Mittelstreifen, die ihrerseits in einem fein granulierten Gewebe liegen.

Die von BASSLER aus Timor beschriebene Art *Pol. tripliseriata* zeigt zwischen den Zoözialreihen Längsleisten, die zwischen den Zoözien je einen Dorn tragen. Diese Eigenheit liess sich an den vorliegenden Exemplaren nicht beobachten. Die Art aus Nordtibet zeigt auf 5 mm Zweiglänge auch nur 13 Zoözien, während man aus der Beschreibung BASSLERS auf 16 und mehr schliessen kann.

Polypora tibetana n. sp.

Taf. XIX, Fig. 5, 7.

Es liegt ein wohlerhaltenes Exemplar vor, dessen Rückseite auf der Anwitterungsfläche eines Gesteinsstückes sichtbar ist. Diese ist nur sehr schwach gewölbt und durchwegs mit Längsstreifen versehen. Teilweise gehen diese auch auf die Dissepimente über. Eine feine Granulierung ist vereinzelt zu beobachten.

Auf 10 mm Breite des flachen Netzes liegen 5—7 Zweige, deren Breite zwischen 0,8 und 1,1 mm schwankt. Auf 10 mm Länge des Zoariums liegen 6 breit ovale bis runde Fensterchen, deren Länge 1,4 mm (extrem 1,82 mm) und deren Breite (0,8—1,0 mm) ist. Auf 5 mm Länge der Zweige sind 12 meist rhomboidale Zoözien sichtbar. Diese liegen in 4 Reihen geordnet, nur vor Gabelungen sind 5 Reihen sichtbar. Wo die Zoözialreihen an Dissepimenten vorbeilaufen, ragen mitunter Zoözien weit in den Raum der Querbrücken hinein und in einem Falle sind ausser der Reihe zusätzlich noch zwei Zellen entwickelt, die am Rande der Dissepimente liegen.

Die Breite der Dissepimente beträgt an der schmalsten Stelle in der Mitte 0,45—0,5 mm, jedoch nicht selten auch 0,7 mm. Zwischen den Zoözien ist ein fibröses Gewebe entwickelt, in dem Anhäufungen feiner Poren sichtbar sind.

Die Art ist durch auffallend kurze und breite Fensterchen und die geringe Anzahl von Zoözien auf 5 mm Länge charakterisiert.

Polypora macrops Bassler.

Taf. XX, Fig. 1, 5, 7.

1929, pag. 78, Taf. XVIII, Fig. 11—13.

Ein mir vorliegendes Exemplar ist dadurch charakterisiert, dass die Querbrücken fast die Dicke der Zweige erreichen und so eng stehen, dass die dazwischenliegenden Fensterchen nahezu kreisrund erscheinen. Der Netzbau ist überaus regelmässig. Auf 10 mm Breite des Zoariums kommen 10 Zweige mit einer durchschnittlichen Breite von 0,6—0,8 mm, auf 10 mm Netzlänge kommen 10 Maschen. Die Fensterchen schwanken je nach der Schnittlänge des Dünnschliffes in der Breite zwischen 0,38—0,45 mm und in der Länge zwischen 0,57—0,68 mm. Die kurzen Dissepimente erreichen Dicken von 0,53—0,68 mm. Die Zoözialöffnungen sind rund mit einem ganz schwachen Peristom und umgeben von reihenweise angeordneten feinen Tuberkeln. An den Ansatzstellen der Dissepimente ragen die Zoözien oft beträchtlich in den Raum der Querbrücken hinein, so dass sie diese bedeutend verengen.

Die Zoözien sind in 4 Reihen geordnet, doch zeigen die Stellen der Dichotomie auch 3 bis 5 Reihen.

Das mir vorliegende Exemplar ist nach der nicht zellentragenden Rückseite zu schwach konvex gekrümmt. Die Rückseite der Zweige zeigt eine gleichmässig schwache Wölbung und die übliche Längsstreifung.

Polypora sp.

Taf. XX, Fig. 3, 4.

Eine zur genauen Bestimmung ungenügend erhaltene Form zeigt folgende Abmessungen: Auf 10 mm Breite des Zoariums 12 Zweige und in der gleichen Länge 11 Maschen. Auf 5 mm Zweiglänge liegen in einer Reihe 18—19 Zoözien, die im allgemeinen 4 reihig geordnet sind. Breite der Zweige 0,45—0,64 mm, Länge der Fensterchen 0,45—0,67 mm, Breite 0,38—0,40 mm. Dicke der Dissepimente 0,54—0,60 mm. Die Fensterchen sind im Umriss breitoval bis rund und das Zoarium zeigt im Bau grosse Ähnlichkeiten mit *Polypora macrops* BASSLER. Doch hat das vorliegende Netz andere Masse. Nähere Details sind nicht festzustellen.

Polypora sp. ex. gr. orbicribrata KEYS.

Taf. XX, Fig. 2, 8, 9.

Vergl. dazu NIKIFOROVA 1938 pag. 142.

Das vorliegende unvollständige Exemplar zeigt folgende Masse: 6 Zweige auf 10 mm Breite, und 5 Maschen auf die gleiche Länge des Zoariums. Auf 5 mm Zweiglänge liegen c:a 13 Zoözien. Die Breite der Zweige ist 1,4—1,52, die Breite der Dissepimente rund 0,7 (0,9?). Länge der Fensterchen 1,14—1,21, ihre Breite ist 0,40—0,80 mm.

Die erhaltene, nicht zellentragende Rückseite ist gestreift und trägt unregelmässig verteilte Höckerchen. Auf den Zweigen sitzen 6 Reihen von Zoözien, deren Mündungen rund sind und die sich, soweit sie an den Flanken der Zweige liegen, kräftig nach aussen und gegen die Dissepimente wenden.

Nahe der Oberfläche legt sich an den Zellmündungen rund um das runde Operculum ein faseriges Gewebe mit vereinzelten Poren. Dieses Gewebe bildet einen breiten runden oder unbestimmt polygonalen Kranz. Zwischen den so gestalteten und lose liegenden Zellenmündungen liegen eckige, runde oder auch länglich gestreckte Gebilde in unregelmässiger Verteilung. Ohne Zweifel handelt es sich, wenigstens teilweise um accessorische Poren. Sie sind vereinzelt auch auf den Dissepimenten zu beobachten.

In tiefer liegenden Schnittlagen schliessen sich die Umhüllungen der Zellöffnungen zusammen, werden oval und schliesslich breit hexagonal. Die erwähnten accessorischen Poren verschwinden hier vollständig und das die Zellöffnungen umschliessende Hüllgewebe bildet sinusartig geschwungene Bänder.

Ramipora TOULA.
Ramipora hochstetteri TOULA.

Taf. XXI, Fig. 1—7.

1875 TOULA, Spitzbergen, 1875. Pag. 230, Taf. X, Fig. I a, b.
1938 NIKIFOROVA, Paläontologie 196, 276.

Das Genus *Ramipora* wurde 1875 von TOULA im wesentlichen auf Grund äusserer Merkmale aufgestellt. Die aus Spitzbergen stammende Art *Ram. hochstetteri* als Genotyp zeigt ein netzförmiges Wachstum ganz bestimmter Bauart: Von einem Stämmchen erster Ordnung zweigen paarweise gegenständige Zweige II. O. ab, welche untereinander durch ebenso abzweigende Äste III. O. verbunden sind. Diese Verbindung geschieht so, dass sich die Zweige III. O. treffen und miteinander irgendwie verschmelzen. Wie die Abbildung TOULAS zeigt, kommen jedoch auch Zweige III. O. vor, welche blind endigen. (Taf. 6, Fig. 7.)

Die Beobachtungen an den Exemplaren aus Tibet bestätigen diese Tatsachen vollständig und vermögen ergänzend noch einige Details zu liefern. Durchwegs konnte beobachtet werden, dass die Zweige II. O. auf beiden Seiten des zentralen Stämmchens nicht in einer Ebene liegen, sondern miteinander einen Winkel von 130—140° einschliessen. Die gleiche Eigentümlichkeit zeigen auch die Ästchen III. O. und die aus ihnen gebildeten Kommissuren. Durch die Verschiedenheit der Abzweigungswinkel kommen die aus den Zweigen III. O. entstandenen Kommissuren auch verschieden hoch zu liegen.

An den sehr zahlreichen Bruchstücken, die ich bei den Präparationen in den Gesteinsstufen finden konnte, zeigte sich immer wieder, dass die Netze die Tendenz haben, auseinander zu fallen, so dass jeweils die Stammstückchen mit den gegenständig angeordneten Verzweigungen übrigbleiben, während der netzförmige Habitus des Baues verschwindet.

Dieser recht regelmässig beobachtete Umstand veranlasst mich, kurz auf das von NIKIFOROVA aufgestellte Genus *Ramiporidra* einzugehen. Dieses lässt bei sonst gleichem Bauplan die Bildung der Kommissuren vermissen, so dass die Zweige alle blind endigen. Auch der innere Aufbau des Zoözialsystems entspricht vollkommen dem Genus *Ramipora.*

Nach dieser Definition gehören, wie NIKIFOROVA 1936 sehr richtig hervorhebt, auch alle von SHULGA—NESTERENKO (SHULGA—NESTERENKO *Gonocladia-Ramipora,* 1933) aus dem Petchoraland beschriebene *Ramipora*arten eigentlich dem Genus *Ramiporidra* an.

Wenn nicht der Zufall bei vorsichtiger Präparation der Gesteine einige durch Kommissuren zu Netzen verbundene Bruchstücke geliefert hätte, wären auch die Exemplare aus Nordtibet zum Genus *Ramiporidra* zu zählen gewesen. Die besondere Art der Erhaltungsfähigkeit und die Tatsache, dass die einzelnen An-teile eines Netzes nicht in einer Ebene liegen, wodurch auch Anwitterungsoberflächen nur Netzteile zeigen können, lassen mir die Aufstellung des Genus *Ramiporidra* bis zur Vorlage weiteren gut erhaltenen Materials noch als unsicher erscheinen. Die sowohl bei den Abbildungen Toulas, wie auch bei meinem Material zu beobachtende beginnende Regellosigkeit der Bildung von Kommissuren im Bereich der Zweige III. O., lassen diese Erscheinung auch als eine stark auf die Spitze getriebene Spezialisierung nach einer Richtung hin erscheinen. Es bleibt daher abzuwarten, ob das Merkmal der Kommissuren zur Charakteristik eines selbständigen Genus genügend ist. Überdies wissen wir nicht, ob nicht vereinzelt auch Bildung von Kommissuren bei *Ramiporidra*arten vorkommt, die uns ja, wie die Abbildungen Shulga—Nesterenkos zeigen, nur in Bruchstücken erhalten sind.

Der Innenbau von *Ramipora* ist gleich dem des sehr nahe verwandten Genus *Goniocladia* Etheridge durch eine senkrecht stehende Medianwand gekennzeichnet, an deren beiden Seiten sich die Zoözien anlagern. An der Ober- und Unterseite sind die Stämmchen gekielt. Die Zoözialöffnungen liegen beiderseits des Kieles nur an der Oberseite, während die Rückseite mit ihrem weit schwächeren Kiel keine Öffnungen trägt. Innerhalb der Zweige liegt an der Medianwand ein feines Blasengewebe, welches gegen die Aussenwand zu von einem aus Kapillaren bestehenden Gewebe, im Schnitte ähnlich einem Pallissadengewebe, abgelöst wird.

Die Exemplare aus Nordtibet zeigen folgende Artmerkmale:

Breite der Zweige: 0,90—1,15 mm.

Dicke der Zweige: 1,0—1,28 mm.

Ein konstantes Verhältnis zwischen der Breite und Dicke der Zweige konnte nicht beobachtet werden, immer jedoch sind die Zweige dicker. Der Querschnitt der Stämmchen ist daher oval, mit einer Zuspitzung auf der zelltragenden Seite, die durch einen kräftig ausgebildeten Kiel hervorgerufen wird. Auf der Rückseite ist ein Kiel nur ganz schwach ausgeprägt. Die Präparate zeigen auch, dass die Zweige höherer Ordnungen dem Hauptstämmchen an Breite und Dicke gleichkommen können, ja dieses sogar vereinzelt übertreffen.

Die Entfernung der Abzweigungsstellen der Ästchen II. O. oder III. O. ist ebenfalls nicht konstant und liegt zwischen 2,14—3,28 mm. Da die Zweige II. O. verschieden starke Krümmungen aufweisen, laufen sie nicht einander parallel und es werden die zu Kommissuren verbundenen Ästchen der III. O. verschieden lang. Die gleichen Unregelmässigkeiten sind auch den Abbildungen Toulas und Nikiforovas zu entnehmen.

Die Abzweigungswinkel der Ästchen schwanken zwischen 65—75°.

Eine zellentragende Oberfläche ist mir nicht erhalten, so dass über die Zahl der Zellreihen nichts gesagt werden kann. In einem senkrechten Querschnitt erscheinen jederseits der Medianwand 3 Zoözialröhren übereinander. Diese Zahl vermehrt sich bei einem schiefen Schnitt bis zu 8, da hiebei mehr der flach nach aufwärts strebenden Tuben getroffen werden. Bei ihrem Austritt aus der Zone des medialen Blasengewebes schwenken die Tuben verstärkt nach aussen, doch kommen knieartige Abknickungen nur selten zu stande.

Cystodictya ULRICH.

Zoarium aus zwei an einer Medianebene ausstrahlenden, Rücken an Rücken zusammenliegenden Zoözienlagen. Im inneren Teil zwischen den Zoözialröhren ein feines Blasengewebe. Das Zoarium formt im Querschnitt elliptische, hie und da dichotomierende Zweige. Die scharfen Längsränder tragen keine Zoözialöffnungen. Diese annähernd elliptisch im Querschnitt, in Längsreihen angeordnet (mit oder ohne Längsrippen dazwischen), Lunarien vereinzelt vorhanden.

Cystodictya sphenoides n. sp.

Taf. XVII, Fig. 6—9. Taf. XVIII, Fig. 1.

Eine kleine Anzahl parallelrandiger Stämmchen mit längsgerichteten Porenreihen zeigen einen Querschnitt, der linsen-spindelförmig ist. Der Querschnitt weist in seiner Längsachse eine mediane Lamelle auf, von welcher nach beiden Seiten des Stämmchens die Zoözialtuben ausstrahlen. Am Ursprungsort der Zoözialtuben, wo diese an der Medianplatte anliegen, ist ein schwaches, aber stets vorhandenes Blasengewebe entwickelt, welches nach aussen von einem dichten faserigen Gewebe abgelöst wird.

Die Eigentümlichkeit des Innenbaues, sowie das Fehlen von Poren zwischen den Zoözialöffnungen lässt die Zugehörigkeit der vorliegenden Exemplare zum Genus *Cystodictya* erkennen.

Die Stämmchen messen 2,1—2,6 mm im grösseren Durchmesser und 1,2—1,4 mm im kleineren Durchmesser. Die seitlichen Ränder sind meist als scharfe Kanten entwickelt, entlang der keine Zoözienreihen entwickelt sind. Auf 5 mm Länge des Stämmchens liegen in einer Reihe 10 Zoözialöffnungen. Auf einer Seite des Zweiges sind durchschnittlich 6 Reihen angeordnet. Ein wenig unter der Oberfläche liegender Tangentialschnitt zeigt, dass die Längsreihen der Zoözien zwischen parallelen Bändern liegen, die sich auf den im vorliegenden Falle allerdings nur schlecht erhaltenen Oberflächen der Stämmchen als schwache Längsrippen erkennen lassen.

