Contributions to the Geology of Northern Mongolia

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Article VII.—CONTRIBUTIONS TO THE GEOLOGY OF NORTHERN MONGOLIA[1]

ABSTRACTED FROM THE ORIGINAL RUSSIAN AND ANNOTATED

BY RADCLIFFE H. BECKWITH[2]

FOUR TEXT FIGURES

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[1]Publications of the Asiatic Expeditions of The American Museum of Natural History. Contribution No. 128.
[2]University of Wyoming; Geologist Central Asiatic Expeditions, 1926.

INTRODUCTION

Many scientific explorers working in Mongolia find difficulty in obtaining accurate information on what has already been accomplished in the country, because much of the exploration has been carried out by Russians and described in their own language. Most scientific readers desiring information on certain parts of the country encounter similar difficulties and are confronted with the alternative of learning to read Russian or remaining content with incidental, and often incomplete, summaries of the results of Russian explorers given in works written in English, German or French. The writer found himself in a similar predicament when sent to China in 1926 as geologist of the Central Asiatic Expeditions of The American Museum of Natural History. Civil wars in China, prevented the expedition from leaving Peking, and the writer was given time and opportunity to study Russian.

The purpose of the present paper is to make available in English certain parts of a Russian publication which was first received by American libraries in 1927. The publication gives the results of a general scientific expedition sent into northern Mongolia in the summer of 1925 by the Soviet National Committee. The expedition did not travel as a unit, but was divided into a number of parties occupied in different areas with different problems. Consequently the two published volumes consist of a number of papers by different authors on a variety of subjects, such as archaeology, geology, botany, soils and Mongolian philology. The present paper deals only with the parts of the general work which aid in building up a more complete geological history of Mongolia. For this reason most of the Russian papers are not considered here and parts of the geological papers have not been abstracted because they deal with economic geology, which is of only local interest.

A small part of the territory covered by the Russian geologists had already been traversed by the Third Asiatic Expedition of The American Museum of Natural History in 1922, and the Russians made use of the American expedition's preliminary announcements published in the *Novitates* of The American Museum of Natural History. As a result there is striking accordance in the conclusions of the two expeditions on certain aspects of the geology of Mongolia. The territory studied by the Russians, however, provides data on chapters of the geological history which are not represented in central and southern Mongolia. The area in the northwestern part of the country studied by Levedeva provides a record of marine sedimentation during the Silurian, followed by folding and the intrusion of granites in Upper Palaeozoic times. The part of northeastern Mongolia crossed by Kupletsky on his reconnaissance furnished evidence of a period of granitic intrusion following the deposition of sediments assigned to the Palaeozoic and Jurassic. The geological and physiographic investigations of the terraces of the Jargalante rivers in north-central Mongolia carried out by Polynov and Krasheninnikov show that the warping and faulting which began in the Jurassic or Cretaceous, have caused drainage changes in comparatively recent times.

In preparing the abstracts, no attempt was made to adhere strictly to the wording of the original papers, since a translation from Russian to English is almost certain to be ambiguous. It was also considered advisable to rearrange some of the material in order to bring together all the facts bearing on a given problem. In addition, the abstracter has inserted comments from place to place in order to call attention to data bearing on the subject which were gathered by other geologists. The comments are enclosed in brackets [ ]. The references to the bibliography at the end of the paper are enclosed in parentheses ( ). Bibliographic references found within bracketed comments refer to publications used by the abstracter. Otherwise they refer to publications used by the Russian author. The titles of the abstracts have been changed and shortened from the original, but complete literal translations of the original titles are given in footnotes.

THE GEOLOGY OF THE EASTERN BORDER OF THE KHARKIRA RANGE[1]

By Z. A. Lebedeva

Abstracted from the Original Russian and Annotated

By R. H. Beckwith

The Mongolia and Uriankhai Expedition of the Academy of Sciences of the U. S. S. R. was sent out in 1923 for the purpose of making a reconnaissance of the Kobdo *aimak* in northwestern Mongolia. The series of geological sections of the eastern slope of the Kharkira range made by I. P. Rachkovsky, leader of the expedition, showed that the area presented a number of interesting problems in the stratigraphy of the Lower Palaeozoic sediments and the tectonic history of a large district. He was, however, unable to gather extensive data bearing on these problems because of lack of time. The geological party of the Soviet expedition of 1925, under the leadership of Z. A. Lebedeva, was sent to the critical

[1]Lebedeva, Z. A. 1926. 'Geological explorations of the eastern border of the Kharkira massif of northwestern Mongolia.' Northern Mongolia, I, Preliminary accounts of the geological, geochemical and soil-botanical expeditions on the work carried out in 1925. Publications of the Academy of Sciences of the U. S. S. R., Leningrad.

area to continue the work begun by Rachkovsky. The party entered the field early in September and left for the Siberian border soon after the middle of October.

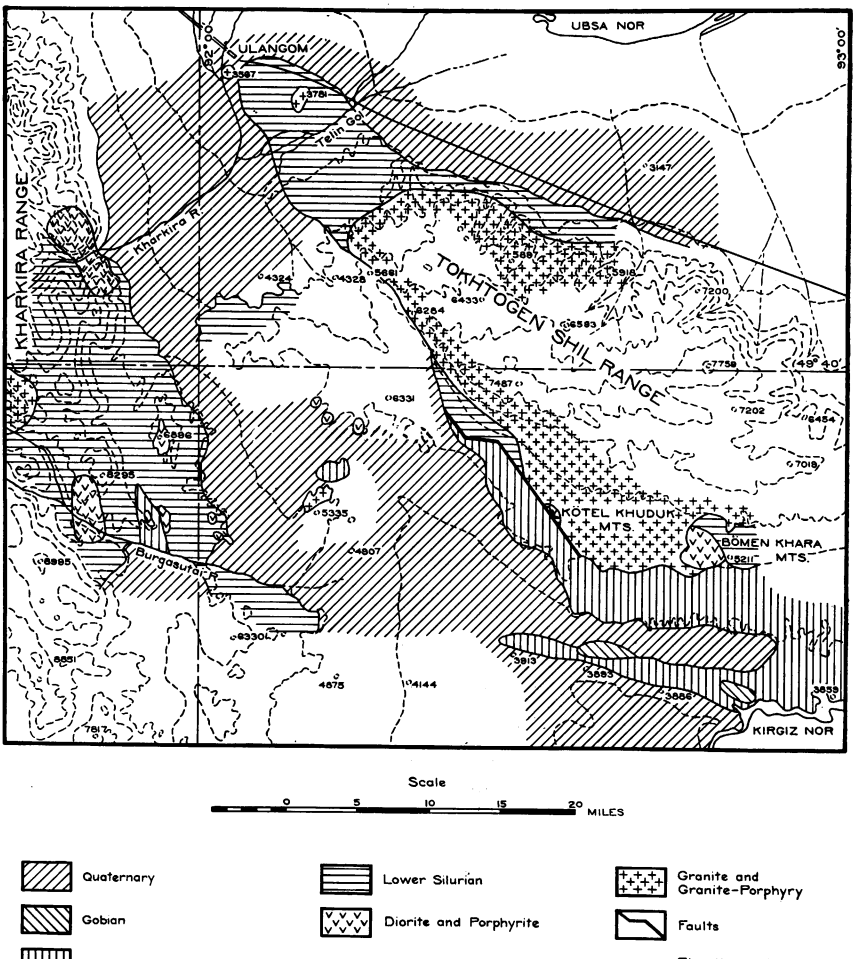

Fig. 1. Geological Map of the Eastern Border of the Kharkira Range. (After Lebedeva.)

LOCATION AND TOPOGRAPHY.—A large portion of northwestern Mongolia falls within the physiographic province known as the Valley of the Lakes, a great, roughly circular, intermontane depression some 300 miles in diameter. It is bounded on the north by the Tannu Ola range, on the west and south by the Sailugem range and the Mongolian Altai, and on the east by the Khangai Mountains. The Valley of the Lakes is intersected by a number of minor ranges which divide it into basins, the lowest portions of which are occupied by a few large lakes such as Ubsa Nor, Kirgiz Nor, Khara Usu, Khara Nör (Durga Nor), and Achit Nor. There are, in addition, a large number of smaller lakes. The streams from the mountains flow into the basins, from which there are no outlets to the sea.

The area studied (Fig 1) includes the southwestern part of the basin of Ubsa Nor and the northwestern part of the basin of Kirgiz Nor. The parallel, 49° 40′ north, passes through the middle of the area, and the meridian, 93° east from Greenwich,[1] forms its eastern boundary.

The western part of the area is occupied by the Kharkira range, a southern branch of Tannu Ola. The average elevation of the peaks in the northern part of the range west of Ubsa Nor does not exceed 10,500 feet. Southward the crest ascends to 13,000 feet and then descends to about 8, 500 feet west of Kirgiz Nor. The boundary between the northern part of the range and the Ubsa basin is an almost straight line extending to the northwest. Farther south the boundary becomes less sharp, and west of Kirgiz Nor it is marked by a wide belt of foothills. The heads of the valleys in the central part of the range, such as those of the Kharkira and Tugun Rivers, are occupied by glaciers. Below the glaciers the valleys are trough-shaped and are crossed by terminal moraines giving evidence of former more extensive glaciation.

The central portion of the area is occupied by another range, Tokhtogen Shil, the northwestern extension of the Khan Koko range. The western side of Tokhtogen Shil descends gradually and gives way to isolated groups of hills, leaving an easy passage from Ubsa Nor to Kirgiz Nor. On the north the range is bounded by a single steep scarp trending west-northwest. On the south there is a descent to the level of the Kirgiz Nor basin in three distinct scarps. The top of the range is flat and along it passes a road with such easy grades that it could be used by automobiles.

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[1][On Lebedeva's map the eastern boundary is marked 62° 40′ and the meridian near the west boundary is marked 61° 40′. In the text it is stated that these figures are longitude east from Greenwich. This is obviously an error, since all large scale maps show Kirgiz Nor between the meridians, 90° east and 95° east from Greenwich. It is quite probable that the author followed the Russian convention of taking longitude measurements from the Pulkovo observatory, which is ten miles from Leningrad at longitude 30° 19′ 40″ east from Greenwich. There are also errors in the scales on the original Russian map. The graphic scale indicates that a degree of longitude at latitude 49° 40′ is some 725 kilometers, which is approximately ten times the true value. The representative fraction does not check with the graphic scale nor with the value of the length of a degree of longitude at latitude 49° 40′. In the preparation of the map (Fig. 1) the writer has assumed that the longitude measurements on the original map were from Pulkovo and has added 30° 20′ to them. The graphic scale on figure 1 was computed on the basis of the number of miles to a degree of longitude at latitude 49° 40′.]

A few small rivers flow from the Kharkira range into the basins of both of the lakes. The heads of their valleys are wide and open, but narrow to steep-walled canyons where the streams leave the mountains. None of the streams reach the lakes. Instead, they deploy over the lowlands, where the water sinks into the loose gravel and sand, evaporates, or is used for irrigation. No permanent streams flow from Tokhtogen Shil, although there are a number of springs around its borders. The floors of the intermontane basins are almost flat gravel and sand plains varied by a few groups of low hills consisting of more resistant igneous rocks projecting through the younger sediments. Only the lower portions of the basin floors are covered by the waters of Ubsa Nor and Kirgiz Nor, the respective levels of which are 2,448 feet and 3,379 feet.

Silurian Rocks.—The Burgasutai River rises near the crest of the Kharkira range and flows eastward into the Kirgiz basin. The upper valleys of both forks are wide and open, but below their junction the river flows in a deep canyon, the walls of which provide almost continuous exposures for fifteen miles. For several miles above the junction, both branches cut a series of fine-grained, purplish-gray sandstones containing a few beds of coarser, cross-laminated sandstone. The strike varies from N. 5° W. to N. 10° W. The dip is to the west and lies between 35 degrees and 40 degrees. Farther west the sandstones pass gradually into green slates and phyllites. This change is undoubtedly the result of metamorphism by granites which were found a short distance to the north by the Rachkovsky expedition. Below the junction, the river crosses a mass of diorite with a porphyritic border phase. The relations between the diorite and the sandstones are not clear, since the north fork flows along the contact.

To the east of the diorite mass is a series of sediments consisting of purplish, andesite porphyry,[1] tuffs and gray and purple crystalline limestones. The whole series has been intensely folded and is cut by numerous dikes of diorite, andesite porphyry and granite porphyry. The beds stand at high angles and vary in strike from N. 10° W. to N. 15° W. Because of the folding and igneous intrusions, it is difficult to work out the stratigraphic succession, but in one place the beds in a syncline exposed in the canyon wall give the following succession:

3. Gray crystalline limestone.
2. Purple limestone.
1. Tuff.

[1][The original text reads "porphyrite," a term still used by European petrographers. The American term, "andesite porphyry," is almost its exact equivalent and has been substituted for "porphyrite" in all cases.]

In 1923 Rachkovsky found archaeocyathids[1] in the limestones of this series where they are exposed along the right bank of the river. The same series, consisting of tuff, purple limestone and gray limestone with archaeocyathids, occurs in an isolated area three miles down the Burgasutai River on the left bank. This area is also cut off on the east by masses of fine-grained diorite and andesite porphyry.

Farther east the valley widens and crosses a succession of normal sedimentary rocks which are divided into two series. The lower one consists of green, arenaceous shales with bands, from 10 cm. to 50 cm. thick, of greenish-gray, argillaceous limestone, and a few bands, varying up to 50 cm. in thickness, of light gray, quartz sandstone. The calcareous bands contain the same fauna as that collected in this vicinity by Rachkovsky during his reconnaissance. It consists of brachiopods, trilobites and cephalopods (Orthoceratidæ) and, according to D. V. Nalivkin, is of Lower Silurian age. The lower part of the upper division, which lies conformably upon the lower one, is composed of purplish-red, fine-grained sandstones containing coarser-grained, gray quartz sandstone bands similar to those in the lower series. Calcareous bands are conspicuously absent. The purplish color is probably the result of intermixture of fine tuffaceous material, for in the upper part of the series there are beds of purple tuff. Microscopic examination of the tuffs has shown that they are of andesitic composition and are similar to the tuffs interbedded with the limestones farther up the river. The tuffs are confined to the upper part of the purplish sandstone series, and associated with them are bands of purple limestone varying in thickness up to seven feet. In the uppermost portion there are bands of gray crystalline limestone similar to the thick limestones of the archaeocyathid beds. The thickness of the Lower Silurian of the Burgasutai River section, for which the name "Burgasutai formation" is proposed, is at least 1,000 feet.

The green shales and purple sandstones are both cut by fine-grained diorites and by porphyritic and vesicular rocks of andesitic composition. The intrusions are small hypabyssal bodies, many of which occur in the form of sills. They have produced marked contact metamorphic effects on the sandstones, which have been converted to green jasper in the border zones around the igneous rocks. The sediments and the diorite and andesite porphyry are cut by a younger set of granite porphyry and syenite porphyry dikes. These are most abundant on the south side of the Burgasutai valley and were probably derived from the granites found to the south by the Rachkovsky expedition.

[1][Coral-like organisms belonging to the Coelenterata.]

The Lower Silurian has been intensely folded in the vicinity of the junction of the two branches of the Burgasutai. The folds become more open farther to the east. They are sharper in the vicinity of the diorite and andesite porphyry masses than in other places, and here deformation also resulted in faulting. The close association of diorite and andesite porphyry masses with the most intensely deformed sediments leads to the conclusion that the igneous intrusions were already in place at the time of folding and acted as centers of resistance to the compressive stress. The fact that the folds are sharper and more complex on the west sides of the intrusions indicates that the pressure came from the west.

A question of major importance is that of the relation between the beds bearing archaeocyathids and those containing a Lower Silurian fauna. Since archaeocyathids are considered as typical Cambrian forms, it would be logical to expect that the Lower Silurian lies on the archaeocyathid beds, possibly with unconformity. No exposures were found along the Burgasutai or to the north of it in which these relations are clear. The two series, moreover, have apparently had the same tectonic history. The archaeocyathid beds along the Burgasutai have been much more sharply folded than the Lower Silurian sediments downstream, but to the north and northeast the folds in the archaeocyathid beds are quite gentle. Although the folds in the Lower Silurian are quite open in most places, the westernmost exposures of the Lower Silurian in the Burgasutai section show that here deformation has been as intense as anywhere in the area of outcrop of the archaeocyathid beds. Both series also have the same strike. In the western part of the area where folding was very intense, the strike is north-northwest, while farther to the east it is nearly due east. It is, therefore, inferred that there is no angular unconformity between the two series.

The archaeocyathid beds and the Lower Silurian were not found involved in a single simple structure in which it would have been possible to be certain of their age relations. There is, however, close similarity between the archaeocyathid beds and the uppermost part of the Lower Silurian in the succession of different types of rock. Upon the purplish-red sandstones of the Lower Silurian lie tuffs which pass upward into a succession of alternating bands of tuff and purple limestone. At the top of the series are beds of gray crystalline limestone. This leads to the following tentative correlation:

Lower Silurian	Archaeocyathid Beds
Gray crystalline limestone	Gray crystalline limestone
Tuffs and purple limestones	Purple limestones with archaeocyathids
Tuff	Tuff
Purplish-red sandstone	
Green arenaceous shale with Lower Silurian fauna	

This tentative correlation is made on the basis of succession of different lithologic types and position of outcrop of the various members in an area of complex folded and faulted structure. Although archaeocyathids have long been regarded as typical Cambrian forms, they have recently been described by Grabau (5) from the Ordovician of North China. Since the correlation is not based on a continuous succession of well exposed beds, it is presented merely as an hypothesis for consideration by other workers.

Lower Silurian sediments are found in several other small isolated areas. In the Bömen Khara Mountains the succession is as follows:

5. Purple sandstones with bands of arenaceous limestone containing siliceous pebbles of various colors.
4. Fine-grained, reddish-purple sandstone.
3. Green argillites with bands of white quartz sandstone.
2. Coarse-grained, white quartz sandstone with bands of green argillite near the top and bands of fine-grained, dark purple sandstone near the bottom.
1. Tuffs similar to those of the Burgasutai River section.

A characteristic feature of the sandstones is cross-lamination indicating deposition in shallow water. In this respect they differ markedly from the sediments of the Burgasutai formation, which were deposited in deeper water. Intrusive rocks, principally in the form of sills, are present throughout the succession. Some of them were undoubtedly derived from the diorite mass forming the core of the mountains. The beds dip away from this mass in all directions except to the west where the diorite is in contact with younger granites. Although the strike of the beds along the eastern side of the diorite mass is north-northwest, the predominant trend of the folds is nearly due east. No fossils were found in the sediments, but the lithologic character of the rocks indicates a close connection with those of the Burgasutai River section. Since the succession in the Bömen Khara Mountains begins with tuffs similar to those near the top of the Burgasutai formation, it is believed that the shallow-water sediments of the Bömen Khara Mountains may be younger than the Burgasutai formation and should be designated by another name, "Bömen Khara formation."

The western part of the Bömen Khara Mountains is composed of granites, which are clearly younger than the diorite, since granitic dikes cut the diorite, and xenoliths of diorite are included in the granites. The granites extend some seven miles westward to the group of low hills called the Kötel Khuduk Mountains, which are also composed of granites and diorites. In the igneous rocks are included a few patches of strongly metamorphosed, folded and sheared limestones and tuffs. The silicified green sandstones along the contact of the main diorite intrusion strike north-northwest parallel to the major axis of the intrusion. The granites of the Kötel Khuduk Mountains are also younger than the diorites.

The Lower Silurian is exposed to the southwest of the Tokhtogen Shil range. The sediments are predominantly argillaceous but contain a few bands of calcareous sandstone, calcareous shale and quartz sandstone. Mud cracks are fairly abundant in the shales. Fossils were collected from the calcareous bands by Rachkovsky. They were examined by D. V. Nalivkin, who states that they are of late Lower Silurian age. The presence of calcareous bands in the lower part of the series indicates that the upper part of it may be younger than the Bömen Khara formation, in which calcareous layers are most abundant near the top. The strike varies little from due east. The sediments are cut by numerous andesite porphyry sills.

In the west end of the Tokhtogen Shil range and along Telin Gol, Silurian rocks are also exposed. The lower beds are fine-grained, purple sandstones with bands of greenish-gray shale and white quartz sandstone. A Lower Silurian marine fauna was collected from the white sandstones. The upper part of the series consists of alternating layers of tuff and limestone. This series is possibly the equivalent of the upper part of the Burgasutai formation. The strike varies little from due east. Dioritic intrusions and later granitic intrusions are abundant.

The diorites and andesite porphyries mentioned above are undoubtedly of Silurian age, since they are closely associated with andesitic tuffs interbedded with the Silurian sediments. The granite porphyry and syenite prophyry dikes which cut the diorites and sediments are younger and are apophyses of larger granitic intrusions. Extensive granite bodies, which are probably parts of a bathylith, are found in the southern part of the Kharkira range and in the center of Tokhtogen Shil.

DEVONIAN AND PERMO-CARBONIFEROUS SEDIMENTS AND AGE OF THE GRANITES.—Rachkovsky found Devonian sediments, Permo-Carboniferous continental sediments and large masses of granite in the central part of the Kharkira range. Both the Silurian and Devonian are cut by the granites, which are overlain with sedimentary contact by the Permo-Carboniferous. These relations fix the age of the granites as Middle Paleozoic.[1]

JURASSIC CONTINENTAL SEDIMENTS.—A considerable part of the area studied is underlain by a series of sediments of continental origin, consisting of coarse clastics, thin beds of carbonaceous shale and other bands composed of plant remains. This series is found in isolated patches near the base of the Kharkira range and in large continuous exposures along the southern and southwestern margins of Tokhtogen Shil.