Vereinzelt teilen sich die Stämmchen dichotom. Vor einer Gabelung sind dann 7 Zoözialreihen nebeneinander und unmittelbar nachher nur 5 zu beobachten. Die Öffnungen sind länglich oval mit einem längeren Durchmesser von 0,23—0,26 mm.

Im Längsschnitt sieht man den Verlauf der Zoözialtuben, die an der Aussengrenze der Blasengewebszone eine schwache Krümmung machen und senkrecht auf die Oberfläche hinausstossen. Hemisepten oder Diaphragmen sind nirgends zu beobachten. Die ovalen Tubenquerschnitte zeigen überall annähernd gleichmässig dicke Wände.

Dichotrypa ULRICH.

Das Zoarium ist breit und flach, sonst wie *Cystodictya.*

Dichotrypa inflata n. sp.

Taf. XVI, Fig. 6—8, Taf. XVII, Fig. 1, 2. Textfigur 1.

Die von einem flachen und breiten Zoarium stammenden Querschnitte dieser Art zeigen einen flach spindelförmigen Umriss, zum Teil mit säbelartiger Krümmung. Die grösste Dicke von 3—4 mm wird im mittleren Teil erreicht, während gegen die Enden, also die seitlichen Ränder des Zoariums hin, eine allmähliche Verdünnung eintritt. Die nicht porentragenden Ränder sind teils stumpf kantig, teils aber auch deutlich schneidenförmig ausgezogen (Textfig. 1). Immer sind die Oberflächen des Zoariums flach oder sehr wenig gekrümmt.

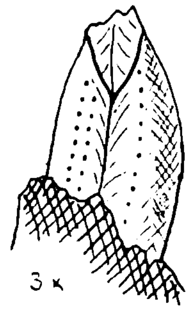

Fig. 1.

Die vorliegenden Exemplare lassen einen Schluss auf die genaue Gestalt des Zoariums nicht zu, doch sind Ausdehnungen von mindestens 20 mm in jeder Richtung nachweisbar.

Die Querschnitte zeigen eine durchlaufende Medianplatte, von welcher aus nach beiden Richtungen kurze und kaum gekrümmte Zoözialtuben nach den beiden Oberflächen streben, die sie meist im rechten Winkel erreichen. Die inneren, der Medianplatte naheliegenden Teile sind von einem Blasengewebe erfüllt, welches aber schon vor der Hälfte der Länge der Zoözialtuben immer undeutlicher wird. In Tangentialschnitten kommt dieses Blasengewebe örtlich zwischen den fast kreisförmigen Querschnitten der Zoözialtuben immer wieder zum Vorschein. Diaphragmen oder Hemisepten fehlen den Zoözialtuben vollständig.

Auf den Oberflächen sind die Zoözialtuben reihenweise nach Längs- und Diagonalrichtung geordnet, doch sind nicht selten auch unregelmässig stehende Öffnungen zu beobachten. Im Tangentialschnitt erweisen die Zoözialtuben einen breitovalen bis kreisrunden Umriss von 0,27—0,34 mm im Durchmesser.

Infolge weitgehender Zerstörung der Oberfläche durch Verwitterung lässt sich über die Art des Austrittes und über das Vorhandensein eines Peristoms nichts aussagen. Dünnschliffe in tangentialer Richtung zeigen kleine dunkle polygonale Flecken, die sich in ein bis zwei Reihen geordnet zu Pentagonen zusammenschliessen, die die Zoözialtuben umgeben. Ein kleines Stück der Anwitterungsfläche zeigt zwischen den Zoözialöffnungen Austritte nadelfeiner Poren, welche auch die freie Fläche einer macula einnehmen. Eine endgültige Entscheidung über die Natur dieser Poren ist vom vorliegenden Material aus unmöglich.

In sehr seltenen Fällen konnten an den Querschnitten von Zoözien lippenartige Einstülpungen in das Lumen beobachtet werden, die vielleicht als Lunarien anzusprechen sind.

Auf 2 mm in jeder Richtung der Oberfläche kommen 4—5 Zoözienschnitte. Maculæ (nicht zellentragende Plätze) sind ziemlich unregelmässig gestaltet und zeigen Durchmesser von 1,38—2 mm. Ihre Anordnung auf der Oberfläche des Zoariums ist nicht festzustellen.

Trotz des Mangels einiger Details ist die Art durch die charakteristische Gestaltung des Zoariums und die gegebenen Massverhältnisse genügend definiert.

Dichotrypa clavaeformis n. sp.

Taf. XVII, Fig. 3—5.

Es liegen einige Bruchstücke und ein ziemlich vollständig erhaltenes Exemplar vor.

Das Zoarium ist länglich fladenförmig und scheint mit einer Schmalseite auf dem Substrat aufgewachsen zu sein. Der abgebildete Querschnitt liegt in der Nähe der vermuteten Auflagerungsfläche. Querschnitte im breiteren (zentralen) Teile des Zoariums werden vergleichsweise flacher und denen der zweiten hier beschriebenen Art ähnlich.

Vom vollständigen Stück konnten folgende Masse abgenommen werden:

Maximale Breite des Zoariums: 10 mm
gemessene Länge „ „ : 22 mm (vollständig wahrscheinlich gegen 30)
Dicke „ „ : 4.8 „

Der Innenbau entspricht vollständig den früheren Beschreibungen. Die Zoözialtuben zeigen ovalen bis fast kreisförmigen Umriss mit Durchmessern von 0,19—0,30 mm. Die Zwischenräume zwischen ihnen sind 0,3—0,4 mm breit.

Die Öffnungen sind in strengen Längs- bzw. Diagonalreihen angeordnet. Auf 2 mm Erstreckung des Zoariums in der Längsrichtung liegen 2 Zoözien und ein kleiner Zwischenraum. In der Querrichtung gleicher Länge kann man 5 Längsreihen messen.

Die strenge Anordnung der Zoözialöffnungen wird nur durch die regelmässigen maculæ (zoözienfreie Plätze) unterbrochen, die ebenfalls längsgestreckt sind. Ihr Längendurchmesser ist 1,2—1,5 mm, der Querdurchmesser 0,95—1 mm. Sie sind alternierend angeordnet, in einer Entfernung von 2,5—3 mm voneinander.

Oberflächennahe Tangentialschnitte zeigen ein streifiges, die Zoözialtuben umfliessendes Gewebe. Dieses wird nach der Tiefe zu von Blasengewebe abgelöst. Mesoporen wurden nicht beobachtet.

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TAFELERKLÄRUNG.

Taf. XVI.

Fig. 1. *Cyclotrypa megastoma* n. sp. Fundort 79, 5, 4 x, Längsschnitt.
Fig. 2. „ „ „ „ 79, 4, 2 x, Querschnitt.
Fig. 3. „ „ „ „ 79, 3 x, Längsschnitt eines anderen Exemplares.
Fig. 4. „ „ „ „ 79, 1,5 x, angewitterte Oberfläche.
Fig. 5. „ „ „ „ 79, 10 x, Ausschnitt aus Querschnitt.
Fig. 6. Gesteinsoberfläche mit Bruchstücken von *Dichotrypa inflata*, n. sp. und einem Zweig von *Cystodictya sphenoides n. sp.* Fundort 77, 1,5 x.
Fig. 7. *Dichotrypa inflata n. sp.* Fundort 83, 7 x, Querschnitt durch ein unvollständiges Stück.
Fig. 8. „ „ „ „ 83, 18 x, Ausschnitt daraus.

Taf. XVII.

Fig. 1. *Dichotrypa inflata n. sp.* Fundort 83, 29 x, Querschnitt aus einem anderen Exemplar.
Fig. 2. „ „ „ „ 83, 19 x, Tangentialschnitt eines dritten Stückes.
Fig. 3. *Dichotrypa clavaeformis*, n. sp. Fundort 77, 4 x, Tangentialschnitt eines fast vollständiges Exemplares.
Fig. 4. „ „ „ „ 77, 5 x, Querschnitt aus der Nähe der Basis des gleichen Exemplares.
Fig. 5. „ „ „ „ 77, 18 x, Ausschnitt aus dem Tangentialschnitt. Bei tieferer Schnittlage erscheint die Blasengewebszone.
Fig. 6. *Cystodictya sphenoides n. sp.* Fundort 77, 5 x, Stämmchen im Gestein.
Fig. 7. „ „ „ „ 77, 5 x, dto, Tangentialschnitt.
Fig. 8. „ „ „ „ 77, 6,5 x, Längsschnitt eines Stämmchens.
Fig. 9. „ „ „ „ 77, 18 x, typischer Querschnitt.

Taf. XVIII.

Fig. 1. *Cystodictya sphenoides n. sp.* Fundort 77, 17 x, Detail aus Taf. II, fig. 8.
Fig. 2. Batostomella spinigera, var. nov. acanthostellata. Fundort 77, 2,2 x, Uebersicht über ein Exemplar.
Fig. 3. „ sp. Fundort 77, 1,5 x, Ansicht des Stückes im Gesteil.
Fig. 4. „ *spinigera, var. nov. acanthostellata*, Fundort 77, 16 x, Stück eines Querschnittes.
Fig. 5. „ *spinigera, var. nov. acanthostellata*, Fundort 77, 16 x, Längsschnitt eines Zweigstückes.
Fig. 6. „ *spinigera var. nov. acanthostellata*, Fundort 77, 38 x, Tangentialschnitt mit seltenen Mesoporen und sternförmigen Acanthoporen.
Fig. 7. „ sp. Fundort 77. Tangentialschnitt mit behöften Acanthoporen.

Taf. XIX.

Fig. 1. *Fenestella parviuscula* Bassler, Fundort 83, 13 x.
Fig. 2. *Fenestella cf. Colymaensis* Nekh., Fundort 83, 35 x.
Fig. 3. *Fenestella permiana* Stuck., *var. nov. pentagona*, Fundort 83, 8 x.
Fig. 4. *Fenestella sp. aff. pulchradorsalis* Bassler, Fundort 83, 16 x.
Fig. 5. „ „ „ „ „ 83, 1,4 x.
Fig. 6. *Polypora tibetana n. sp.* Fundort 83, 4 x.
Fig. 7. „ „ „ „ 83, 1,7 x.
Fig. 8. *Polypora timorensis* Bassler, var nov. regularis, Fundort 83, 16,4 x.
Fig. 9. *Polypora goldfussi*, Eichwald, Fundort 83, 4 x.

Taf. XX.

Fig. 1. *Polypora macrops* Bassler, Fundort 82, 1,6 x.
Fig. 2. *Polypora sp. ex. gr. orbicribrata* Keys, Fundort 77, 11 x, Querschnitt.
Fig. 3. *Polypora sp.* Fundort 83, 4 x.
Fig. 4. „ „ „ 83, 19 x.

Fig. 5. *Polypora macrops* BASSLER, Fundort 1065, 19 x.
Fig. 6. *Polypora sp. ex. gr. tripliseriata* BASSLER, Fundort 83, 3,8 x.
Fig. 7. *Polypora macrops* BASSLER, Fundort 82, 3,6 x.
Fig. 8. *Polypora sp. ex. gr. orbicribrata* KEYS. Fundort 77, 17 x.
Fig. 9. „ „ „ „ „ „ „ 77, 4 x.

Taf. XXI.

Fig. 1. *Ramipora hochstetteri* TOULA, Fundort 77, 4 x, Netzstück im Gestein.
Fig. 2. „ „ „ 6 x, gleiches Stück, zur Verdeutlichung abgedeckt.
Fig. 3. „ „ „ Fundort 83, 32 x, Längsschnitt.
Fig. 4. „ „ „ „ 83, 22 x, Querschnitt, etwas schief getroffen.
Fig. 5. „ „ „ „ 83, 22 x, Querschnitt an einer Verzweigungsstelle.
Fig. 6. „ „ „ „ 83, 4 x, Längschnitt.
Fig. 7. „ „ „ „ 83, Originalexemplar TOULAS, skizziert zur Verdeutlichung des Verzweigungssystemes ca 2,5 x.

APPENDIX C

MESOZOISCHE FOSSILIEN AUS DEM TSCHIPTSCHAK-TAL UND LINGSCHI-TANG

von HANS FREBOLD.

Die nachstehend beschriebenen Fossilien, die von Herrn Dozent Fil. Dr. ERIK NORIN während der von Dr. SVEN HEDIN geleiteten Zentralasienexpedition an verschiedenen Punkten im Tschiptschak-Tal und im Lingschi-tang gesammelt wurden, sind trotz ihres fast durchweg recht mangelhaften Erhaltungszustandes zum Teil recht wichtig, da sie eine Vervollständigung des auf Grund früherer Untersuchungen gewonnenen Bildes über die Stratigraphie dieser geologisch ja nicht eingehend bekannten Gebiete Tibets gestatten.

Die Fundpunkte sind auf der von Dr. ERIK NORIN entworfenen geologischen Übersichtskarte Pl. A eingetragen. In dieser sind auch die von DE TERRA während der Centralasienexpedition Dr. TRINKLERS ausgebeuteten und von STAESCHE (1932) beschriebenen Fundstellen in der Nähe der „Roten Kette" des Lingschi-tangs verzeichnet. Herrn Dr. ERIK NORIN spreche ich auch an dieser Stelle meinen besten Dank für die Überlassung der Materialien zur Untersuchung und für seine mir freundlichst gemachten Mitteilungen über die Fundumstände aus.

FOSSILIEN AUS DER TRIAS.

Fossilien, die mit Sicherheit in die Trias gehören, liegen mir nur von einem Fundpunkt vor, nämlich von der Lokalität 74 b. Dieser Fundpunkt liegt etwas nordöstlich der roten Kette, ein wenig ausserhalb des auf DE TERRAS geologischer Karte eingetragenen mesozoischen Gebietes. Die mir von diesem Fundpunkt vorliegende Form ist *Dielasma julicum* BITTNER, die durch eine Reihe von Exemplaren, welche aber meistens recht schlecht erhalten sind, vertreten ist.

Diese Art wurde auch aus DE TERRAS Material, das nur ca. 10 km weiter südlich (an DE TERRAS Fundpunkt 72 r) gesammelt war, von STAESCHE (1932) beschrieben. Es erübrigt sich, hier nochmals eine Beschreibung dieser Art zu geben, zumal auch die gute Übereinstimmung der mir vorliegenden Stücke mit den von STAESCHE (1932, auf Tafel 21 in Figur 17) gegebenen Abbildungen keinen Zweifel an der Identität der verglichenen Stücke aufkommen lässt.

Während DE TERRA zusammen mit *Dielasma julicum* BITTNER eine Reihe anderer Fossilien fand, die ebenfalls von STAESCHE beschrieben sind, enthalten die wenigen mir vorliegenden Stücke an bestimmbaren Fossilien nur die genannte *Dielasma*. Es kommen zwar Bruchstücke anderer Fossilien vor, jedoch sind diese unbestimmbar.

In Spiti kommt *Dielasma julicum* in der karnischen und norischen Stufe vor, STAESCHE stellt DE TERRAS Funde dieser Art in die norische Stufe. Als Gestein gab STAESCHE dunkelgrauen bituminösen Kalk an. In einem solchen liegen auch die mir vorliegenden, von Dr. NORIN gesammelten Stücke von *Dielasma julicum*. Hiernach erscheint es mir ausser Zweifel, dass die mir vorliegenden Stücke in den gleichen Horizont gehören wie DE TERRAS Material, das ja auch, wie bereits gesagt, an einer Lokalität gesammelt wurde, die nicht weit von NORINS Fundpunkt entfernt liegt.

Unter den übrigen mir vorliegenden Materialien finden sich ganz ähnliche Gesteine mit unbestimmbaren Fossilresten, die von der Lokalität 74 a stammen. Es ist sehr wahrscheinlich, dass hier der gleiche Horizont vorliegt.

FOSSILIEN AUS DEM JURA.

Jurafossilien habe ich von verschiedenen Fundpunkten als solche bestimmen können. Sie verteilen sich auf ein grösseres Gebiet. Der östlichste Fundpunkt (Lokalität 76) liegt von dem westlichsten (Lok. 68) ungefähr 190 km entfernt.

Aus den gefundenen Fossilien geht mit grösster Wahrscheinlichkeit das Vorliegen von zwei altersverschiedenen Horizonten hervor, von denen der eine in den unteren Dogger, der andere in das Bathonien-Callovien gehört.

Fossilien aus dem unteren Dogger.

Die wenigen und sehr schlecht erhaltenen Fossilien, die in den unteren Dogger gestellt werden können, wurden von Dr. NORIN an der *Lokalität 76* gesammelt. Diese Lokalität liegt in der östlichen Fortsetzung des von DE TERRA (1932) auf seiner geologischen Karte eingezeichneten Gebietes mit mesozoischen Bildungen. Das von dieser Lokalität vorliegende Gestein ist ein dunkelgrauer bituminöser Kalk. In diesem Kalk sind Fossilreste nicht selten, aber sie sind mit wenigen Ausnahmen meistens ganz unbestimmbar. Diese Ausnahmen sind: eine Form, die mit *Camptonectes lens* Sow. ident oder nahe verwandt ist, und eine *Trigonia*. Zu diesen Formen ist folgendes zu sagen:

Camptonectes lens Sow.

Vollständig erhaltene Exemplare liegen mir nicht vor. Immerhin lässt sich die Artzugehörigkeit noch ziemlich sicher bestimmen. Dies gilt besonders von einer vorliegenden linken Klappe. Sie war etwas höher als breit und ist mässig stark gewölbt. Die charakteristische Skulptur ist an einigen Stellen noch schwach erkennbar. Beide

Ohren sind gut erhalten, das vordere ist grösser als das hintere. Beide Ohren sind gegen die übrige Schale deutlich abgegrenzt.

STAESCHE (1932) nennt von den nahe gelegenen Lokalitäten 88 r und 89 r DE TERRAS ebenfalls *Camptonectes lens*. Die von ihm abgebildeten Exemplare (1932, Tafel 21 Figur 26, 27) sind kleiner als meine, jedoch weist er im Text auf das Vorliegen grösserer Stücke in DE TERRAS Sammlung hin.

Trigonia sp. indet.

Tafel XXII, Figur 1.

Ein einzelner schlecht erhaltener Steinkern einer *Trigonia* liegt vor. Ihre Umrisse sind nicht mehr sicher zu erkennen, die Ausbildung der Area überhaupt nicht. Scheinbar waren der Vorderrand und der Unterrand nur wenig gebogen. Ungefähr 16 nur schwach gekrümmte Rippen sind auf dem vorderen Schalenteil vorhanden. Die Areakante ist etwas erhaben. Über die ev. Skulptur der Area lässt sich wegen unzureichender Erhaltung nichts sagen.

Eine Bestimmung der Form kann nicht mehr vorgenommen werden. Die von STAESCHE (1932) beschriebenen beiden Trigonien, die von DE TERRAS nahe gelegenen Fundpunkten 88 r bzw. 89 r stammen, scheinen nicht zu der vorliegenden Form zu gehören.

Aus den vorliegenden Fossilien — *Camptonectes lens* und *Trigonia* sp. indet. — liesse sich das genaue Alter der an der Lokalität 76 auftretenden Gesteine nicht ohne weiteres bestimmen. Offenbar handelt es sich aber um die gleichen Bildungen, die etwas weiter westlich, nämlich an DE TERRAS Lokalitäten 88 r und 89 r, nachgewiesen sind, von wo mehr Fossilien vorlagen. Diese sind von STAESCHE in den unteren Dogger gestellt, ein Alter, das man daher auch für die Bildungen an der Lokalität 76 annehmen muss.

Chlamys (Radulopecten) aff. *tipperi* Cox.

Tafel XXII, Figur 2.

Vom *Fundpunkt 69* liegen mir nun einige weitere Fossilien vor, die zwar ebenfalls nicht genauer bestimmbar sind, aber doch auf das Vorhandensein eines gleichalten oder auch bereits jüngeren, zum Bathonien oder Bajocien gehörenden Horizontes an dieser Lokalität, die ca. 75 km südöstlich von der Lokalität 68 liegt, sprechen. Es handelt sich vorwiegend um *Chlamys*formen, die offenbar alle zu ein- und derselben Art gehören. Alle Formen sind entweder mit der Schalenaussenseite mit dem Gestein verwachsen oder liegen nur in Steinkernen vor, sodass ein vollständiges Bild von der Ausbildung der Skulptur nicht gewonnen werden kann.

Das auf Tafel XXII in Figur 2 abgebildete Stück weist eine Anordnung der Rippen auf, die es wahrscheinlich macht, dass die Form in die Gruppe *Radulopecten* gehört.

Die in der Mitte liegende Rippe tritt besonders stark als eine deutliche Erhebung gegenüber den anderen Rippen hervor. Die 4. Rippe, die rechts von dieser Mittelrippe liegt, scheint ebenfalls kräftiger als die übrigen Rippen zu sein, sie ist aber bei weitem nicht so kräftig, wie die Mittelrippe. Ob auch die 4. Rippe links von der Mittelrippe kräftiger war als die übrigen Rippen, lässt sich nicht mehr feststellen. Das besonders kräftige Hervortreten der Mittelrippe ist auch bei einem anderen der mir vorliegenden Bruchstücke deutlich zu erkennen.

Ein anderes der vorliegenden Stücke zeigt im Gegensatz hierzu in der Mitte der Schale einen breiteren und stellenweise auch tieferen Rippenzwischenraum als zwischen den anderen Rippen. Dieser breite Rippenzwischenraum in dieser Schale entspricht offenbar der Erhebung der Mittelrippe in den im vorhergehenden beschriebenen Schalen.

Eine ähnliche Skulptur findet sich bei einer Reihe von *Chlamys*formen, die als *Radulopecten* (Rollier) zusammengefasst sind. Hierzu gehören u. a. (vgl. Cox, 1936, Seite 19 und Arkell, 1931) *Pecten hemicostatus* Morr. u. Lycett aus dem Bathonien und *Pecten inaequicostatus* Phill. Diese Formen sind dadurch charakterisiert, dass auf der linken Klappe 5 Rippen mehr oder weniger symmetrisch angeordnet sind, denen auf der rechten Klappe Vertiefungen entsprechen. In den Zwischenräumen zwischen diesen Rippen fehlen radiale Rippen entweder vollständig oder sind unregelmässig entwickelt. Cox (1936, S. 18) beschreibt nun aus dem Bathonien-Bajocien des südlichen Persien eine neue Form, die er *Chlamys (Radulopecten) tipperi* benennt. Bei dieser neuen Art treten auf der linken Klappe 5 Rippen, die symmetrisch angeordnet sind, stärker hervor als die übrigen Rippen. Die in der Mitte liegende Rippe ist wiederum die kräftigste unter den fünfen. In den Zwischenräumen liegen dann sekundäre Rippen, und zwar je drei rechts und links der Mitte und je zwei in den äusseren Zwischenräumen. Auf der rechten Klappe entspricht der starken Mittelrippe der linken Klappe eine mediane radiale Vertiefung. Ferner treten hier 8—9 ziemlich unregelmässig verteilte gerundete Rippen an jeder Seite der Vertiefung auf, wobei die weitesten Zwischenräume wieder an den Stellen liegen, wo sich auf der linken Klappe die stärkeren Rippen finden.

Was nun das besonders starke Hervortreten der Mittelrippe der linken Klappe und der Median-Vertiefung der rechten Klappe sowie die Zahl der Rippen betrifft, so entsprechen diesen Merkmalen die mir vorliegenden, hier auf Tafel XXII in Figur 2 abgebildeten Stücke sehr gut. Demgegenüber sind die übrigen Rippen bzw. Rippenzwischenräume bei den mir vorliegenden Stücken alle von mehr oder weniger gleicher Stärke bzw. Breite — soweit der schlechte Erhaltungszustand noch eine Feststellung zulässt. Aber auch unter den von Cox (1936, Tafel 1 Figur 1—5) abgebildeten Stücken von *Chlamys (Radulopecten) tipperi* Cox finden sich Formen, bei denen die Stärke der genannten Rippen zu beiden Seiten der Mittelrippe nicht besonders verschieden ist. Da auch die Umrisse der hier in Figur 2 auf Tafel XXII abgebildeten linken Klappen sehr gut derjenigen der von Cox l. c. in Figur 3 und 4 abgebildeten Formen entsprechen, dürften die mir vorliegenden Exemplare auf jeden Fall in die Nähe von Cox' Form zu stellen sein, weshalb ich sie als *Chlamys (Radulopecten)* aff. *tipperi* Cox bezeichne. Ich halte es für sehr gut möglich, dass die beiden Formen sogar vollständig mit einander ident sind, jedoch müsste man besser erhaltenes Material haben, um das mit Sicherheit sagen zu können.

Mir liegen noch einige weitere Pectiniden vor, die vielleicht mit der soeben beschriebenen Form ident sind. Sie gehören ebenfalls zu *Chlamys,* sind jedoch zu mangelhaft erhalten, als dass sich Näheres aussagen liesse.

Von der gleichen Lokalität — also 69 — liegt mir unter anderen Fossilresten noch eine *Lopha* vor, die aber keine nähere Bestimmung mehr gestattet.

Es sei darauf hingewiesen, dass auch STEFANINI (1928) aus seinem Material einige *Chlamys*-Bruchstücke beschrieb, darunter *Chlamys inaequicostatus.* Auch STAESCHE (1932) hat ein unbestimmbares *Chlamys*-Bruchstück abgebildet. In beiden Fällen handelt es sich um Dogger-Callovien-Vorkommen. Zwischen diesen über 150 km von einander entfernt liegenden Vorkommen vermitteln nunmehr NORINS Funde an der Lokalität 69, die auf jeden Fall zeigen, dass sich der Jura auch in diesem Gebiet, das auf der geologischen Karte von DE TERRA noch keine geologischen Signaturen aufweist, findet. Cox's *Radulopecten tipperi* stammt aus Schichten, die entweder ins Bajocien oder Bathonien gehören, und es dürfte das richtigste sein, ein gleiches Alter für die vorliegenden Formen anzunehmen.

Fossilien aus dem Bathonien-Callovien.

Bathonien oder Callovien konnte ich unter den von NORIN gesammelten Materialien als an zwei Lokalitäten — nämlich 68 und 75 — vorkommend bestimmen.

Lokalität 68 liegt im Tschiptschak-Tal, 75 etwas nordöstlich der roten Kette. Die Entfernung zwischen diesen beiden Punkten beträgt ungefähr 175 km. Die von diesen beiden weit von einander entfernt liegenden Punkten stammenden Fossilien sind vorwiegend Ammoniten, die in Form von Bruchstücken, Abdrücken und schlecht erhaltenen Steinkernen vorliegen. Während im Tschiptschak-Tal schon früher Ammoniten gefunden waren, die von STEFANINI beschrieben wurden (1928), waren solche aus dem Gebiet der roten Kette bisher unbekannt. Wie noch gezeigt wird, handelt es sich an den beiden Fundpunkten um den gleichen Horizont, nämlich Callovien oder Bathonien, das somit als so weit nach Osten reichend nachgewiesen ist.

Da die vorliegenden Ammoniten sehr schlecht erhalten sind, ist es natürlich nicht möglich, sie genau zu bestimmen, jedoch kann kein Zweifel darüber bestehen, dass es sich um die gleichen oder um nahe verwandte Formen handelt, wie sie von STEFANINI l. c. aus dem Tschiptschak-Tal beschrieben worden sind.

Der hier auf Tafel XXII in Figur 3 abgebildete Abdruck eines grossen, vom Fundpunkt 75 stammenden Windungsbruchstückes könnte den Formen entsprechen, die STEFANINI als *Perisphinctes furcula* NEUM. beschrieben und abgebildet hat, jedoch sind die Rippen bei meinem Exemplar, wenigstens in der Nähe des Endes der Windung, mehr nach vorn gezogen als es bei einigen von STEFANINIS Exemplaren der Fall ist. Während bei dem von STEFANINI l. c. auf Tafel 9 in Figur 2 abgebildeten Exemplar die Rippen von der Teilungsstelle ab nach hinten gebogen sind, sind sie bei dem auf der gleichen Tafel in Figur 5 abgebildeten Stück im vorderen Teil der Windung mehr nach vorn gezogen. Das gleiche scheint bei dem von STEFANINI auf Tafel 11 in Figur 2a abgebildeten Exemplar der Fall zu sein. Dies entspricht dann also mehr den Verhältnissen, wie es das hier von mir abgebildete grosse Windungsbruchstück zeigt. Das hier weiterhin abgebildete Fig. 4, ebenfalls vom Fundpunkt 75 stammende Stück, das leider recht verdrückt ist, scheint bezüglich des Rippenverlaufes dem von STEFANINI auf Tafel 9 in Figur 2 abgebildeten Exemplar von *Per. furcula* NEUM., nahe zu kommen.

Mir liegen andere sehr schlechte Abdrücke vor, bei denen die Rippen einen ähnlichen Verlauf zeigen wie das von STEFANINI auf Tafel 9 in Figur 3 abgebildete Windungsbruchstück, bei dem auch der unterhalb der Teilungsstelle liegende Teil der Rippen nicht nach vorn gezogen ist.

Es muss aber darauf aufmerksam gemacht werden, dass die hier genannten und z. T. abgebildeten Formen teilweise auch mit Verwandten des *Per. furcula* NEUM. verglichen werden können. Solche Formen sind z. B. die von SPATH (1931, Tafel 48, Figur 5 bzw. 8) abgebildeten Formen *Choffatia balinensis* NEUM. und *Choffatia baluchistanensis* NOETLING.

Während nun die bisher besprochenen mir vorliegenden Stücke wahrscheinlich zu dem von STEFANINI als *Per. furcula* NEUM. beschriebenen Formenkreis gehören, dürfte das bei dem hier auf Tafel in Figur 5 abgebildeten Stück nicht so sicher der Fall sein, zeigen doch bei diesem auch die oberhalb der Teilungsstelle liegenden Rippenteile eine verhältnismässig starke Vorwärtsbewegung. Es muss natürlich als ganz ausgeschlossen bezeichnet werden, dieses Stück irgendwie genauer einordnen und bestimmen zu wollen, jedoch sei darauf aufmerksam gemacht, dass es sich möglicherweise auch um eine Form handeln kann, die SPATH (1931) als *Indosphinctites* bezeichnet hat, die zu *Choffatia*, zu der SPATH auch *Per. furcula* NEUM. stellt, in näherer Beziehung steht.

Schliesslich bilde ich hier noch eine kleine, ebenfalls vom Fundpunkt 75 stammende Form ab (Tafel XXII, Figur 6), die ebenfalls keine nähere Bestimmung mehr gestattet. Möglicherweise handelt es sich ebenfalls um eine Form aus dem Formenkreis der *Choffatia furcula*, aber es ist auch möglich, dass sie zu *Grossouvria* und zwar in die Verwandtschaft von *Grossouvria curvicosta* OPPEL gehört. Das von SPATH (1931) auf Tafel 63 in Figur 8 abgebildete Stück von *Gr. curvicosta* weist einen ganz ähnlichen Rippentyp auf.