The westernmost exposures are on the left bank of the Burgasutai River, seven miles below the junction of the two branches. Here there are only small remnants of brownish-green, coarse-grained sandstones filling hollows in an undulating erosion surface cut on the Silurian rocks. Farther downstream, a large, continuous area extends a considerable distance north from the river. The sediments lie on a peneplaned surface cut across the Silurian sediments and associated igneous rocks. The Jurassic consists of coarse conglomerates, with boulders up to three feet in diameter, and well rounded and unsorted gravel embedded in a sandy matrix. In addition, there are thin bands of sand which mark the cross-bedding of the coarser material. The boulders and larger pebbles are diorite, while the smaller pebbles are predominantly green shale. Interbedded with the coarse clastics are a few thin layers of carbonaceous shale from which fragmentary plant remains were collected. M. F. Neiburg examined these specimens and among them identified *Pithyophyllum Nordenskiöldii* Nath., and *Podozamites lanceolatus* L. and H. In addition, there were a few imperfectly preserved fragments of ferns which were doubtfully referred to *Cladophlebis* sp. The first two species are characteristic of the Jurassic of Asia.

A small remnant of the Jurassic conglomerates occurs midway between the Kharkira range and Tokhtogen Shil to the north of the mouth of the Burgasutai River. There are also patches of gravel in the same vicinity which give evidence of the former existence of the Jurassic. Most of the Kirgiz Nor basin is covered by alluvium and soil, and consequently it is difficult to tell whether the Jurassic was once continuous across the floor of the basin.

A strip of Jurassic conglomerates extends eastward from a point half-way between the mouth of the Burgasutai River and Kirgiz Nor

[1][Lebedeva gives no description of the lithological character of the Devonian nor the evidence on which the age determination was made. She mentions that the Permo-Carboniferous sediments are of continental type but gives no summary of the evidence on which the age determination was made. A footnote gives as authority for the statements above, "Data of the Mongolian-Uriankhai Expedition of 1923." The reviewer has attempted to obtain these data from the U. S. S. R., but apparently they have not been published.]

to the northwest shore of the lake. The scarp bounding the strip on the south is the first step upward from the lake bed to Tokhtogen Shil. From the first scarp a flat surface extends some six miles northward to a second scarp. The bench between the scarps is underlain by coarse conglomerates with boulders up to six feet in diameter derived from the granites and Silurian rocks. In these sediments a few fragments of fossil wood were found. The second bench, which extends northward from the second scarp to the base of the Tokhtogen Shil Mountains, is also underlain by Jurassic conglomerates with boulders of local origin up to seventeen feet in diameter. In a few places along the east side of the Bömen Khara Mountains, the conglomerates can be seen in contact with the Silurian. Erosion has carried away most of the Jurassic, exposing the gently rolling, peneplaned floor on which the conglomerates were deposited.

The southwestern border of the Tokhtogen Shil range is also composed of Jurassic conglomerates and sandstones which are faulted down against the Palaeozoic rocks. A number of faults striking from N. 20° W. to N. 30° W. were followed out, but there are other faults striking nearly east. The resulting boundary between the Jurassic and Palaeozoic is consequently a zigzag line with long stretches trending north-northwest and shorter ones trending east.

Jurassic sediments are also found in the Ubsa basin along the Shurgu Uliasty River outside the area represented on the map.

The Jurassic sediments must have covered a considerable part of northwestern Mongolia. They were formed by the deposition of sediments in continental basins and thus provide evidence that this part of Asia had been raised above sea level before the Jurassic. The continental régime, however, was initiated long before the Jurassic, for the Permo-Carboniferous sediments found by the Rachkovsky expedition in the central part of the Kharkira range are of the same continental type. A period of extensive erosion must have intervened between the folding of the Silurian rocks and the deposition of the Jurassic, since the Jurassic lies on a gently rolling surface with only a few slightly projecting masses of more resistant igneous rocks. This surface has essentially the character of a peneplane. It has been exposed in a number of places by subsequent erosion, which has left only small patches of conglomerate in the depressions. The present topography of a considerable part of the Valley of the Lakes is probably the result of the stripping of the pre-Jurassic peneplane.

CRETACEOUS AND TERTIARY SEDIMENTS.—Upon the eroded surface of the Jurassic lies a succession of conglomeratic sandstones and shales of various colors. This series is found only in small patches around the northwestern edge of Kirgiz Nor and on top of the first bench above the level of the lake bed. Fish vertebrae and other bones were collected from the sandstones near Chona Dolokha spring. The sandstones in the vicinity of the springs, Naryn Buluk and Ketsu Buluk, yielded a few bones of higher vertebrates. This meager and fragmentary fauna was not sufficient to determine whether the rocks are of Cretaceous or Tertiary age. Consequently it is proposed to designate the sediments by the name "Gobian series," a term originally used by Obruchev (8:301).[1] [This term is practically synonymous with "Later Sediments" as used by Berkey and Granger (1).] The surface on which the Gobian series lies is also probably a peneplane, but one of much smaller relief than that on which the Jurassic was deposited, largely because of the absence of Jurassic and post-Jurassic igneous rocks. Ancient peneplanes are known in other parts of Central Asia as a result of the work of Berkey and Morris (3) in Central Mongolia, and Obruchev (8) in Dzungaria.

DEFORMATION OF THE JURASSIC AND GOBIAN.—The movements which affected the continental sediments were radically different from the orogeny which folded the Silurian sediments and the associated igneous rocks. The folds in the Jurassic and Gobian are local and inconstant in strike and their relation to faulting is clear. The first two scarps to the north of Kirgiz Nor trend eastward and are the result of faulting. The folds in the Jurassic of the southwest border of the Tokhtogen Shil range trend west-northwest parallel to the major faults of the locality. The Gobian series has been only slightly affected by fault movements.

ORIGIN OF SURFACE FEATURES.—[Lebedeva gives no connected account of the origin of the surface features of the area. It is, therefore, considered advisable to assemble here the data bearing on this subject.

The abrupt and almost straight front of the northern portion of the Kharkira range and the absence of foothills along its base give strong evidence that the boundary between the range and Ubsa basin is a fault of great displacement. The steep scarp on the north side of the Tokhtogen Shil range is probably also a fault scarp. On the south and southwest sides of the range are two sets of faults, respectively striking east and northwest, along which the Jurassic has been turned on edge and brought

[1][The first number refers to the bibliography at the end of this paper. The number after the colon refers to the page of the publication cited in the bibliography.]

into contact with older rocks. It is apparent that fault movements were in progress soon after the deposition of the continental Jurassic sediments and must have continued sporadically into Cretaceous or Tertiary times, since the Gobian sediments are also slightly tilted. The fault scarps forming the southern boundaries of the two benches to the northwest of Kirgiz Nor are on comparatively non-resistant Jurassic conglomerates and therefore cannot be very old. It seems likely, therefore, that faulting continued until comparatively recent times. The major topographic features, the two ranges and the basins, may have been outlined even before or during Jurassic time. The boulders of local origin, six feet in diameter in the Jurassic conglomerates of the first bench north of Kirgiz Nor, and the increase in size of boulders northward to a maximum diameter of seventeen feet in the conglomerates of the second bench, indicate that a high, steep land mass from which the sediments were derived stood only a short distance to the north. It is, therefore, probable that the Tokhtogen Shil range was already functioning as a rising block even during Jurassic time.

The gently rolling character of the upper surface of the Tokhtogen Shil range and the steep scarps which form a large portion of its boundaries, suggest that the surface is an uplifted ancient peneplane. In this respect the range is quite similar to the Baga Bogdo and Artsa Bogdo ranges of the eastern Altai described by Berkey and Morris (4:311 to 314). These ranges are blocks bounded on the north by fault scarps. Their gently rolling upper surfaces, which are portions of a tilted peneplane, descend gradually to the south. The peneplane is believed to be of Lower Cretaceous or Middle Tertiary age. It seems fairly certain that the peneplane on the Tokhtogen Shil range is not the surface on which the Jurassic sediments were deposited, since these sediments give evidence of extensive removal of material from the range during the Jurassic. It can, therefore, be concluded that the peneplane is post-Jurassic in age. The matter of placing an upper limit to the age of the peneplane, however, is very difficult because of the lack of a fairly complete record of post-Jurassic sedimentation in the surrounding territory.

The nearly flat lowlands around Ubsa Nor and Kirgiz Nor are floored by rocks varying from hard igneous intrusives to unconsolidated gravels. The lowland surface is described by Lebedeva as a peneplane, but this term cannot be properly applied, for a peneplane is an erosion surface developed by streams whose base-level is the sea. The surface might be called more properly an "erosion plane," a term applied by

Berkey and Morris (4:332) to the surface beveling both the younger sediments of the talas to the south and east of the Valley of the Lakes and the hard igneous rocks between them. The Gobi erosion plane observed in the area visited by the Third Asiatic Expedition is believed to have been formed by processes of desert erosion during the early Pleistocene, since the surface bevels sediments ranging in age from Cretaceous to Pliocene (4:347) and is overlain by Pleistocene alluvial fans at the bases of the faulted ranges. The surface of the Ubsa Nor and Kirgiz Nor lowlands is in part, at least, a true desert erosion plane, but in several localities small pockets of Jurassic conglomerates fill shallow depressions in an erosion surface truncating Palaeozoic rocks. Lebedeva concludes that the topography of these localities varies but little from that of pre-Jurassic times, and that large portions of the present lowlands are stripped parts of the pre-Jurassic peneplane.]

GEOLOGICAL HISTORY OF THE REGION.—The oldest rocks in the area studied in detail are the Silurian sediments and the associated diorites and andesite porphyries of approximately the same age. The sediments were deposited in the border zone between a continental mass on the east and a geosyncline on the west. The Silurian strata are the youngest beds found in this zone, but sediments of Lower Devonian age deposited near the center of the geosyncline were found farther west in the Kharkira range by Rachkovsky. The Silurian and Devonian here were involved in the Hercynian movement and were thrown into folds trending north-northwest. At the same time great granite masses were intruded. The Lower Silurian of the eastern border of the geosyncline was outside of the area of intense folding and here there are no extensive folds with the Hercynian trend.

After an interval of erosion, Permo-Carboniferous continental sediments were deposited on the folded Silurian and Devonian sediments and their associated intrusive rocks in the area which is now the central part of the Kharkira range. From Lower Silurian time to the Jurassic, the territory farther east was subjected to continuous erosion and was slightly affected by an orogenic movement which gave the gentle folds of easterly trend found in the Silurian between the Kharkira range and Tokhtogen Shil. This was probably the Tian Shan movement of late Palaeozoic time.

The post-Silurian period of erosion in the eastern part of the region planed down the older rocks to a gently rolling surface, above which projected a few knobs composed of igneous rocks. Upon this surface the coarse Jurassic conglomerates were deposited. It is probable, as pointed out above, that block-faulting began some time before or during the Jurassic and has continued from time to time since then. During Cretaceous or Tertiary times, the Gobian sediments were deposited on the eroded surface of the Jurassic, but they may not have covered extensive areas. In comparatively recent times, the higher mountains were glaciated and the lowlands were subjected to a process of erosion which planed down the rocks to a gently rolling surface, which, in places, merges into the stripped pre-Jurassic peneplane.

DISCUSSION

[The later part of the geological history of northwest Mongolia is almost identical with that of central and north-central Mongolia. Both regions have stood above sea-level since the end of the Palaeozoic, and the known Mesozoic and Tertiary sediments were all deposited in continental basins. Central Mongolia, however, was subjected to a period of folding and igneous intrusion during the Jurassic. Berkey and Morris (4:291 to 294) describe a number of localities in which the Jurassic sediments are folded and cut by dikes which do not penetrate the Cretaceous. The Jurassic in the area studied by Lebedeva is disturbed only by faults and minor folds resulting from faulting, and no igneous rocks younger than Devonian were observed.

Silurian and Devonian sediments have been found only in northwestern Mongolia. In other parts of the country, the Upper Palaeozoic is represented by only a few isolated remnants, such as those of Pennsylvanian and Permian age near Sair Usu (4:294 to 296) in central Mongolia, the Carboniferous limestone along Edsin Gol south of Gashiun Nor in southern Mongolia mentioned by Potanin and Obruchev, and minor exposures to the west of the Ordos noted by Obruchev. It is, therefore, fairly certain that most of Mongolia stood above sea level during the Lower Palaeozoic.]

THE GEOLOGY OF NORTHEASTERN MONGOLIA[1]

By B. M. Kupletsky

Abstracted from the Original Russian and Annotated

By R. H. Beckwith

The petrographic party of the Soviet expedition of 1925, in charge of B. M. Kupletsky, was sent out from Urga to make a geological reconnaissance of northeastern Mongolia. Field work was begun early in July and was concluded a month later.

Route and Topography.—The first week was spent in the immediate vicinity of Urga and in the area of the Gorikho granite mass (Fig. 2). From here the party followed the northern road eastward across the Kerulen River. They then followed its left bank southward to the crossing of the southern road, along which they continued eastward to the Tugulgutui Nuru mines, situated almost due north of the great bend of the Kerulen River and some 200 miles east-southeast of Urga. The return journey was made along the southern road.

The region traversed is the western part of the transition zone from the Kentei range on the north to the Mongolian plains on the south. The topography may be described as a rolling plain varied by low ridges. The northwestern part of the region in the vicinity of Urga and the Tola River is penetrated by a few outlying spurs of the Kentei range reaching altitudes of 5,000 feet to 6,000 feet. To the southeast the ridges gradually decrease in height, and the portion of the region east of Tsenkirin Gol is a typical steppe with mean elevation of approximately 4,000 feet.

The principal rivers are the Tola and the Kerulen. In the case of the left tributaries of the Tola and the right tributaries of the Kerulen, the general trend of the valleys is from southeast to northwest. In the territory east of the Kerulen, the valleys extend, in general, from east to west. The difference in trends of valleys in the two regions is closely connected with the structural trends of the older rocks lying between the Kerulen and Tola and the younger Upper Palaeozoic and Jurassic sediments east of the Kerulen. The rivers of the region have winding courses, and their valleys are in the stage of maturity. In the summer of 1925 there was water only in the upper parts of the valleys, in spite of the fact that the year was one of abnormally high precipitation.

[1]Kupletsky, B. M. 1926. Toward the geology of eastern Mongolia. Northern Mongolia, I, Preliminary accounts of the geological, geochemical and soil-botanical expeditions on the work carried out in 1925. Publications of the Academy of Sciences of the U. S. S. R., Leningrad.

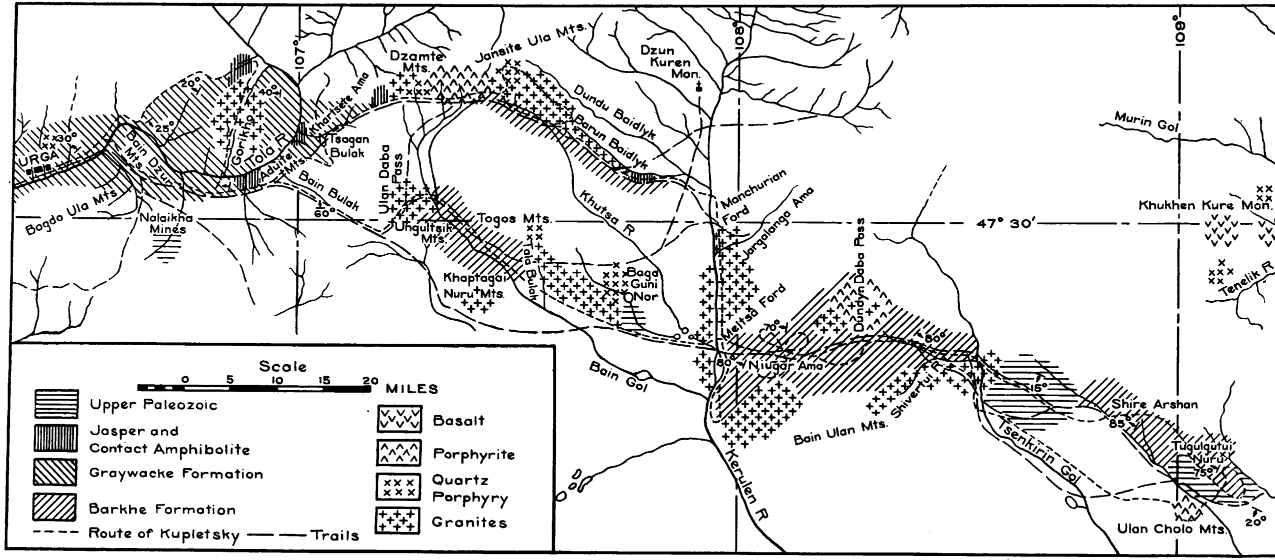

Fig. 2. Reconnaissance Geological Map of Part of Eastern Mongolia. (After Kupletsky.)

Latitude and longitude are not given on the original map. The positions of the parallel and meridians were computed on the basis of the position of Urga, given as latitude 47.58° N., longitude 106.40° E. from Greenwich, in J. G. Bartholomew's "Advanced Atlas of Physical and Political Geography," edition of 1917

Western District Between Urga and the Kerulen

Barkhe Series.—The oldest rocks of sedimentary origin in the region are a thick succession of slates with a few bands of limestone. Fossils are absent, and consequently an exact determination of the age of the rocks cannot be made. The lithologic character, however, indicates that the rocks belong to the series studied farther north in the Kentei range by M. A. Usov (10:920) and to which he gave the name "Barkhe formation."[1]

The principal areas of outcrop of the series in the western district are south of the eastern portion of the road from Urga to Dzun Kuren and in the Togos and Ungultsik Mountains. There are also several other smaller areas, not shown on the geological map, along the Tola River. The rocks most typical of the Barkhe series are dark green or black slates. Microscopic examination of thin sections shows that they are composed of very fine grains of quartz, microperthite and oligoclase embedded in a groundmass containing sericite. In some specimens the groundmass is a mixture of calcite and chlorite. Although fossils are absent, the general character of the rocks and the beds of limestone suggest that the sediments are of marine origin.

The Barkhe series has been sharply folded and metamorphosed both by lateral pressure and by the intrusion of younger igneous rocks. The results of folding and dynamic metamorphism are clearly visible in the vicinity of Tsagan Buluk, where a bed of impure limestone interbedded in the slates is being worked by Chinese for lime. The bed is from six feet to ten feet thick, stands on edge and strikes N. 30° E. Fracture cleavage is present throughout the limestone, and in some places the rock has been extensively brecciated.

During the time of deposition of the Barkhe series there were local extrusions of basic magma. The resulting igneous rocks were later folded and fractured along with the sediments. The conclusion of Usov (10:922) that there was no vulcanism during the Barkhe time is incorrect. Evidence of volcanic action is found in the head of Bain Buluk, one of the tributaries of the Tola. At this place the slates strike N. 65° W., and dip 60 degrees to the northeast and show cleavage with various orientations. Within the slates are two igneous sheets, some 70 feet or 80 feet apart, and with respective thicknesses of seven feet and thirteen feet. They are conformable with the bedding of the slates. The sheets are slightly different in microscopic character, but are closely similar in

[1][Kupletsky also uses the terms "Barkhe formation" and "Graywacke formation," but since both of these units are very thick, it seemed advisable, for the purposes of this paper, to change the names to "Barkhe series" and "Graywacke series."]

mineralogical composition. One has a dense texture and is light in color. The other is a fine-grained gray rock. Both have been so extensively carbonated that in the field they were taken for limestones. Microscopic examination showed that they are carbonated and chloritized andesite porphyries with andesitic groundmass. A characteristic feature is the extensive development of secondary albite both in the groundmass and in the andesine phenocrysts. One specimen shows the effects of the action of later granitic magma, which introduced quartz, biotite and micropegmatite into the groundmass and replaced the borders of the phenocrysts with micropegmatite.

Similar albitized andesite porphyries with phenocrysts of basic plagioclase in an albitized and chloritized groundmass, are also found as sheets in the Barkhe series in the Argaste Ama valley beyond the pass leading out of the head of the Bain Buluk valley.

GRAYWACKE SERIES.—Around Urga and in the territory forming the northern part of the watershed between the Tola and the Kerulen, the predominant rocks are a series of compact, greenish-gray, graywacke sandstones alternating with bands of dark slates. The series contains neither organic remains nor limestones and was probably deposited on a land surface. In the Bain Buluk valley and west of the Togos Mountains, the series begins with a basal conglomerate and lies unconformably on the Barkhe series. In the Yalbyk and Barkhe valleys farther north, Usov (10:927) found that the Barkhe rocks are overlain unconformably by a sequence of graywackes and slates beginning with a basal conglomerate. The sediments around Urga, therefore, belong to the "Graywacke formation" of Usov. The graywacke sandstones are medium-grained and consist of fragments of quartz, acid oligoclase and microperthite embedded in an argillaceous cement. Grains of epidote, titanite and chlorite pseudomorphs after green amphibole are fairly abundant. A few pebbles of quartz porphyry with felsitic groundmass were also found.

[The abstracter has examined thin sections prepared from specimens collected from the same series a few miles south and southwest of Urga by Berkey and Morris. In addition to mineral grains, rock fragments are also present. Some of the specimens are composed almost entirely of subangular andesite fragments, and are therefore comparable to andesite tuffs. Other thin sections contain bent plates of slightly chloritized biotite. These are larger than the average fragments of volcanic rock. They were introduced during sedimentation and are not a product of recrystallization. There are also fragments of micropegmatite and large grains of various feldspars near the acid end of the seres, in addition to quartz grains showing the "blotchy" extinction so often seen in the quartz of granites. The graywacke sediments were derived from a terrane in which there were andesites, granites and probably schists. The process of weathering by which the clastic material was prepared for transportation must have been predominantly one of mechanical disintegration with little or no chemical decomposition. Otherwise the fragments of extrusive rock would not have been preserved in their fresh state and the biotite would have been destroyed. The sediments were deposited fairly close to the place of origin of the clastic material, since most of the grains are quite angular and the biotite could not survive long transportation.]

The graywackes and slates are cut by numerous granitic intrusions and large areas of the sediments bordering the intrusive bodies have been converted to green and red jaspers and to amphibolites cut by veinlets of quartz and epidote. In a number of instances the metamorphosed zone extends from one igneous mass across to another, indicating that granites are present almost everywhere at only a slight depth below the surface and that all of them are probably parts of a bathylith.