SPATH ist (1933, Seite 806) auch kurz auf die von STEFANINI beschriebene Karakorumfauna eingegangen. Er schreibt hier u. a.: „But the great majority of the figured specimens can at once be recognised as belonging to well-known Callovian types, especially the Reineckeids and Hecticoceratids, while the Perisphinctes are, perhaps, close to the forms of the macrocephalus beds."

Die hier von mir von den Lokalitäten 68 und 69 genannten und abgebildeten Formen würden daher am ehesten für das Vorliegen der Macrocephalen-Schichten sprechen, die SPATH (1933, S. 758) zum Bathonien stellt. STEFANINI stellte die von ihm beschriebene Tschiptschak-Fauna — mit Ausnahme einiger typisch älterer Formen — in das Callovien. Welcher dieser beiden Horizonte, Bathonien oder Callovien, nun in Wirklichkeit vorliegt, lässt sich auf Grund des mir vorliegenden schlechten Materials nicht sagen. Jedenfalls handelt es sich hier um einen jüngeren Horizont als er durch die weiter oben beschriebenen Fossilien — *Camptonectes lens* und *Trigonia sp.* indet. — wie auch durch die von STAESCHE beschriebene Fauna des unteren Doggers repräsentiert wird.

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GENERAL INDEX

PLATES

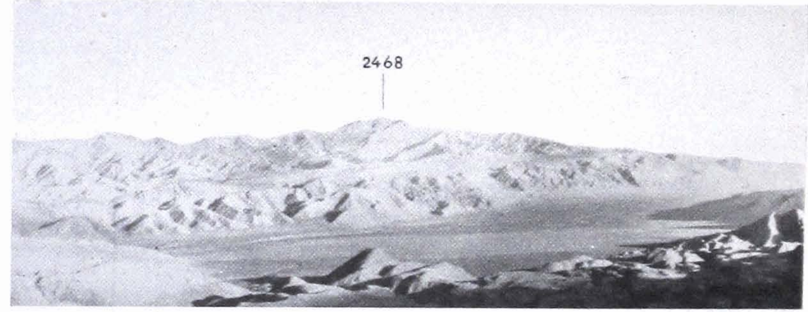


Fig. 2. Duwa-kir (Yagme-tagh) seen from the pass 2014 near Tash-ariq (Text fig. 6); a syncline of Tertiary beds enclosing Pleistocene boulder deposits.

Fig. 1. The K'un-lun frontier south-west and west of Langhru Village (Khotan district).

Fig. 3. The Mitaz ranges, looking south and west from hill station at Mitaz Village (Text fig. 4).

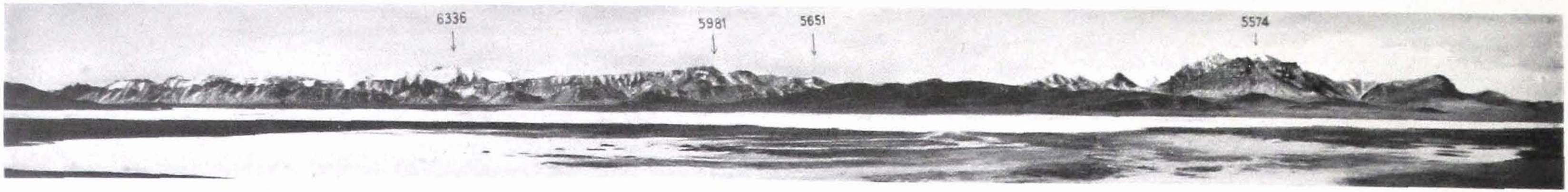


Fig. 1. The Cretaceous plateau along the southern border of Aq-sai-chin, seen from Camp N618.

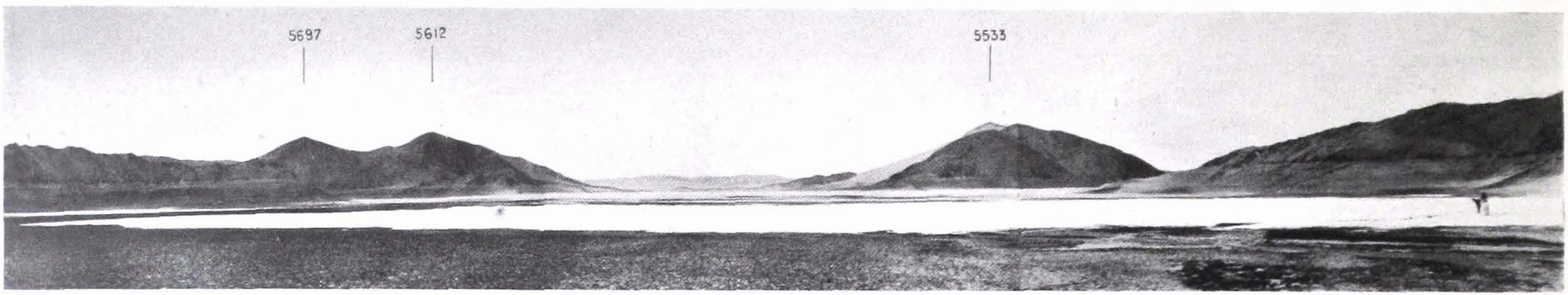


Fig. 2. Beach lines in the Mangrik Basin, looking south-west, south, and south-east from the northern shore of the lake at Camp A455.

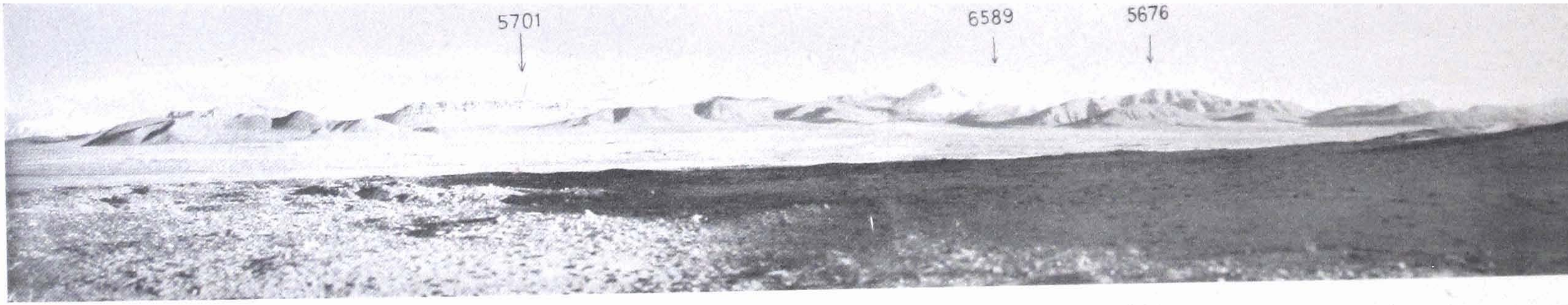


Fig. 1. The southern border of the Aq-sai-chin seen from Camp N617.

Fig. 2. Plateau of Cretaceous sandstone north-east of Camp N699, Loqzung Mountains.

Fig. 3. Looking north from Camp N699, Loqzung Mountains.

Fig. 1. The northern border of the basin of Tsaggar-tso, looking north-west, north, and north-east from Camp N707.

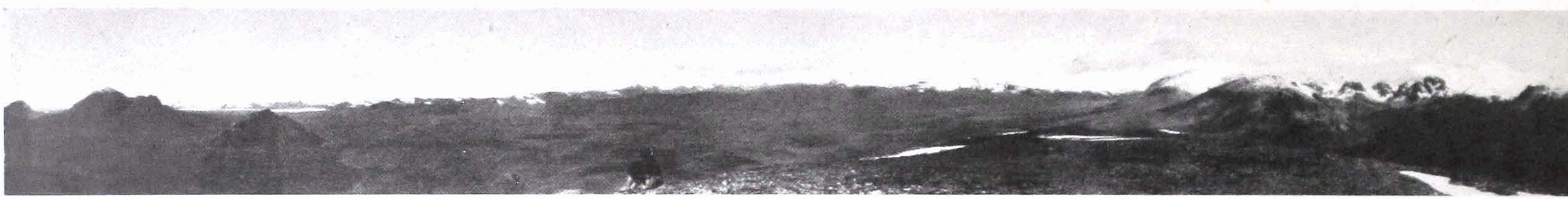


Fig. 2. Panoramic view of the north-western Ling-zhi-thang, looking north-west, south, and south-east from hill station at Camp A722.

AMBOLT phot.

Fig 3. The Chang-lung Range, looking east and south from point 5910. Ambolt phot.

Fig. 1. Panoramic view of the Mawang-kangri from a station 6 km east-north-east of Camp N705, looking south-west and south-east.

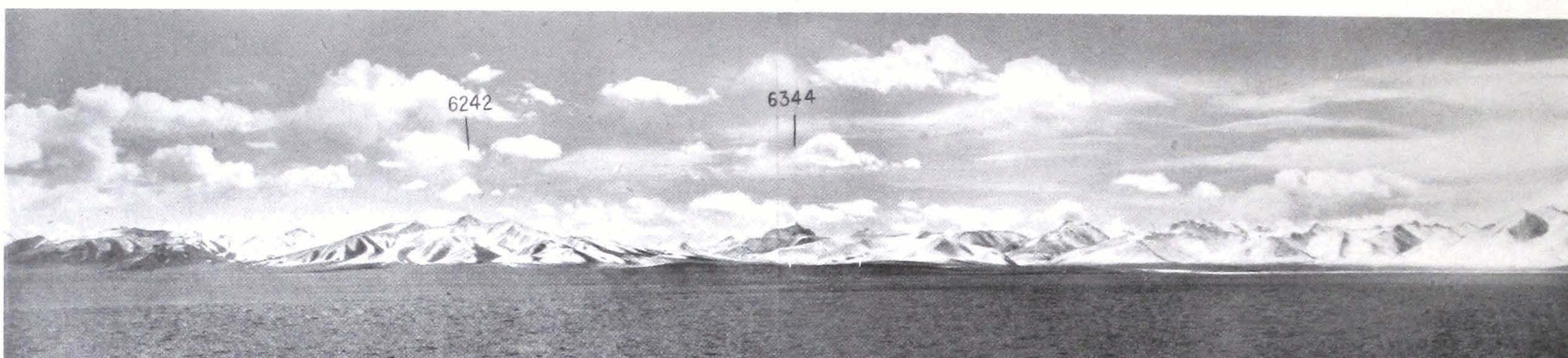


Fig. 2. Eastern extension of Fig. 1, looking south-east and east.

Fig. 1. The basin of Dyap-tso, looking west and north from Camp N731.

Fig. 2. From same station looking north and south-east.

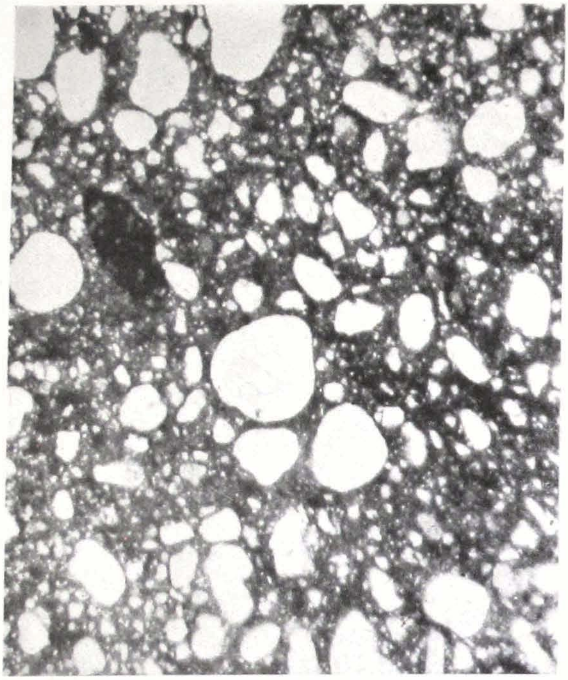


Fig. 1. Detritus-bearing siltstone from the Horpatso Series, Spec. 1116. 1 nic., 20 diam.

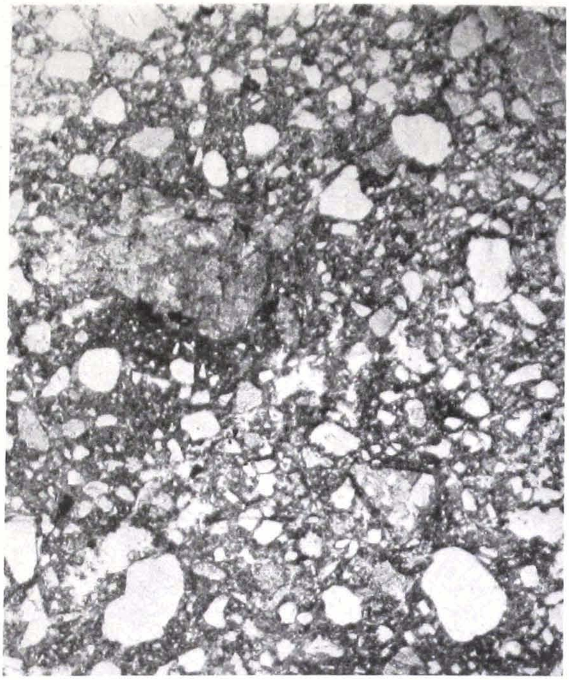


Fig. 2. Detritus-bearing siltstone from the Horpatso Series, Spec. 1117. 1 nic., 20 diam.

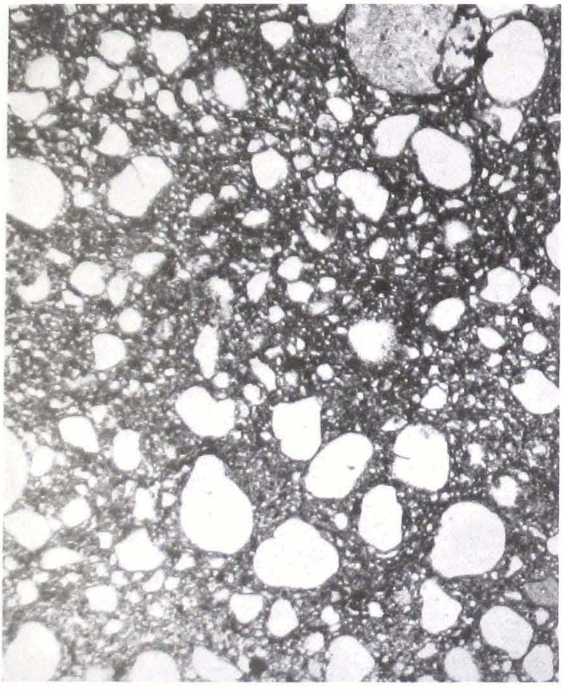


Fig. 3. Detritus-bearing siltstone from the Horpatso Series, Spec. 1142. 1 nic., 20 diam.

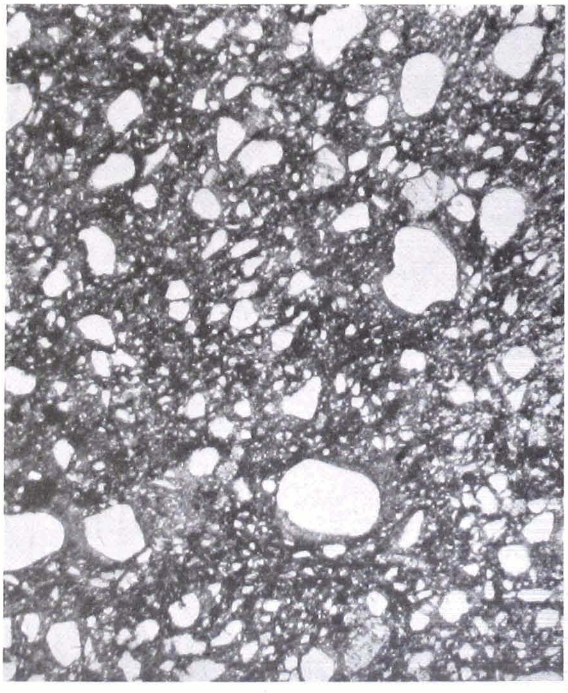


Fig. 4. Detritus-bearing siltstone from the Horpatso Series, Spec. 1146. 1 nic., 20 diam.

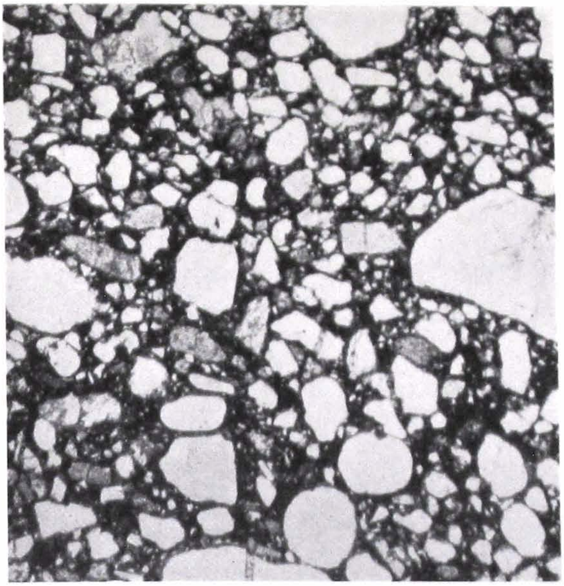


Fig. 1. Detritus-bearing siltstone from the Hor-patso Series, Spec. 1147. 1 nic., 20 diam.

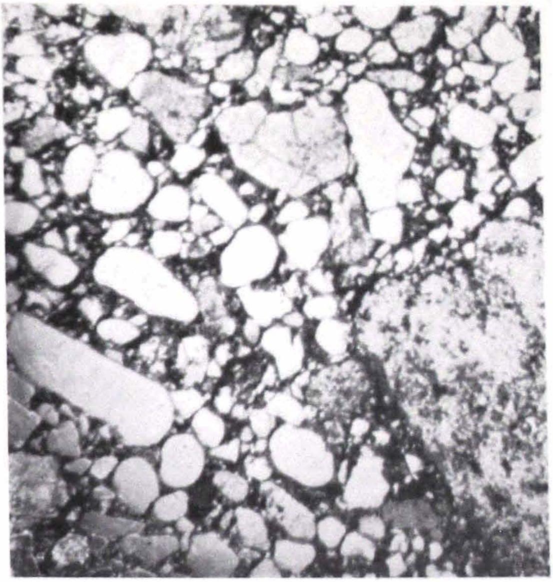


Fig. 2. Detritus-bearing siltstone from the Hor-patso Series, Spec. 1148. 1 nic., 20 diam.

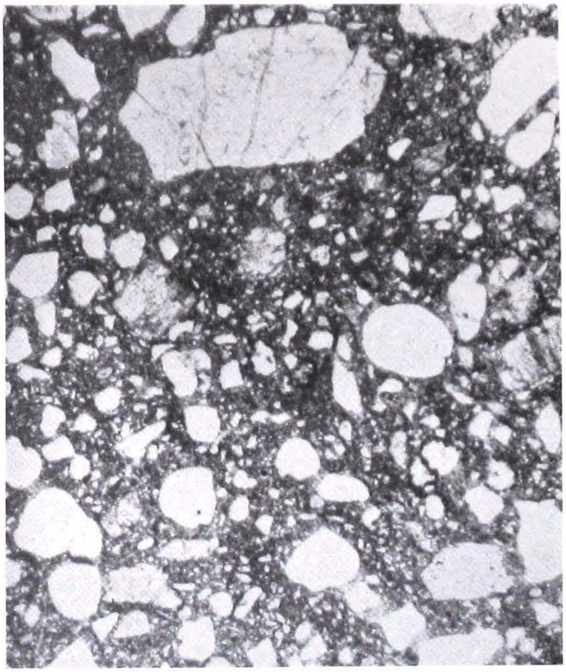


Fig. 3. Detritus-bearing siltstone from the Hor-patso Series, Spec. 1156. 1 nic., 20 diam.

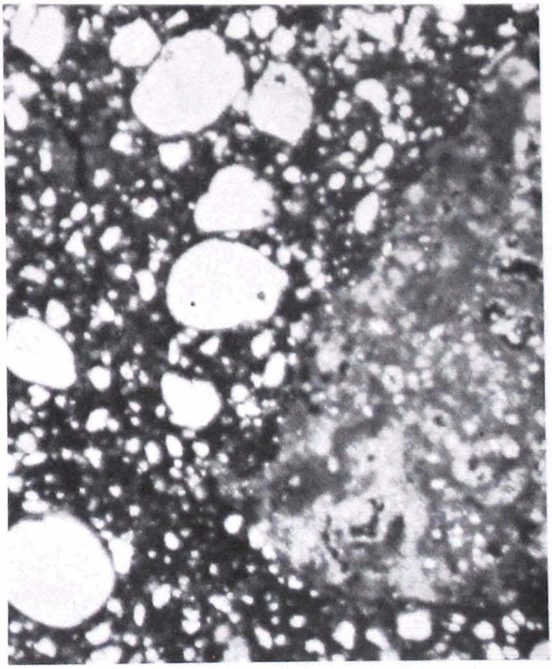


Fig. 4. Sub-Cambrian, boulder-bearing, calcareous silt from Quruq-tagh, Eastern T'ien-shan, Spec. 114. 1 nic., 20 diam.

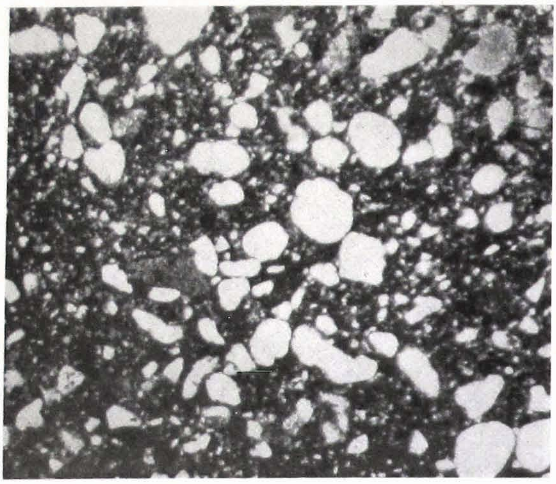


Fig. 1. Matrix of Sub-Cambrian tillite from Leirpollen, northern Norway. 1 nic., 20 diam.

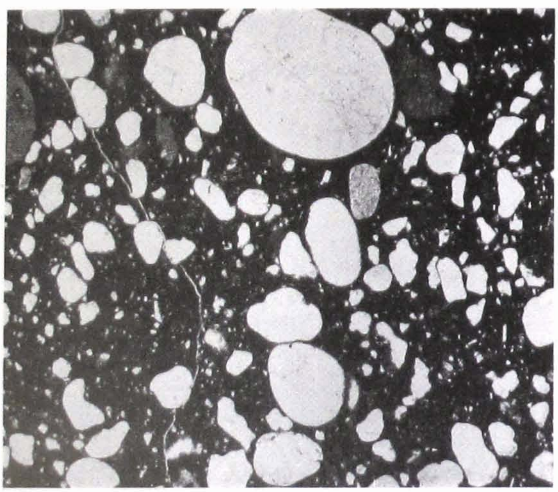


Fig. 2. Matrix of tillite from Tillite Canyon, East Greenland. 1 nic., 20 diam.

Fig. 4. Detritus-bearing siltstone from near Gogra, Chang-chenmo; Hedin Coll. 1 nic., 20 diam.

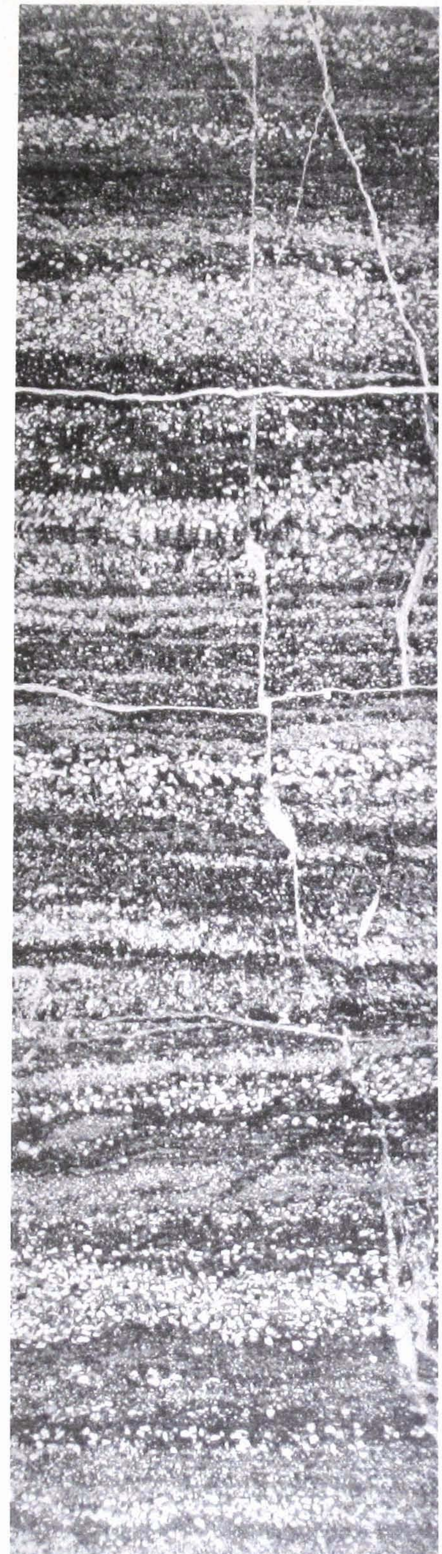


Fig. 3. Laminated silt from the Horpatso Series, Spec. 1118. 1 nic., 10 diam.

Fig. 1. Siltstone with pocket of sand, Horpatso Series, Spec. 1140. Almost all the sand consists of perfectly rounded grains of beach quartz. 2 diam.

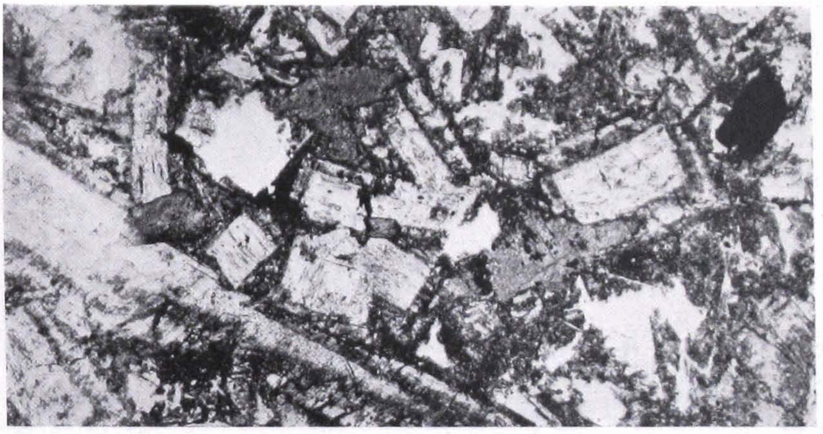


Fig. 2. Quartz-monzonite. Spec. 1086, from Qizil-davan, Loqzung Mountains. 1 nic., 20 diam.

Fig. 3. Leucite-shonkinite, Spec. 1050, Qaraqash Valley above Ali-nazar-qurghan. Pseudomorph after leucite coated with biotite. 1 nic., 40 diam.

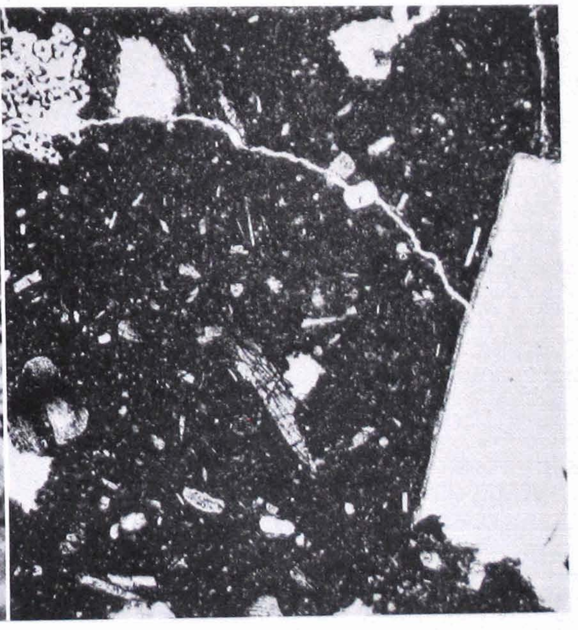


Fig. 4. Hyaline hypersthene-latite, Spec. 987, eastern K'un-lun Plains. In the upper left hand corner a strongly resorbed phenocryst of andesine. 1 nic., 25 diam.

Fig. 1. Augite-latite, Spec. 982, eastern K'un-lun Plains. 1 nic., 100 diam.

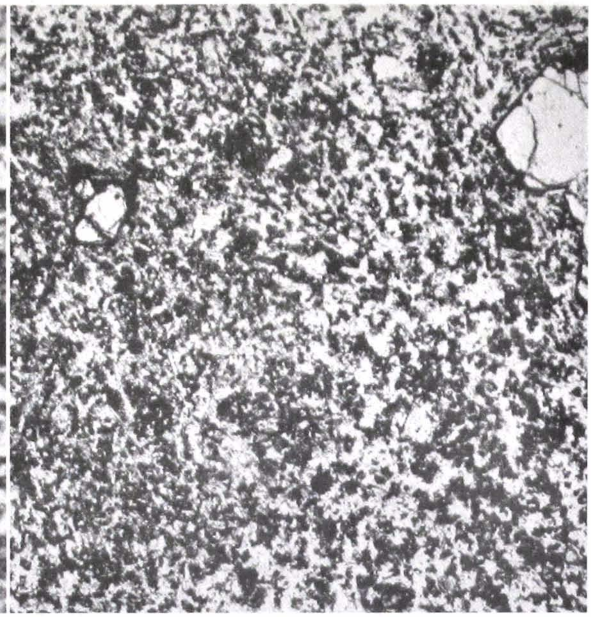


Fig. 2. Crinanite, Spec. 933, with phenocryst of olivine, Camp N627. 1 nic., 25 diam.

Fig. 3. Augite-latite, Spec. 943. Dike in the effusive latite of the plateau 5300. Eastern K'un-lun Plains. 1 nic., 100 diam.