In general, the sediments are only slightly folded. Sharp folds are present only in the immediate vicinity of granite masses, where strong lateral pressure was exerted during intrusion. In most cases it is difficult to determine the position of the beds because of the development of cleavage during folding. As far as can be determined, the strike is inconstant, but in the vicinity of the Gorikho granite mass it varies from N. 20° E. to N. 70° E. The dip is, in general, to the northwest and varies from 20 degrees to 50 degrees.

Ages of the Barkhe and Graywacke Series.—[Kupletsky gives no discussion of the respective ages of the Barkhe and graywacke series, but the subject has received attention from Usov (10), who studied both series in the Kentei range, and from the geologists of the Third Asiatic Expedition, who visited the type area of the graywacke series near Urga and also found certain slates and crystalline limestones, which may be the equivalent of the Barkhe series, on their traverse northwestward from the Chinese border at Kalgan to Urga.

Usov (10:920 to 934) found that the Barkhe formation, consisting principally of slates of various colors, limestones and subordinate beds of graywacke sandstone, forms only a small part of the Kentei range. The principal area of outcrop of the formation is a strip along the southeast edge of the range. Although the original character of the rocks has been changed by dynamic and contact metamorphism, they still maintain features which indicate that they were deposited in a sea of medium depth. After the completion of deposition, the beds were compressed and thrown into sharp folds trending northward. During the end stages of folding, small stocks of granodiorite were intruded. These were deformed and mylonitized during a later period of folding and can thus be distinguished from later intrusives.

A long period of erosion followed the orogenic movement, and the mountains must have been planed down to a surface of low relief, since the basal conglomerates of the graywacke formation are thin and in some places are absent. The conglomerates contain slate fragments derived from the older sedimentary series and rounded pebbles of granodiorite. The succeeding sediments of the graywacke formation are medium-grained graywacke sandstones, dark slates and argillites. Limestones are almost entirely absent. Usov believes that most of the sediments were deposited in shallow marine water, but notes that some of the clastics in the Iro valley are crisscross-bedded. This he interprets as resulting from wind action. The interval of deposition was followed by an orogenic movement which gave folds trending to the northeast in the western part of the Kentei range. The folds in the eastern part of the range approach an eastward trend and lie nearly at right angles to those in the Barkhe formation. The post-graywacke folding was much less intense than the preceding one and had little effect on the folds and cleavage in the Barkhe rocks. During the second orogeny there was another granodiorite invasion giving igneous bodies of bathylithic dimensions. These now form most of the Kentei range.

Usov concluded that the Barkhe and graywacke formations are both of pre-Cambrian age. His conclusions are based principally upon his failure to find any fossils in them. He points out, however, that the intense metamorphism to which the rocks have been subjected would tend to destroy all organic remains, and that certain kinds of sediments, such as the graywacke sandstones, are not of the type in which fossils would be preserved. On the other hand, limestones and carbonaceous slates and shales, which are common rock types in the Palaeozoic of Siberia, are not found in the Kentei range. He provisionally assigns the graywacke formation to the Algonkian and the Barkhe formation to the Archaean.

The Third Asiatic Expedition followed a route leading from Kalgan, which is situated on the Chinese border northwest of Peking, to Urga, then southwest to the eastern ranges of the Altai and back along their northern border to Kalgan. Along this route Berkey and Morris (4:300 and 398) found areas with a great succession of schists, phyllites and limestones, which were metamorphosed, folded and eroded before the deposition of the graywacke series. These metamorphics are of the same lithologic character as the Barkhe series and are similarly related to the graywacke series. It is probable that these schists, phyllites and limestones, which are correlated with the Lower Proterozoic Wu T'ai system of China, are of approximately the same age as the Barkhe series.

Berkey and Morris (4:399) found a succession of graywacke sandstones and slates in the vicinity of Urga and named it the "Khangai series" because of its extensive occurrence in the Khangai Mountains to the west. The rocks included by them under this name are undoubtedly the equivalent of the "Graywacke formation" of Usov and Kupletsky. The geologists of the Third Asiatic Expedition state that, although they did not see the top or bottom of the series, it must be at least 20,000 feet thick. Their account of the lithological character and history of these rocks for the area to the southwest of Urga is very similar to the two Russian geologists' accounts of the same rocks in the Kentei range and to the south of it. Berkey and Morris believe that the Khangai series of northern Mongolia was deposited on a land surface and are in agreement with Kupletsky on this point. They provisionally assign it to the Upper Proterozoic, on the basis of the absence of fossils, the structure, and the relation of rocks which apparently represent the southern extension of the series to the undoubted marine Upper Palaeozoic rocks found at Sair Usu and Jisu Honguer. They state, however, that they are fully aware that the graywackes farther east and north are regarded as of Palaeozoic age by some Russian geologists, who report fossils from certain localities.]

UPPER PALAEOZOIC SEDIMENTS.—In the western area there are two isolated patches of sediments believed to be of Upper Palaeozoic age. The best known one is twenty-five miles southeast of Urga at the Nalaikha coal mine, which was being worked by ten Chinese in the summer of 1925 to provide fuel for the Urga electric power plant. B. S. Dombrovsky, the geologist who examined the mine at this time, reports that the coal seam varies in thickness up to five feet and dips steeply to the southwest. Its structure is rather complex. Plant impressions in the overlying shale indicate that the beds are of Upper Palaeozoic age, probably Permian. That the coal is comparatively young is indicated by the following analysis made in the laboratory of the Leningrad Polytechnic Institute:

Coke[1]	55.90%
Ash	4.84
Moisture	14.30
Sulphur	.54
Calorific value	6,036 cal.

Qualitative tests for humic acid showed that it is present in considerable amounts. The products of distillation did not give an acid reaction. The coal is therefore a type intermediate between lignite and bituminous.

[Kupletsky mentions that Dombrovsky found plant impressions in the shale above the coal seam, but gives no list of plant species. It is the abstracter's opinion that it would be well to reserve judgment as to the age of the coal-bearing sediments in the absence of conclusive palaeontologic evidence. It is probable that the coal occurs in the series of coal-bearing sediments well known in other parts of Mongolia, which Lebedeva (7:23 to 27) assigned to the Jurassic on the basis of plant species present, and which Berkey and Morris (4:292 to 294) also assigned to the Jurassic on the basis of similarity in lithologic character and deformation history to the Jurassic of North China.]

Coal is also found west of the Kerulen, two miles south of Baga Guni Nor. Here, according to V. I. Lisovsky, the upper coal bed is twelve feet below the surface and lies almost horizontally.

[In the section on economic geology, Kupletsky lists the coal deposits near Baga Guni Nor and says that they may be of Tertiary age because of their porous character. Palaeontologic evidence as to their age is not given.]

IGNEOUS ROCKS.—A large part of the western district is floored by igneous rocks. Basic types are comparatively rare, and, with the exception of the sheets in the Barkhe series, are represented only by the andesite porphyries at the head of Bain Gol. These will be considered below in connection with the andesite porphyries of the eastern district. The predominant igneous rocks are members of the granite family, with a distinct tendency toward porphyritic structure. With them are associated quartz porphyries which form the upper portions of the granitic intrusive bodies. Even from a considerable distance, areas of these rocks can be easily distinguished by their jagged erosion forms standing out against the background of rounded hills underlain by metamorphosed sediments. The intrusions are not all of the same age. Differences in

[1][The total of the constituents reported is only 75.58 per cent. Apparently the remaining 24.42 per cent. of the proximate analysis is assumed to be volatile hydrocarbons.]

mineralogical composition and structure make it possible to distinguish the following three types:

1. Younger normal granites are exposed in the Dzamte and Jansite Ula Mountains and extend from here along the divide between the Khutsa River and Barun Baidlyk. They are light yellow in color, fine-grained and of hypabyssal type. The predominant feldspars are orthoclase perthite and microcline perthite. Biotite and oligoclase are accessories. The quartz porphyries associated with these granites are compact, gray rocks with phenocrysts of bipyramidal quartz and yellow orthoclase. In some specimens there are a few phenocrysts of biotite and in others phenocrysts of zoned oligoclase.

2. Quartz-monzonites appear along the middle courses of the Khutsa River and Bain Gol and in the Khaptagai Nuru Mountains. Oligoclase is one of the essential minerals of these rocks. In the associated quartz porphyries, oligoclase is found principally in the groundmass and is subordinate in quantity to the mirocline microperthite of the phenocrysts.

3. Granodiorites similar to those found in the Kentei range by Usov outcrop along the west side of the Kerulen between the mouth of Bain Gol and the Manchurian ford. The predominant feldspar is zoned oligoclase. Biotite and green hornblende make up nearly fifty per cent. of the volume of the rock, which is consequently fairly close in composition to diorite.

Eastern District

The district east of the Kerulen River has certain geological features in common with the western district but differs markedly in others. The oldest rocks are metamorphics which probably belong to the Barkhe series. The graywacke series is absent. Considerable areas are occupied by younger sediments of Upper Palaeozoic or Mesozoic age. In addition, there are large areas of igneous rock, both intrusive and extrusive.

Barkhe Series.—A thick succession of metamorphic rocks is exposed at various places along the road from the Tugulgutui Nuru lead mines to Meltsa ford. To this group belong the phyllites exposed in the hills in the vicinity of the mines, the compact, micaceous slates of Shire Arshan, the siliceous slates and quartzites in the Niugar Ama valley, and similar rocks west of Dundyn Daba pass. The general strike of the rocks is northeast. They dip at high angles or stand on edge. In the western part of the district, the dip is usually to the northwest, and in the eastern part to the southeast. These rocks probably belong to the Barkhe series.

UPPER PALAEOZOIC AND MESOZOIC SEDIMENTS.—Clastic sediments, containing plant remains, beds of carbonaceous shale and coal, are found to the south and west of the Tugulgutui Nuru mines and east of the middle course of Tsenkirin Gol. At all three of these localities there is close similarity in stratigraphic sequence, as shown by the following table:

TSENKIRIN GOL	TUGULGUTUI NURU	
	Section south of mines	Section west of mines
5. Friable, light-colored sandstones with pyrite cubes. Strike N. 55° W. Dip 15° S. W.	5. Coarse sandstones. Strike N. 40° W. Dip 35° S. W.	5. Light friable sandstones with plant stems. Strike N. 70° W. Dip 15° S. W.
4. Conglomerate bed.	4. Conglomerate with angular carbonaceous shale fragments in sandy matrix. Strike N. 40° W. Dip 65°-70° S. W.	4. Conglomerate with angular pebbles and sandy matrix. Strike N. 70° W. Dip 15° S. W.
3. Dense siliceous shales with plant remains. Strike N. 40° W. Dip 45° S. W. 2. Carbonaceous shales with plant remains. Strike N. 70° W. Dip 35° S. W.	3. 2. } Carbonaceous shales with plant remains Strike N. 50° W. Dip 40° S. W.	3. 2. } Carbonaceous sandstones and shales with plant remains. Strike N. 50° W. Dip 40° S. W.
		1. Argillaceous conglomerate with phyllite fragments in argillaceous matrix. Strike N. 55° W. Dip 25° S. W.

In this part of Mongolia the strike of the Upper Palaeozoic series lies between N. 40° W. and N. 70° W., depending upon local conditions.

The dip of the lower beds, the carbonaceous shales, varies from 25 degrees to 40 degrees, while the sandstones lying above the conglomerate dip at lower angles of 15 degrees to 20 degrees.

The best exposed section of these rocks is in the Khotor Bulyk valley west of the lead mines. The northwestern hills of Tugulgutui Nuru are composed of light greenish-gray phyllites striking from N. 30° E. to N. 40° E. and dipping at angles of 75 degrees to 85 degrees to the northwest. The hills break off sharply to the southward to the Khotor flats, and in a traverse in this direction successively younger beds are encountered. The southern boundary of the hills marks the shore zone of the Upper Palaeozoic sea, the sediments of which now fill the Khotor basin and extend northwest to Tsenkirin Gol. At the base of the Palaeozoic series is a bed of conglomerate composed of twisted plates of phyllite and fragments of quartz embedded in a dark argillaceous matrix. Since the conglomerate extends along the southern boundary of the Tugulgutui Nuru hills and was derived from local rocks, it is suggested that the material of the conglomerate was produced by wave erosion on the shore of the ancient Palaeozoic sea. The succeeding carbonaceous shales and sandstones represent a near-shore facies of the marine sediments. It is probable that deep-water sediments of the Palaeozoic sea will be found in the southwestern part of the great bend of the Kerulen River where it changes its course from north to east.

The conglomerate above the carbonaceous shales indicates a retreat of the sea. The succeeding sandstones, composed of grains of quartz, mica and feldspar in an argillaceous matrix, bear plant remains and were therefore deposited on a land surface. The different dips of the carbonaceous shales and the sandstones (see table), together with the occurrence of a conglomerate bed between them, indicate that the conglomerate marks an unconformity. It is therefore possible that the sandstones at the top of the succession belong to the Lower Mesozoic. This is quite consistent with the geological history of the Gobi desert region as given by the geologists of the American expedition (2), who state that here the Upper Palaeozoic is represented by deep-water sediments, and that the Jurassic, which is of continental origin, is unconformable with the Palaeozoic.

[Kupletsky does not report marine fossils from the conglomerate at the base of the section west of the Tugulgutui Nuru mines nor from the overlying carbonaceous sandstones and shales. His conclusion that both members are near-shore marine sediments does not seem to be well founded, especially since he reports the presence of plant remains in the carbonaceous sandstones and shales. He presents no evidence that the two lower members are Palaeozoic in age, and therefore his suggestion that they once graded laterally into the undoubted marine Palaeozoic sediments found by Berkey and Morris some hundreds of miles to the southwest has little value.

It seems to the reviewer that, in the absence of positive palaeontologic evidence, it would be advisable to correlate the sediments classified by Kupletsky as Palaeozoic and Jurassic with the succession of continental sediments of almost identical lithologic character referred by Lebedeva (7:23 to 27) and by Berkey and Morris (4:292 to 294) to the Jurassic.]

IGNEOUS ROCKS.—Extensive areas of granites and andesite porphyries are exposed in the eastern district, but no quartz porphyries were seen. In the district west of the Kerulen, quartz porphyries almost invariably accompany the granites and may be confined to this area. It is possible, however, that they were not found east of the Kerulen because of the limited area examined and the necessary haste of the reconnaissance. Here the following types of igneous rocks have been distinguished:

1. Granodiorites are exposed along the east side of the Kerulen from the Jargalanga Ama River to the mouth of Bain Gol. They are yellowish-gray in color and porphyritic. Gneissoid structure resulting from dynamic metamorphism is a characteristic feature. Oligoclase is the predominant feldspar, but microcline microperthite is present in small quantities. The ferromagnesian minerals are biotite and green hornblende. These granodiorites are probably continuous with the granodiorites west of the Kerulen and of the same age.

2. Normal granites are found south of the Niugar Ama valley and along the Shivertui River. The only feldspar is sericitized microperthite. Biotite and hornblende are both present in some specimens, while in others the ferromagnesians are represented by only one of these minerals.

3. Andesite porphyries form thick sheets in the upper part of the Niugar Ama basin on the divide between the Kerulen and Tsenkirin Gol, and around the head of Bain Gol in the western district. Their petrographic similarity indicates that all of them represent a single phase of extrusion of basic magma, and they will be considered together. The andesite porphyries are dark green and nearly all are amygdaloidal. The phenocrysts are fresh basic plagioclase. In some specimens there are also phenocrysts of augite surrounded by reaction-rims of light yellow

amphibole. The minerals of the groundmass are a plagioclase of somewhat more acid composition than that of the phenocrysts and uralite, chlorite and magnetite. In most of the andesite porphyries the groundmass is a fine-grained aggregate with diabasic structure, but in a few it is glassy. In the localities where the extrusive andesite porphyries appear there are also porphyritic dike rocks of closely similar composition. The groundmass is microgranitic but contains only small quantities of quartz. The dike rocks are intermediate in mineralogical composition between the granodiorites and andesite porphyries. It is, therefore, suggested that the andesite porphyries represent the extrusive phase of the igneous activity which gave origin to the granodiorites.

Ages of the Igneous Rocks.—The available evidence indicates that the granodiorites and andesite porphyries are the oldest igneous rocks. The granodiorites cut the Barkhe series, but no exposures were seen in which they cut younger rocks. In addition, they have a gneissoid structure developed during a period of folding subsequent to their intrusion, and in this respect differ markedly from the normal granites. Some of the andesite porphyries of the Niugar Ama basin enclose fragments of Barkhe quartzites surrounded by zones of amphibole. The andesite porphyries are consequently younger than the Barkhe series. On the other hand, they are never found in association with sediments of Palaeozoic and Jurassic age. The granodiorites and andesite porphyries were formed, therefore, during the interval between the deposition of the Barkhe series and the deposition of the sediments assigned to the Palaeozoic and Jurassic.

The granites are the youngest igneous rocks. North of the Niugar Ama valley, granite dikes cut the andesite porphyries. On the left bank of Tsenkirin Gol opposite the lower end of the Shivertui basin, there are outcrops of granite in contact with Upper Palaeozoic or Jurassic sandstones. The contact zone of recrystallized material is five or six feet wide. From the main granite mass, aplitic dikes extend some distance into the sandstones. Farther south, some 70 feet of sandstone have been converted to yellowish-pink quartzite. The granites are therefore comparatively young and were intruded some time after Upper Palaeozoic or Jurassic times.

THE JARGALANTE TERRACES[1]

BY B. B. POLYNOV AND I. M. KRASHENINNIKOV

ABSTRACTED FROM THE ORIGINAL RUSSIAN AND ANNOTATED

BY R. H. BECKWITH

The party of the Soviet expedition detailed to carry out physiographic, botanical and soil investigation worked under the leadership of B. B. Polynov, soil expert. I. M. Krasheninnikov acted as botanist and geographer. The published works of the party consist of three parts: (1) Geomorphology, (2) Soils and (3) Botany. [This account deals only with the first, written jointly by Polynov and Krasheninnikov.] The party left Urga during the first week of August, 1925, and spent approximately seven weeks in the field. The area investigated includes: (1) the basin of the Ikhe Tukhum Nor, a small lake approximately 30 miles southwest of where the Tola River bends to the northwest 100 miles below Urga, (2) the valley of the Uber Jargalante River, which flows into the lake from the west, and (3) the upper portion of the Ara Jargalante River, which drains westward from the Arctic divide near the head of the Uber Jargalante.

[The eastern part of this area was probably visited in 1922 by the Third Asiatic Expedition. Berkey and Morris (4:96) mention passing a small lake basin between mile 780 and mile 790 on the traverse southwestward toward Tsetsenwang from the bend of the Tola River.]

The region explored can be conveniently divided into two parts of markedly different physiographic character: (1) the mountainous region including the heads of the Uber Jargalante and Ara Jargalante Rivers, and (2) the basin of Ikhe Tukhum Nor. The mountainous region falls into three natural divisions (Fig. 3): (a) the western, including the head of the Ara Jargalante, (b) the central, including the head of the Uber Jargalante, and (c) the eastern, which is part of the foothill belt between the mountains and the lake basin.

CENTRAL DISTRICT

The mountains to the north of the central district outside the area of the map (Fig. 3), when viewed from any point at a considerable distance to the south, appear to form an almost continuous wall with sharp projecting points. Closer examination shows that the mountains

[1]Polynov, B. B., and Krasheninnikov, I. M. 1926. 'Physico-geographical and soil-botanical explorations in the province of the basin of the Uber Jargalante River and the head of the Ara Jargalante.' Northern Mongolia, I, Preliminary accounts of the geological, geochemical and soil-botanical expeditions on the work carried out in 1925. Publications of the Academy of Sciences of the U. S. S. R., Leningrad.

are carved from a mass of granite notched by a series of narrow valleys descending to the east toward the Tukhum basin. The mountains to the south of the Uber Jargalante valley, when viewed from the summit of Uste Mountain or from Tarbagate Mountain, appear as a mass of summits separated by a complex system of valleys descending to a deep main valley, which lies some distance to the south of the Uber Jargalante and runs parallel to it. The nearly flat mountain tops are at approximately the same elevation and are parts of an old erosion surface. [This surface is probably the Khangai peneplane described by Berkey and Morris (4:323).]

The contoured geological map (Fig. 3) shows that the steep upper walls of the Uber Jargalante valley in the central district are underlain by ancient igneous and metamorphic rocks. The lower part of the valley has been carved out of younger sedimentary rocks divided into two series, the Lower Jargalante series of limestones, shales, carbonaceous shales and sandstones, and the Upper Jargalante series, consisting of at least 150 feet of cross-bedded, angular conglomerates and, in addition, sandstones and sandy shales. The older series has been extensively deformed, while the younger lies flat in most places. [The presence of limestones and carbonaceous shales in the Lower Jargalante series and its tilted position are features common to the Cretaceous sediments in adjacent territory in Mongolia (4:353 to 358), and it is therefore probable that the Lower Jargalante series is Cretaceous in age and that the Upper Jargalante is Tertiary.]

In the valley there are three terraces, the intermediate (lowest), second and third (highest). The intermediate terrace is well developed only in the foothill belt east of the Jargalante Gate. The second and third terraces are best developed in the central district. [In numbering the terraces the authors apparently considered the modern flood-plain of the river as the first terrace. This is not consistent with American usage, but there are, nevertheless, three distinct benches above the level of the modern flood-plain. Two of these, the second and third terraces, are both found in the same district.] The modern valley of the river has been eroded, not only into the Upper and Lower Jargalante series, but also into later sediments deposited by the river to form the second terrace.