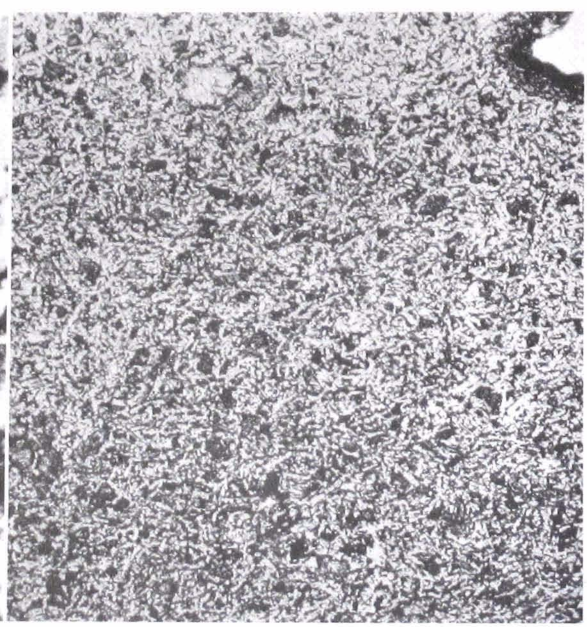


Fig. 4. Effusive latite, Spec. 944, from the plateau 5460, eastern K'un-lun Plains. 1 nic., 25 diam.

TAFELERKLÄRUNG

Taf. XVI.

Fig. 1. Cyclotrypa megastoma n. sp. Fundort 79, 5, 4 x, Längsschnitt.
Fig. 2. „ „ „ „ „ „ 4, 2 x, Querschnitt.
Fig. 3. „ „ „ „ „ „ 3 x, Längsschnitt eines anderen Exemplares.
Fig. 4. „ „ „ „ „ „ 1,5 x, angewitterte Oberfläche.
Fig. 5. „ „ „ „ „ „ 10 x, Ausschnitt aus Querschnitt.
Fig. 6. Gesteinsoberfläche mit Bruchstücken von Dichotrypa inflata, n. sp. und einem Zweig von Cystodictya sphenoides n. sp. Fundort 77. 1,5 x.
Fig. 7. Dichotrypa inflata n. sp. Fundort 83. 7 x, Querschnitt durch ein unvollständiges Stück.
Fig. 8. „ „ „ „ „ 18 x, Ausschnitt daraus.

Taf. XVII.

Fig. 1. Dichotrypa inflata n. sp. Fundort 83, 29 x, Querschnitt aus einem anderem Exemplar.
Fig. 2. „ „ „ „ „ „ 19 x, Tangentialschnitt eines dritten Stückes.
Fig. 3. Dichotrypa clavaeformis, n. sp. Fundort 77, 4 x, Tangentialschnitt eines fast vollständiges Exemp.
Fig. 4. „ „ „ „ „ 5 x, Querschnitt aus der Nähe der Basis der gleichen Exemplares.
Fig. 5. „ „ „ „ „ 18 x, Ausschnitt aus dem Tangentialschnitt. Bei tieferer Schnittlage erscheint die Blasengewebszone.
Fig. 6. Cystodictya sphenoides n. sp. Fundort 77, 5 x. Stämmchen im Gestein.
Fig. 7. „ „ „ „ „ 5 x, dto, Tangentialschnitt.
Fig. 8. „ „ „ „ „ 6,5 x, Längsschnitt eines Stämmchens.
Fig. 9. „ „ „ „ „ 18 x, typischer Querschnitt.

Taf. XVIII.

Fig. 1. Cystodictya sphenoides n. sp. Fundort 77, 17 x, Detail aus Taf. II, fig. 8.
Fig. 2. Batostomella spinigera, var. nov. acanthostellata. Fundort 77. 2,2 x. Uebersicht über ein Exemplar.
Fig. 3. „ sp. Fundort 77. 1,5 x. Ansicht des Stückes im Gesteil.
Fig. 4. „ spinigera var. nov. acanthostellata. Fundort 77, 16 x, Stück eines Querschnittes.
Fig. 5. „ spinigera var. nov. acanthostellata. Fundort 77, 16 x, Längsschnitt eines Zweigstückes.
Fig. 6. „ spinigera var. nov. acanthostellata. Fundort 77, 38 x, Tangentialschnitt mit seltenen Mesoporen und sternförmigen Acanthoporen.
Fig. 7. „ sp. Fundort 77. Tangentialschnitt mit behöften Acanthoporen.

Taf. XIX.

Fig. 1. Fenestella parviuscula BASSLER. Fundort 83, 13 x.
Fig. 2. Fenestella cf. Colymaensis Nekh. Fundort 83, 35 x.
Fig. 3. Fenestella permiana Stuck., var. nov. pentagona. Fundort 83, 8 x.
Fig. 4. Fenestella sp. aff. pulchradorsalis BASSLER. Fundort 83, 16 x.
Fig. 5. „ „ „ „ „ „ 83, 1,4 x.

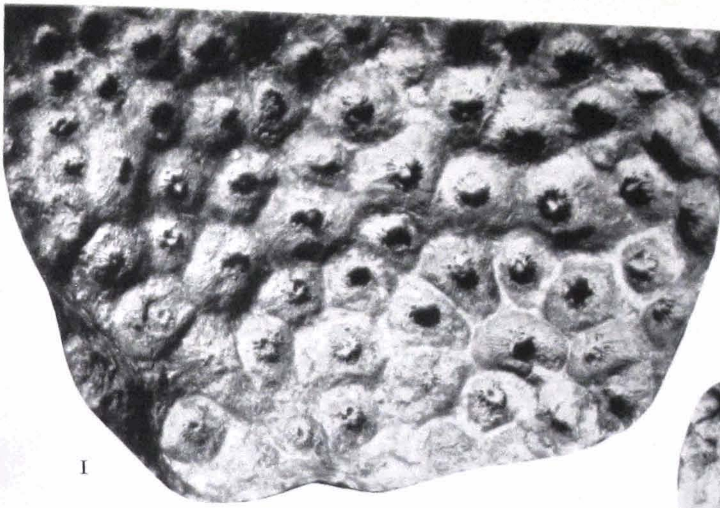
Fig. 6. Polypora tibetana n. sp. Fundort 83, 4 x.
Fig. 7. „ „ „ „ „ 83, 1,7 x.
Fig. 8. Polypora timorensis BASSLER, var. nov. regularis. Fundort 83, 16, 4 x.
Fig. 9. Polypora goldfussi, EICHWALD. Fundort 83, 4 x.

Taf. XX.

Fig. 1. Polypora macrops BASSLER. Fundort 82, 1,6 x.
Fig. 2. Polypora sp. ex. gr. orbicribrata KEYS. Fundort 77, 17 r.
Fig. 3. Polypora sp. Fundort 83, 4 x.
Fig. 4. „ „ „ 83, 19 x.
Fig. 5. Polypora macrops BASSLER. Fundort 1065, 19 x.
Fig. 6. Polypora sp. ex. gr. tripliseriata BASSLER. Fundort 83, 3,8 x.
Fig. 7. Polypora macrops BASSLER. Fundort 82, 3,6 x.
Fig. 8. Polypora sp. ex. gr. orbicribrata KEYS, Fundort 77, 17 x.
Fig. 9. „ „ „ „ „ „ Fundort 77, 4 x.

Taf. XXI.

Fig. 1. Ramipora hochstetteri TOULA. Fundort 77, 4 x, Netzstück im Gestein.
Fig. 2. „ „ „ 6 x gleiches Stück, zur Verdeutlichung abgedeckt.
Fig. 3. „ „ „ Fundort 83, 32 x, Längsschnitt.
Fig. 4. „ „ „ „ 83, 22 x, Querschnitt, etwas schief getroffen.
Fig. 5. „ „ „ „ 83, 22 x, Querschnitt an einer Verzweigungsstelle.
Fig. 6. „ „ „ „ 83, 4 x, Längsschnitt.
Fig. 7. „ „ „ „ Originalexemplar TOULAS, skizziert zur Verdeutlichung des Verzweigungssystemes, ca 2,5 x.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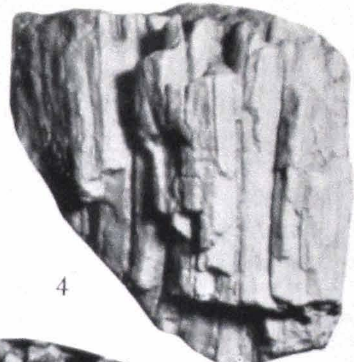
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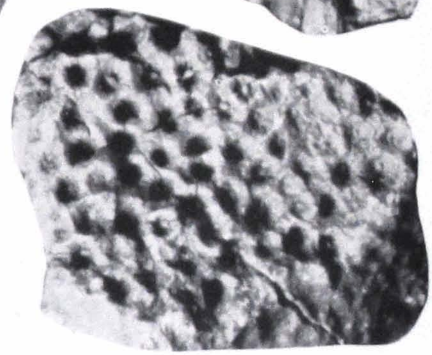
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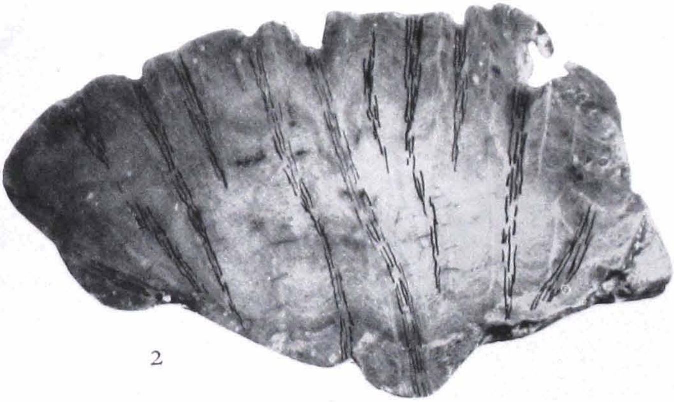
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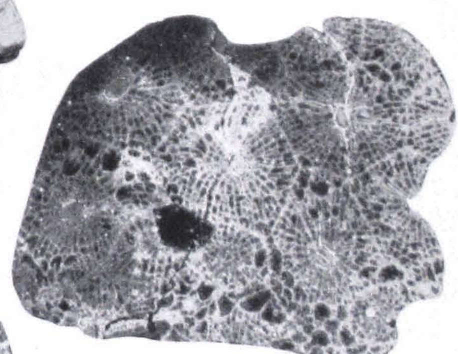
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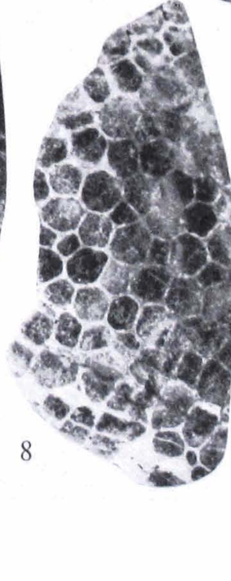
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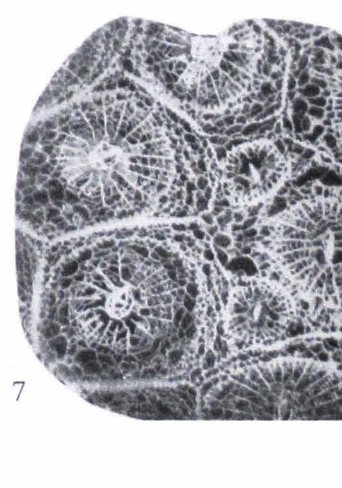
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Pl. XIV.

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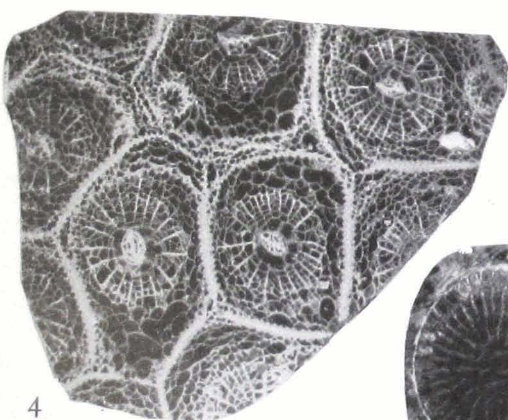

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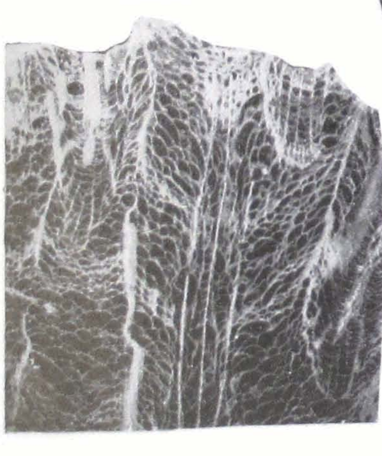

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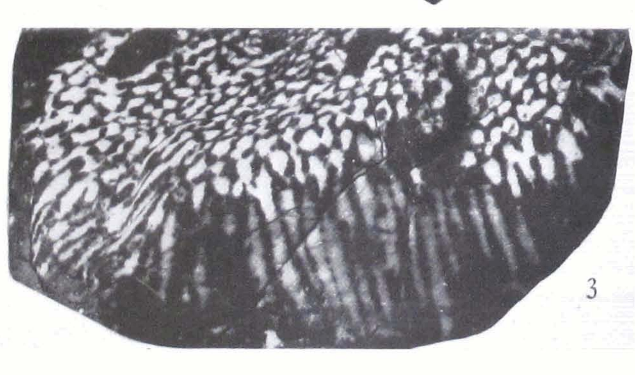

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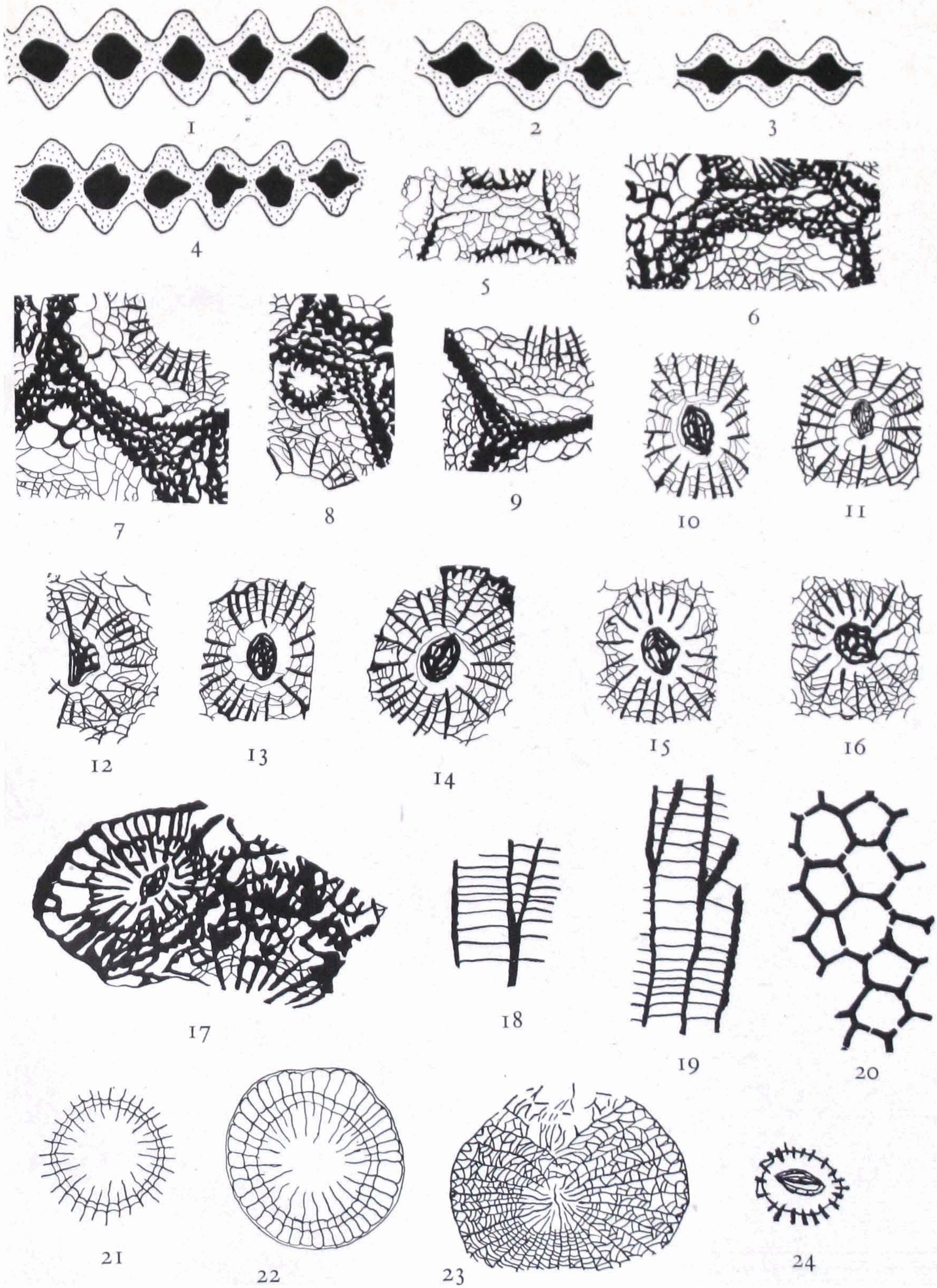
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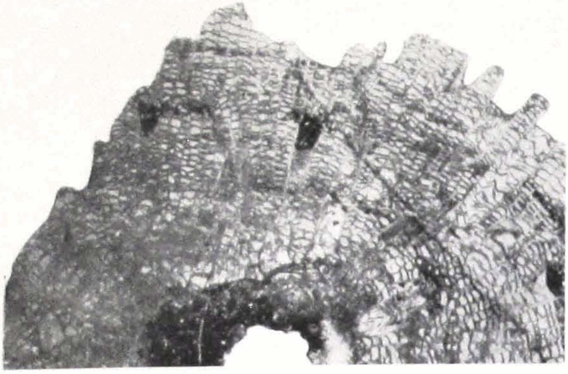