The sources of the modern Uber Jargalante are springs flowing out of Uste Mountain and Batoga Mountain and the small lakes situated among the sands of the divide between the Uber Jargalante and the Ara Jargalante. The river forms a short distance east of the lakes. Its

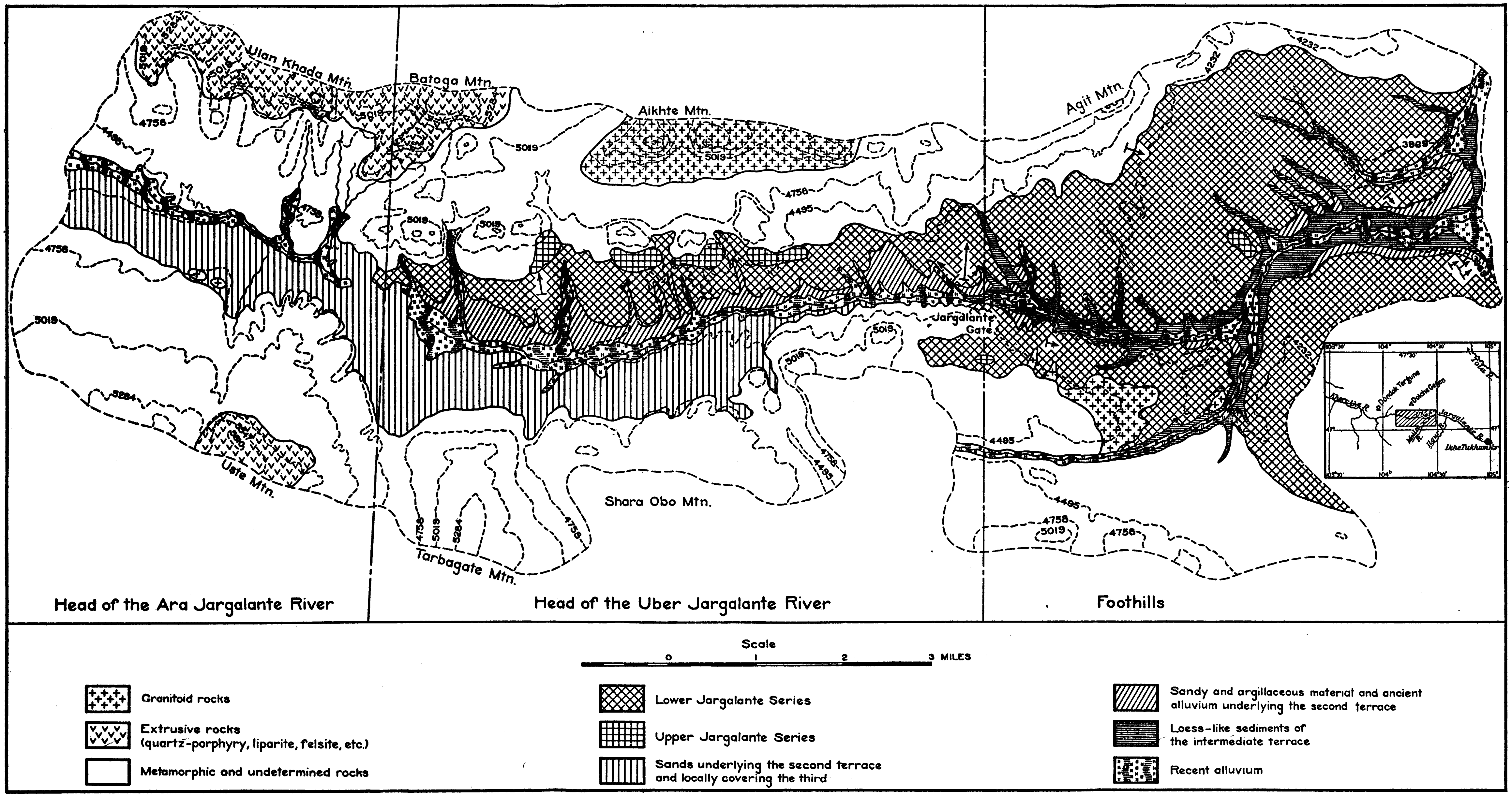

Fig. 3. Geological Map of the Valley of the Uber Jargalante River and the Upper Part of the Valley of the Ara Jargalante. (After Polynov and Krasheninnikov.)

Latitude and longitude are not given on the original map. A small index map in the Russian publication shows the position of the area with respect to the meridians 104° E. and 106° E. and the parallel 48° N. The index map shown here was drawn from the Urga sheet of the map of the Southern Boundary Region of Asiatic Russia, 1888. Russian edition, revised 1911. Scale 1:1,680,000. [Editor American Museum Bulletin.]

width does not exceed twelve or fifteen feet at any place. Its course is sinuous, and meanders are particularly well developed in the eastern part of the region beyond the ridge of hard quartzites at the Jargalante Gate. The river descends more than 300 feet in crossing the area of the map. The narrow stream bed at the head of the river consists of sand covered by swamp grass. Gravel is found beneath a thin layer of the sand. Farther downstream the material of the bed is almost exclusively well rounded gravel covered only locally by a thin layer of fine sediments.

THE SECOND TERRACE.—The second terrace is well defined on both sides of the river above the Jargalante Gate, but there are considerable structural differences between the parts lying north and south of the river. The surface of the northern part consists of a sequence of low ridges and shallow gullies extending from north to south transverse to the general trend of the terrace. The ridges consist of rocks of the Lower Jargalante series capped by a thin veneer of sandy and argillaceous sediments. Exposures in the steep valley walls of the Jargalante Gate show that in the easternmost of the transverse ridges the Lower Jargalante series is underlain by quartzites. The valleys between the ridges are partly filled by argillaceous and sandy alluvium containing granite boulders up to a foot in diameter.

A profile (Fig. 4) along the surface of the northern part of the terrace was constructed by running a traverse with a level. The profile shows that the second terrace has a well defined inclination downward to the east but with a gradient considerably less than that of the flood-plain of the river. The surface of the second terrace is seven feet to ten feet above the flood-plain in the western part of the area, while in the eastern part it is 20 feet to 25 feet above the flood-plain. The profile also shows that the slopes on the west sides of the transverse valleys crossing the terrace are steeper than the slopes on the east sides of the valleys. This peculiarity of the transverse valleys is not what would be expected to result from modern erosion, in which there is a tendency of the tributaries to change their courses toward that of the main stream and thus develop steeper slopes on the east sides of the valleys.

The part of the second terrace south of the river has a fairly even surface. There are no noticeable transverse ridges, and the terrace is dissected only in a few places by short gullies which are apparently of comparatively recent origin. In the eastern part of the district, where the terrace is highest above the flood-plain of the Uber Jargalante, it has not been built, but instead has been cut on quartzites. Farther west it is floored by sands, from beneath which the Lower Jargalante series appears in the edge of the terrace. Finally toward the western[1] border of the district the sandy alluvium increases in thickness, and here the terrace is most certainly of depositional origin.

The second terrace of the Uber Jargalante River is the direct prolongation of the terrace of the Ara Jargalante. The divide between the two streams is only a low ridge covered by sands and sandy soils similar to those of the western part of the Uber Jargalante second terrace. These have been eroded away only at the highest part of the divide and here the Lower Jargalante series is exposed. There is no doubt that both of the valleys were once occupied by the same river.

Over most of the central district the second terrace slopes to the east, but in the vicinity of the Jargalante Gate there is a reversal of slope in the case of the southern half of the terrace. Here it descends to the west, opposite to the direction of slope of the modern flood-plain. Above the terrace are a number of solid rock benches sloping more steeply to the west and merging into the terrace. The reversals in slope were checked with the level, but they are apparent at a glance. It should be noted that the reversed slope does not extend over the whole district, for the altitude of the terrace in the eastern part of the district is considerably less than in the western part near the head of the river. The local westward descent of the terrace is, however, in accord with the peculiar character of the valleys crossing the northern half of the terrace.

THE THIRD TERRACE.—Between the northern edge of the second terrace and the northern boundary of the Uber Jargalante valley are six knobs of ancient igneous and metamorphic rocks arranged in a line from east to west. Each knob is capped by a thin veneer of material consisting of angular pebbles, large boulders and a few streaks of clay. From the summit of each knob a few spurs extend toward the Jargalante River in a fan-like arrangement. The spurs first descend in gradual slopes broken by a minor scarp or two. Below this there is, in the case of most of the spurs, a distinct break to a bench underlain by the Upper Jargalante series, which lies upon and against the ancient metamorphics. This bench is the third terrace. From the third terrace the spurs descend and merge into the transverse ridges of the second terrace.

The valleys separating the knobs have been eroded through the third terrace, but, with one exception, end at the level of the second terrace. This exception is the second valley from the western border of the central area. It is longer and wider than the others and cuts deeply

[1][The Russian text reads "eastern." This is apparently an error, since it is in direct conflict with the geological map and with the context of the first part of the paragraph.]

into the ancient metamorphics. It is probable, however, that the valley coincides with a line of post-Jargalante deformation, since the Upper Jargalante sediments to the west of it lie flat, while to the east of it they have a low dip to the east-southeast.

To the south of the river are a few isolated mountains. Tarbagate Mountain will serve as a good example to illustrate their form. Its almost flat summit merges northward into a fairly gentle slope with minor variations. This slope passes into a bench, the third terrace, which is floored by quartzites. The terrace is bounded on the north by a steep scarp, 130 feet to 155 feet high, descending to the level of the second terrace. The scarp is dissected by a number of short, dry gullies which end on alluvial cones. The surfaces of the alluvial cones are either covered with sod or slightly dissected by secondary gullies which die out on the cones or reach the second terrace. The alluvial cones lie against surfaces sloping 25 degrees or more, and their lower extremities pass beneath the sediments of the second terrace. It is believed that the cones were deposited while the river was at a higher elevation during the time of the building of the second terrace and that they have been preserved because modern erosion is operating extremely slowly.

The lateral valleys on both sides of the Uber Jargalante are, at present, dry. Those on the south side may be divided into two classes. The valleys of the first-class head at the level of the third terrace or above, are only slightly notched into the ancient metamorphics, and descend steeply to the second terrace, where they end in slightly widened mouths. Their predominant trend is from southwest to northeast. They may be described as "hanging" with respect to the modern Uber Jargalante and are probably of the same age as the gullies ending on alluvial cones. The valleys of the second class are found at the level of the third terrace and above. They are in a fairly advanced stage of erosion and in some places are accompanied by minor terraces. At the outer edge of the third terrace they either end in somewhat widened mouths above the second terrace or join one of the valleys of the first class, in many cases nearly at right angles, since the general course of valleys of the second class is from southeast to northwest. They may be described as "hanging" with respect to the second terrace.

The valley which comes out on the level of the third terrace to the east of Shara Obo Mountain deserves special attention. At its junction with the third terrace were found granitic boulders closely similar to adamellite [quartz monzonite], the original source of which is downstream to the southeast of the Jargalante Gate in the eastern district.

The shape of the valley and the slope of its floor, moreover, are inconsistent. In a traverse southeastward from the junction of the valley with the third terrace, it is found that the valley has minor terraces for some distance and then gradually narrows to a canyon which bends noticeably to the eastward. Judging from the shape of the valley, the direction of the traverse is toward the head of the valley, but it is found that the valley floor descends in this direction.

Western District

It has already been stated that the valleys of both of the Jargalante Rivers were once occupied by the same stream. The present divide between them is a low ridge rising only slightly above the second terrace of the Uber Jargalante. The terrace is hardly broken and continues down the Ara Jargalante valley. The mountains of the western district are also very similar to those of the central district. To the north of the Ara Jargalante they are deeply notched by valleys descending westward, while to the south their summits constitute a rolling upland. Major differences between the two rivers, however, are that the Ara Jargalante has a much steeper gradient and is followed by one, or possibly two intermediate terraces lower than the second terrace. Downstream the second terrace rises rapidly above the modern flood-plain because of the steep gradient of the stream. Some six or eight miles below its head, the river leaves the mountains and flows out onto plains varied by only a few minor uplands. The boundary line between the mountains and the plains is sharp and is not marked by a belt of foothills.

Sandy Alluvium of the Second Terrace.—The southwestern portion of the second terrace of the Uber Jargalante is underlain by sandy alluvium. These sands also extend onto the third terrace at Shara Obo and onto the slopes above. At this locality the sands are covered with sod and are exposed only in wind-excavated cavities. From the second terrace north of Shara Obo, the sands continue westward, cover the head of the Uber Jargalante valley and the divide, and extend westward along the Ara Jargalante valley, predominantly on the south side. Here they underlie the modern flood-plain, the intermediate terraces and the second terrace and even the third one at the base of Uste. In this vicinity they have been extensively exposed by erosion, and the resulting products have been piled into dunes of the barkhan type. The dune belt extends down the river to the westward beyond the boundaries of the area studied and appears as a yellow band faithfully outlining the meanders far out onto the plains.

It was first supposed that the sands had been carried by winds onto the slopes of Shara Obo and Uste, but no adequate reason could be found to account for the transportation of the sands onto the lower slopes of these mountains and not onto similarly oriented slopes of Tarbagate, which lies between the two. Upon close examination of the dunes on the slope of Uste, it was found that their steeper sides, in all cases, face east-northeast, and the direction of sand movement is therefore from the slopes into the valley. Exposures at the entrance to the valley east of Shara Obo show that the sands, which are here only three or four feet thick, contain partially rounded and well rounded pebbles. The lower two feet of sediments are well cemented with lime. These sediments could not have been transported by wind. Beneath the loose sands near the top of Uste Mountain, in a number of places greenish-gray sandstones are exposed, and from them the loose sand is derived. Thus it seems probable that the sands on the mountain slopes and the third terrace were derived from older sediments deposited at some earlier date at a higher level. During the process of valley erosion, the sands which once covered the third terrace and higher ground were partially removed from the third terrace. They have survived only in places where they were particularly thick or were so situated that they were not subjected to rapid erosion.

Drainage Changes

In the central district there are a number of topographic features which are out of harmony with the present direction of drainage. The west sides of the valleys crossing the second terrace from the north are steeper than the east sides. The southeastern part of the second terrace near the Jargalante Gate descends to the west, and above it are rock benches inclined more steeply in the same direction. At the level of the third terrace and above, there are valleys which extend from southeast to northwest and end above the level of the second terrace. The first of these valleys east of Shara Obo is widest where it joins the third terrace, is followed by minor terraces and finally narrows to a steep canyon to the southeast, although the valley floor slopes downward in this same direction. At the northwest end of the valley are found pebbles of a peculiar variety of adamellite [quartz monzonite] which is found in place southeast of the Jargalante Gate. The region has undoubtedly been subjected in comparatively recent times to some movement which altered its general position and brought about certain drainage changes. The new conditions, however, have not yet succeeded in destroying all the land forms of the preceding erosion period.

The Jargalante Gate was formed by a stream cutting through a ridge. The ridge is either an anticline or a flexure plunging to the north, since the beds dip steeply on the east side, while on the west side the Lower Jargalante series dips to the north-northeast in the same direction and at approximately the same angle as farther west. Thus the fold is the result of the last deformation to which the Lower Jargalante series in this vicinity has been subjected. Since the axis of the fold plunges to the north, the hard quartzites beneath the Lower Jargalante series appear on the east side of the ridge. It is to be noted that the river has cut into the quartzites instead of taking its course farther north on the soft sediments of the Lower Jargalante series. This peculiarity can be explained as follows: At the time of the building of the second terrace, the head of the Ara Jargalante was east of the present location of the Jargalante Gate and the stream flowed on the softer rocks at a higher level. Later a movement at the Jargalante Gate resulted in relative downward movement of the block to the southeast, causing the Uber Jargalante to capture the headwaters of the Ara Jargalante and carry the divide back to its present position.

[This explanation of the nature of the movement which caused the capture is unsatisfactory, since it does not account for two facts, that the second terrace of the Uber Jargalante descends to the east throughout most of the central district and that the side valley east of Shara Obo descends to the southeast from the third terrace and narrows in the same direction. If the movement which lowered the region of the Tukhum basin had been localized at the eastern base of the mountains, both the terrace and the side valley east of Shara Obo would descend in directions opposite to their present ones. An explanation that avoids these difficulties is as follows:

At the time of formation of the second terrace, the head of the Ara Jargalante was to the east of the present location of the Jargalante Gate. The quartzites had not yet been exposed, and the river flowed over the present site of the Jargalante Gate on soft sediments. At the same time the head of the Uber Jargalante was a short distance farther to the east. The region was then subjected to a warping movement, the hingeline of which passed through the vicinity of the present divide between the two rivers. The warping resulted in relative depression of the block to the east of the hinge line. This decreased the gradient of the upper part of the Ara Jargalante and increased that of the Uber Jargalante, which then eroded headward, captured the head of the Ara Jargalante and began cutting downward toward the quartzites and eventually into them. As warping continued, the part of the second terrace east of the hinge line was tilted downward to the east, and the Uber Jargalante continued to extend headward toward the location of the present divide along the old course of the Ara Jargalante.

The present westward descent of the southern part of the second terrace west of the Jargalante Gate may be the result of a minor fold or flexure which compensated for the displacement by warping or exceeded it. The folding or flexuring may have taken place in the early stages of warping, or it may have come later, in which case the Uber Jargalante is, in part of its course, an antecedent stream.

The work of Berkey and Morris (4:411 to 413) shows that there is abundant evidence of warping and flexuring incident to faulting in this and neighboring parts of Mongolia. They observed warped erosion surfaces in the flatter parts of the country, and from a study of the disconformities in the sediments filling the "gobi" basins, concluded that Mongolia has been subjected to a series of warpings since Lower Cretaceous time.]

Eastern District

The district east of the base of the mountains is occupied by low hills, the tops of which are flat and form a surface descending gradually to the east. The area north of the Uber Jargalante has been more maturely dissected than that to the south, and some of the northern tributary valleys surround uplands of the mesa type.

Lower Jargalante Series.—The rocks which occupy most of the surface of the eastern district belong to the Lower Jargalante series, which has everywhere been subjected to deformation giving dips to the east. The easternmost exposures of the series are in the upland south of the river near Dolche Gegen monastery outside the area of the geological map. The upland surface is here 150 feet above the river bed. In the scarp facing the river, the usual sequence of sediments, (1) sandstones (bottom), (2) shales and carbonaceous shales, (3) limestones, is repeated a number of times and is, in some cases, broken so that the limestones alternate with coarse-grained sandstones. The beds strike from N. 45° E. to N. 60° E. and dip to the southeast at angles of 20 degrees to 30 degrees. These relations indicate that the rocks have been affected by step-faulting.

Upper Jargalante Series.—The hill near the middle of the eastern district north of the river consists of shales and sandstones dipping slightly to the east. The sediments probably belong to the Upper Jargalante series. From them were collected a number of pelecypods.

These were examined by I. P. Khomenko, who identified them as representatives of a form belonging to the family Erycinidae, comparable to *Spaniodontella.* He is of the opinion that the sediments are of Neogene age and most likely belong to the Miocene. The nature of the sediments and the character of the fauna indicate that the sediments were deposited in a pond.

The Second Terrace.—The second terrace of the central district extends into the eastern district. The sediments of which the terrace is built are similar to those farther west. At the top is a layer five feet thick composed of sands and clays. Beneath it is a bed of angular débris and gravel six feet thick. The terrace sediments lie unconformably upon rocks of the Lower Jargalante series dipping at 40 degrees to the east.

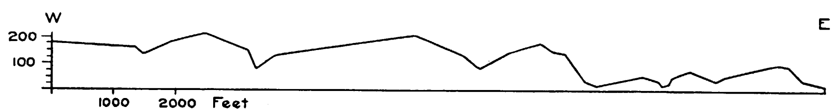

Fig. 4. Longitudinal profile along the northern portion of the second terrace of the Uber Jargalante near the head of the river. (After Polynov and Krasheninnikov.)

The Intermediate Terrace.—In the foothill belt the Uber Jargalante becomes a braided stream flowing in continually shifting channels over a flood-plain built of angular débris and gravel locally covered by finer sediments. Between the flood-plain and the second terrace is the intermediate terrace composed of light brownish-yellow sandy and earthy material with root pores and the property of vertical cleavage. In all respects it resembles loess. The loess-like sediments lie on angular débris and gravel. Strictly speaking the intermediate terrace begins above the Jargalante Gate. Here it is represented by peat-like material. It is clearly developed, however, only in the foothill belt, where it forms a comparatively narrow band along both sides of the river.

Basin Floor and Lake

Beyond the foothill belt the Uber Jargalante continues out onto the even basin floor, which lies at the level of the intermediate terrace. The scarp of the southern part of the second terrace turns south at the boundary of the basin floor and continues in this direction for at least six miles. The northern scarp passes off to the north and northwest, encloses an embayment of the basin floor, again returns to the river and follows it to the shore of the Ikhe Tukhum Nor. From a point halfway between the edge of the foothills and the lake, it is seen that the basin is surrounded by rough mountains except on the south, where the basin floor and second terrace continue to the horizon.

The bed of the river in the basin floor district is well marked, has almost no bends and extends due east. It is often dry. In a traverse along it on September 27, a long search was necessary to find a camping place with water, and here there was only a small pool. On the morning of another day, a small rivulet advanced slowly, filling the depressions and horse tracks in the bed. Its appearance was probably caused by rains falling near the head of the river during the previous night. In addition to the Uber Jargalante, a few other smaller streams flow into the Tukhum basin from the mountains, but their water sinks into the porous sediments before reaching the lake.

Ikhe Tukhum Nor consists of a number of wide, shallow dry hollows connected by broad troughs. The surfaces of both the hollows and troughs are covered with efflorescent salts. In a few places there are ponds only a few square yards in area containing crystalline Glauber's salt. In others there are springs of fresh water coming up through the sediments. The flats around the lake support isolated clumps of saltwort. From Ikhe Tukhum Nor other similar lakes are visible to the northeast.

CONCLUSION

The wide Tukhum basin underlain by ancient igneous and metamorphic rocks was formed just before or during the time of deposition of the Lower Jargalante series. Since the time when the basin came into existence, it has been subjected to deformation, predominantly by faults, during Lower Jargalante and Upper Jargalante time and probably up to the present. The faulting was undoubtedly connected with some general process, the character of which cannot well be inferred from the study of such a limited area. As a result of deformation the basin was first filled with sediments. At this time the Ara Jargalante headed east of the present location of the Jargalante Gate. Relative subsidence of a block southeast of this location caused the Uber Jargalante to capture the upper valley of the Ara Jargalante just after the completion of the second terrace. It is probable that the epoch of formation of the second terrace was one during which erosion was much more active than at present. The process of formation of the intermediate terrace was probably independent of deformation processes and was caused by a lowering of the base-level of erosion.

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