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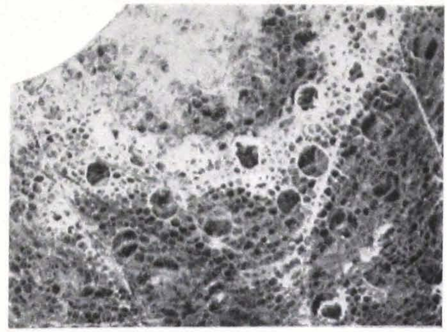

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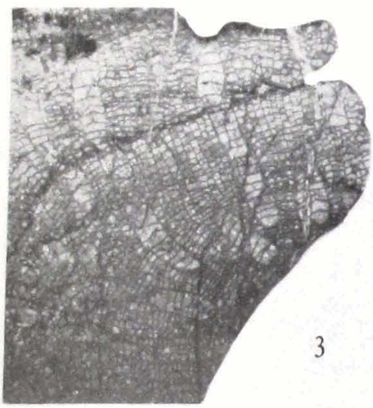

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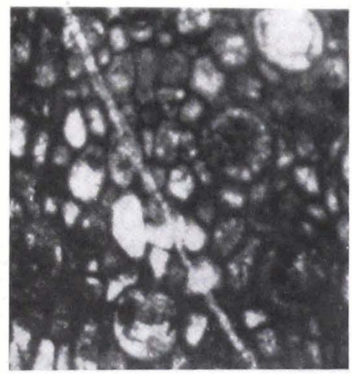

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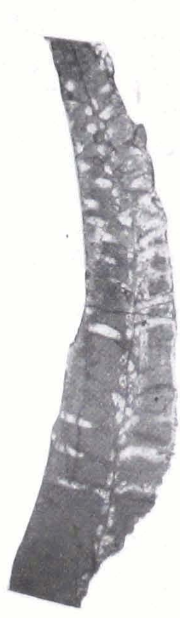

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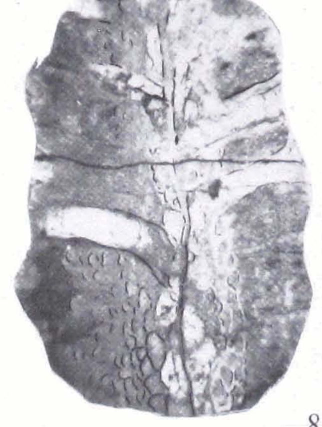

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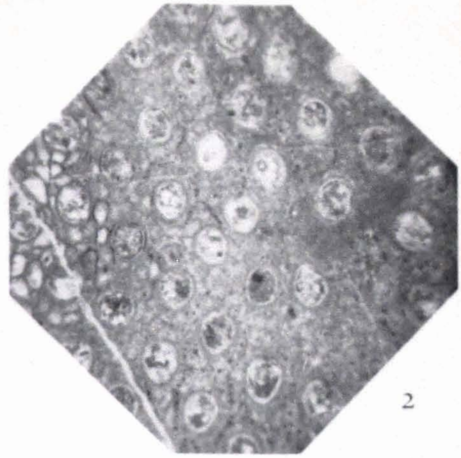

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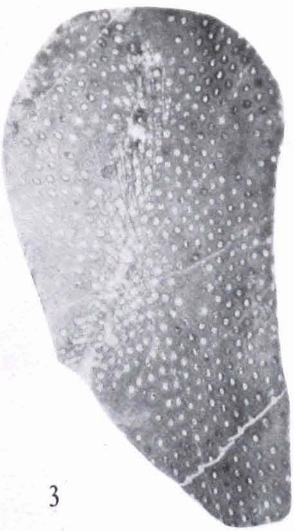

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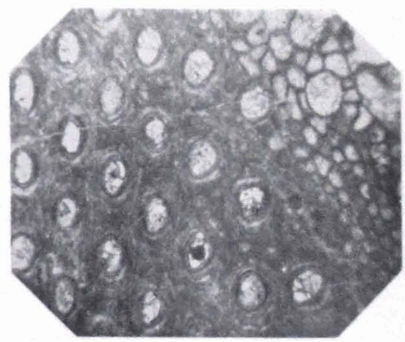

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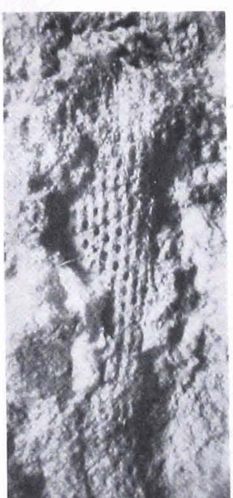

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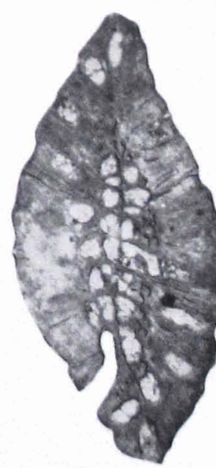

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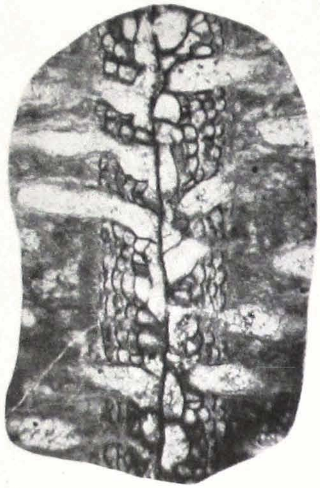
Pl. XVIII.



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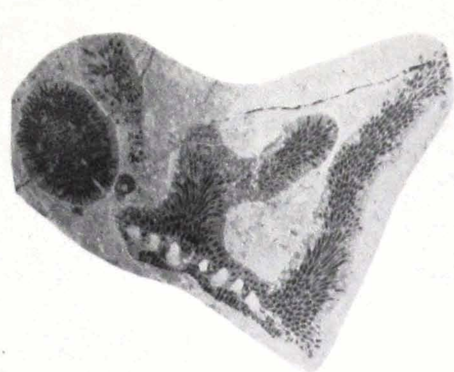

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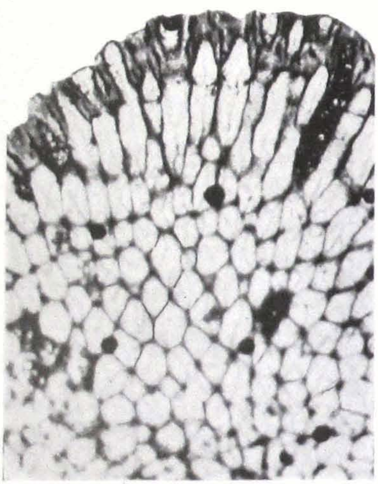

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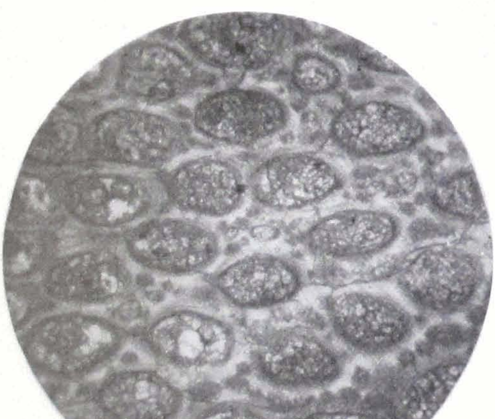

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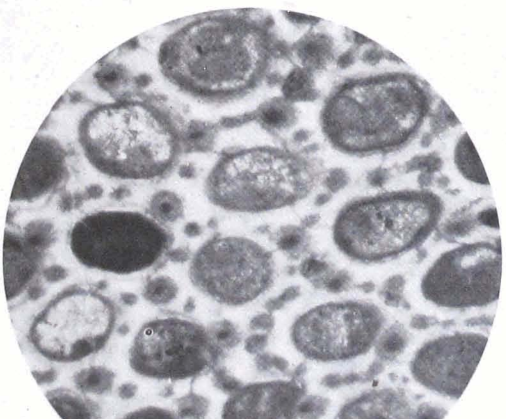

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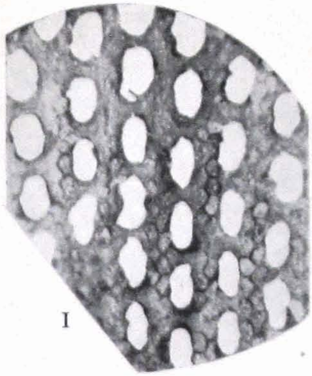

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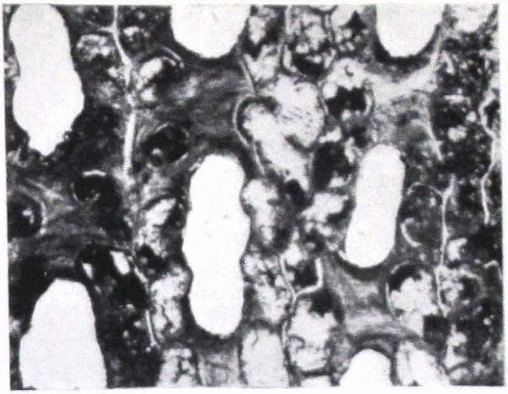

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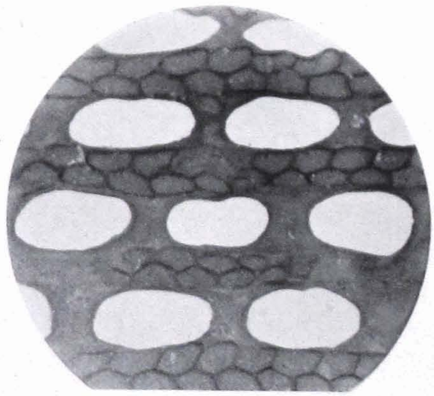

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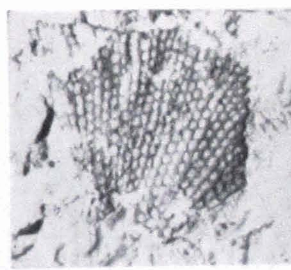

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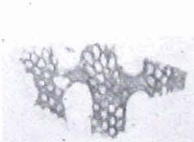

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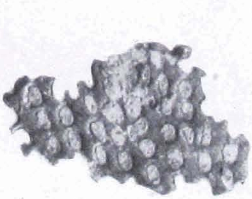

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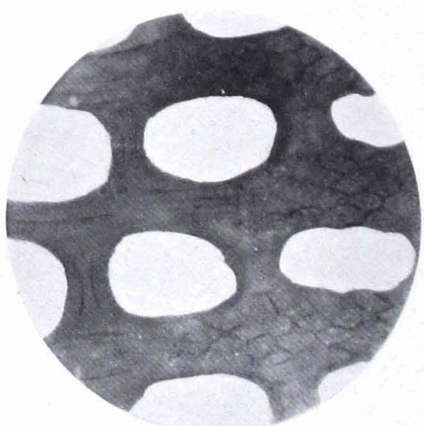

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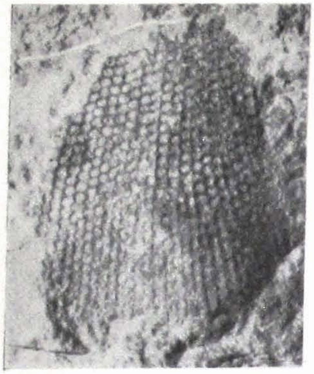

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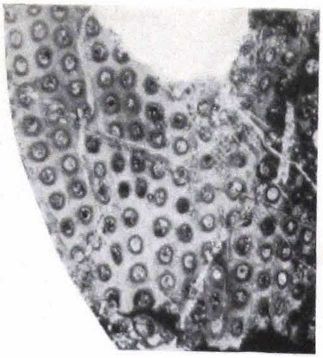

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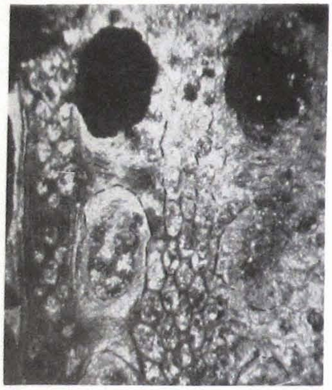

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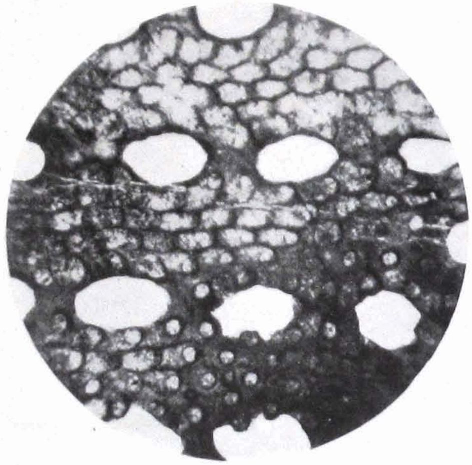

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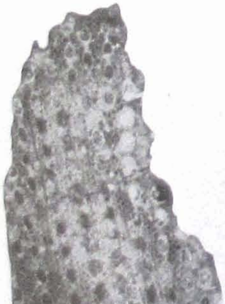

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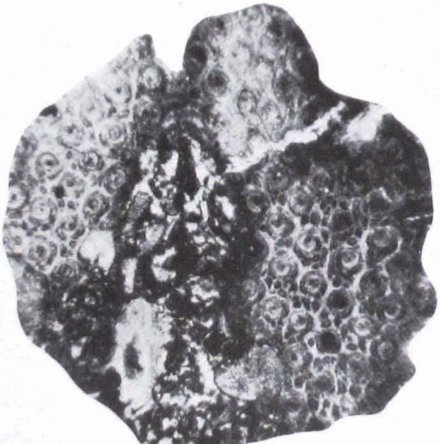

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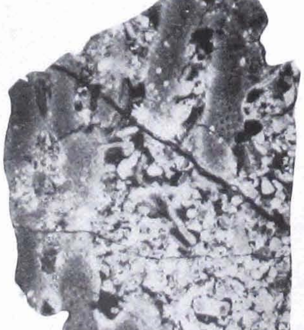

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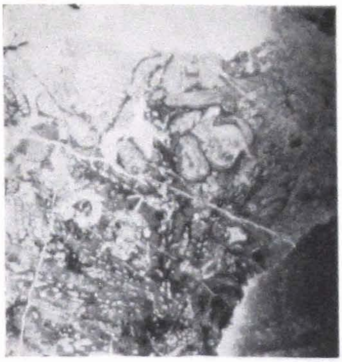

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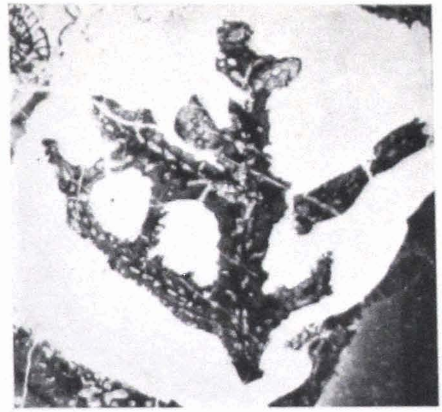

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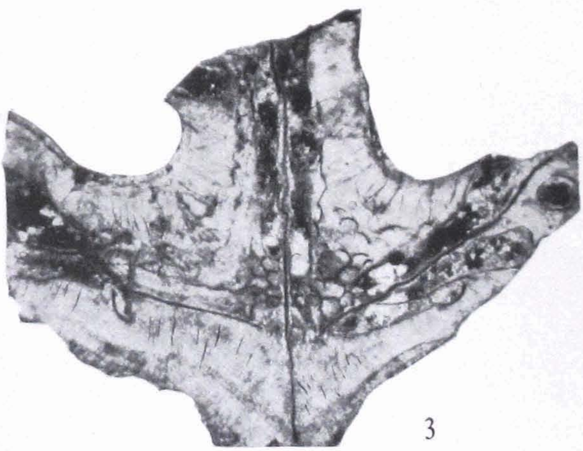

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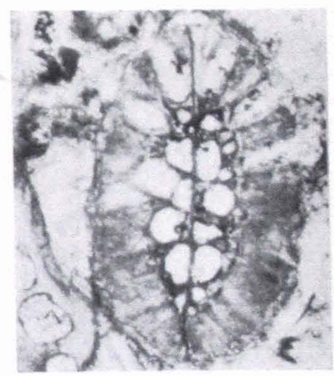

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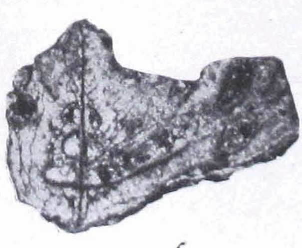

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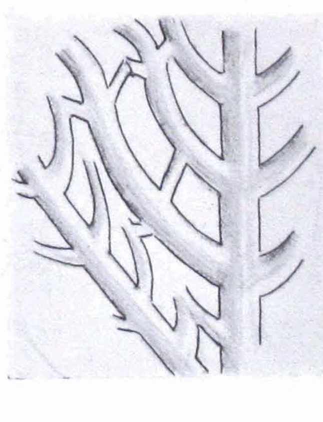

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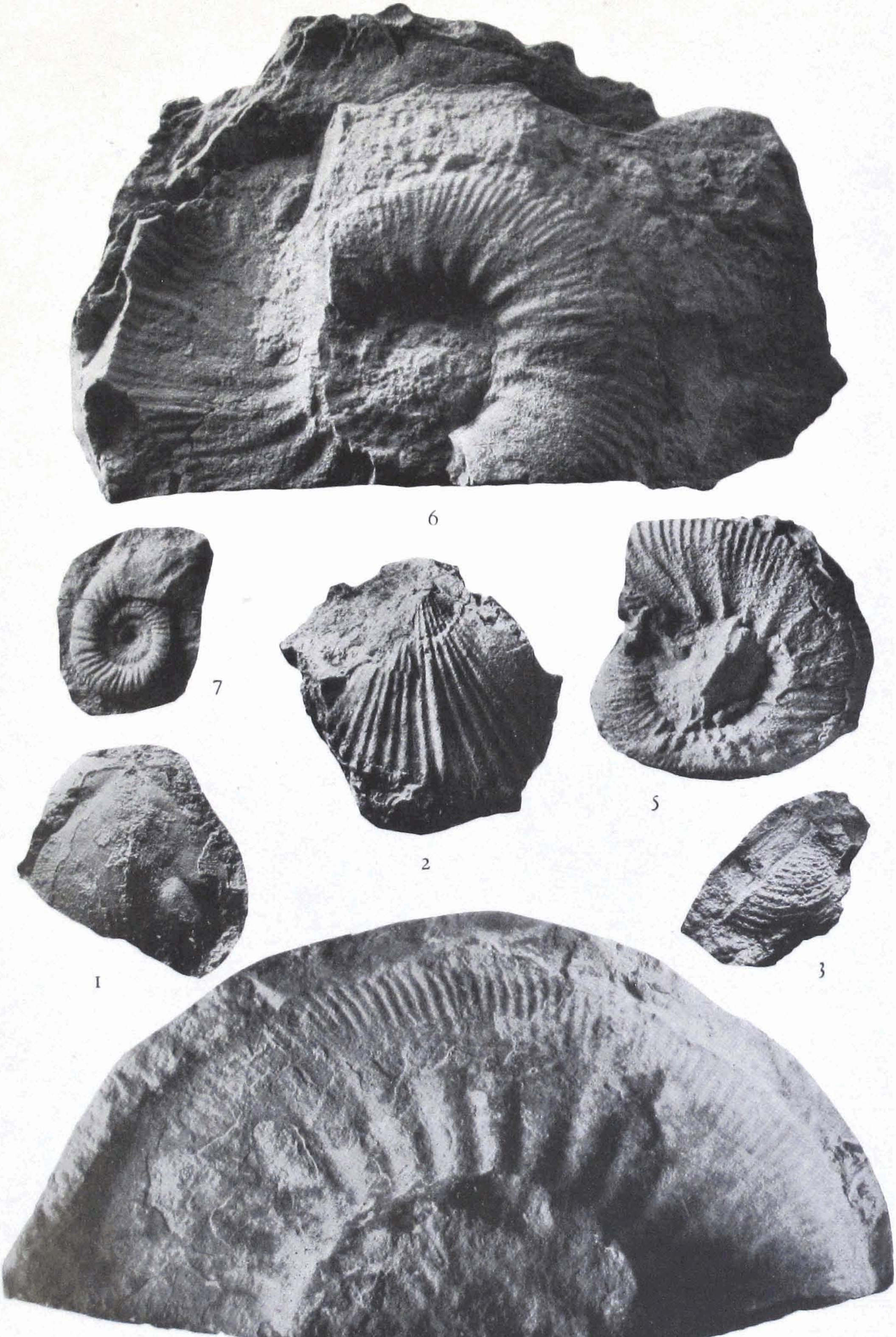
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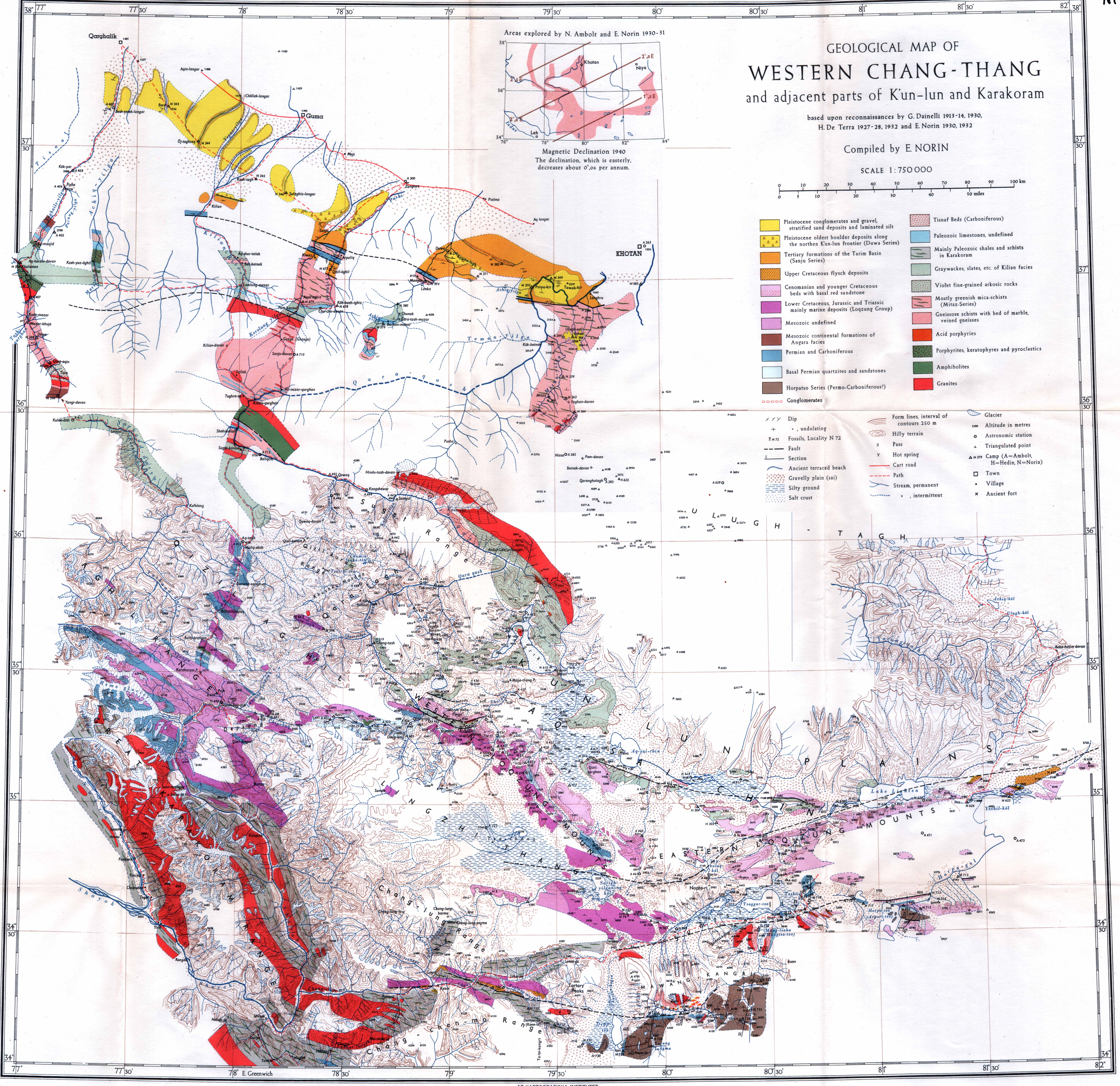

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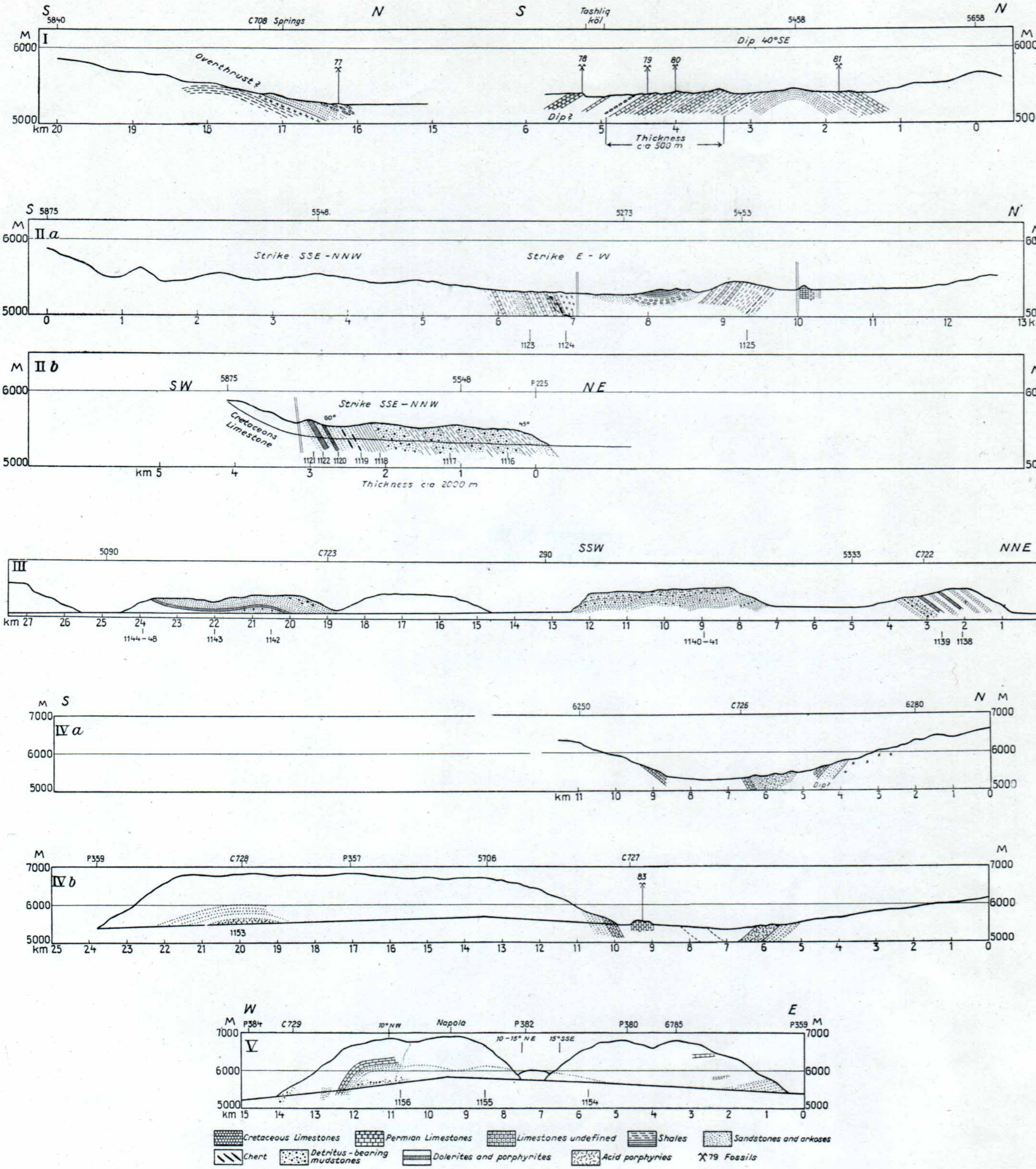
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S
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C708 Springs
Overthrust ?
Dip ?
Toshliq köl
Dip 40° SE
Thickness c:a 500 m
II a
Strike SSE-NNW
Strike E-W
II b
SW
NE
Strike SSE-NNW
Cretaceous Limestone
Thickness c:a 2000 m
III
SSW
NNE
IV a
IV b
V
W
E
Napola
10° NW
10-15° NE
15° SSE
Cretaceous Limestones
Permian Limestones
Limestones undefined
Shales
Sandstones and arkoses
Chert
Detritus-bearing mudstones
Dolerites and porphyrites
Acid porphyries
79 Fossils