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ADDITIONAL NEW FORMATIONS IN THE LATER SEDIMENTS OF MONGOLIA[1]

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INTRODUCTION

During 1925 the Central Asiatic Expedition examined new ground, restudied several districts, and gathered abundant new fossils. It is allowable now to define several additional new formations as another step in the interpretation of the stratigraphy of the Gobi region and as a support to palæontological research.

The so-called "later sediments" of the Gobi region include the nearly horizontal strata which lie above a great unconformity, and so are

[1]Publications of the Asiatic Expeditions of The American Museum of Natural History. Contribution No. 95.

readily distinguished from the deformed and much modified structures of the peneplaned "oldrock floor."[1] For the purposes of the present paper, it matters little whether the oldest of the later sediments be regarded as Upper Jurassic[2] or Lower Cretaceous.[3] This question will be more fully discussed in another report, now in preparation.

All places mentioned in this paper are shown on the map, Fig. 1.

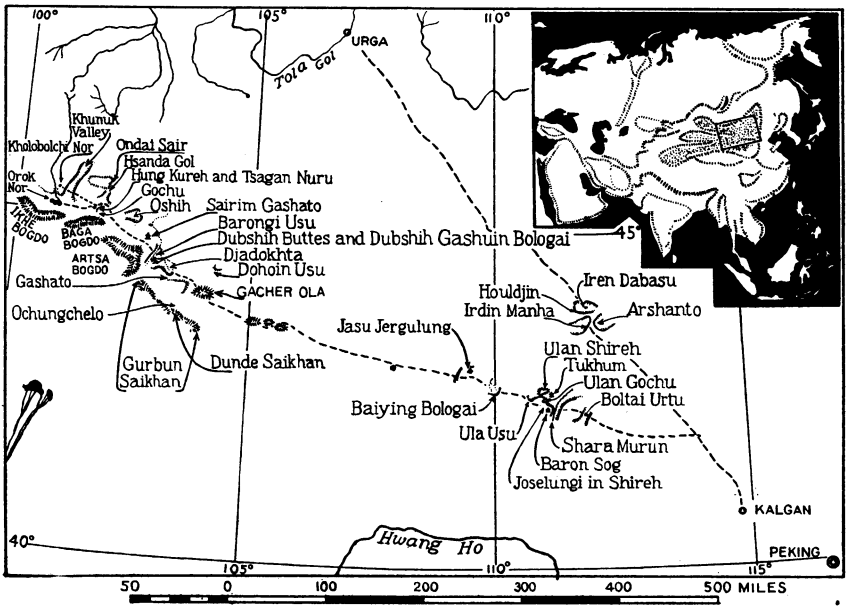

Fig. 1. Map showing the location of places referred to in this paper. (Based chiefly on the survey by L. B. Roberts in 1925.)

[1]Granger, Walter, and Berkey, Charles P. 1922. 'Discovery of Cretaceous and Older Tertiary Strata in Mongolia.' Amer. Mus. Novitates, No. 42. Berkey, Charles P., and Granger, Walter. 1923. 'Later Sediments of the Desert Basins of Central Mongolia.' Amer. Mus. Novitates, No. 77. Berkey, Charles P., and Morris, Frederick K. 1924. 'Basin Structures in Mongolia.' Bull. Amer. Mus. Nat. Hist., Vol. LI, Art. V, pp. 103–127. Berkey Charles P., and Morris, Frederick K. 1927. Geology of Mongolia. Nat. Hist. of Central Asia, Vol. II.

[2]Osborn, Henry Fairfield. 1926. Article, 'Paleontology' in Encyclopædia Britannica.

[3]Berkey, Charles P., and Morris, Frederick K. 1924. 'Basin Structures in Mongolia.' Bull. Amer. Mus. Nat. History, Vol. LI, Art. V, pp. 109–115. Berkey, Charles P., and Morris, Frederick K. 1927. Geology of Mongolia, p. 354.

TABLE OF NEW FORMATIONS

Period	Formation	Thickness	Sediments
		(in feet)	
Pleistocene	Orok Nor	10	Coarse gravels
	Tsagan Nuru	40	White sands
	Khunuk	130	Buff sands and clays
	Joselungi	12	Brown gravel and sands
Oligocene	Baron Sog	30	White and gray sands and clays
	Ulan Gochu	60	Red clays
	Jirilgo (probably equivalent to Hsanda Gol)	40	Red, brown, and gray clays
Eocene	Ulan Shireh (possibly Shara Murun)	300	Red and gray clays and sands
	Elegen	70	Gray sands and clays
	Kholobolchi	500	White and yellow sands and clays
Lower Cretaceous	Dohoin Usu	300	Red clays, sands
	Dubshih	1000	Conglomerates, sands
	Ochungchelo	2000	Clays, sands, conglomerates
	Baiying Bologai	150	Red clays and sands
	Jasu Jergulung (possibly equivalent to Ondai Sair)	100	Black paper shales

LATE MESOZOIC FORMATIONS

At five different localities sediments were found of enough prominence and unity of character to warrant giving them formational designation. It is entirely possible that some of them are simple equivalents of formations already described and more fully defined. But it is more likely that they cannot be matched, and, for present purposes, it is serviceable to treat them as definite formations, recognizing their local rather than their regional significance. Additional studies of the respective faunas will doubtless clear some of the uncertainties of correlation. The list is described, beginning at the base.

JASU JERGULUNG.—About eight miles west of the frontier customs station, Jasu Jergulung, about Lat. 42° 55′ N., Long. 109° 40′ E., there is an eastward-facing escarpment of typical paper-shales, with abundant *Estheria middendorffi*. The beds may be called the Jasu Jergulung forma-

tion, as no native name could be found for the scarp itself, and they may be correlated with the Ondai Sair.[1] The exposed thickness is about 100 feet. The base was not seen; the top is the Gobi erosion plane.

BAIYING BOLOGAI.—At Baiying Bologai, about 27 miles east of the Yamen Jasu Jergulung, there is a basin of red clays and sands, with indurated sandstone members, in which sauropod bones were found. Physically the beds resemble the Oshih sediments. The base of the Baiying Bologai formation rests unconformably upon the beveled edges of tilted sandstones and conglomerates, belonging to the oldrock floor. Rounded pebbles of Permian limestone were found in the conglomerates, hence they are post-Palæozoic. They were deformed and eroded before the deposition of the Baiying Bologai. Tentatively, the conglomerate-sandstone series has been assigned to the Jurassic. The Baiying Bologai formation is beveled by the Gobi erosion plane, and hence its upper limit is unknown. Its thickness is at least 150 feet, and may be considerably more.

OCHUNGCHELO.—Along the northern foot of the Gurbun Saikhan mountains there are upturned conglomerates, sandstones, sands and clays, with a few thin beds of inland-water limestone. Near Ochungchelo, at the front of the Dunde Saikhan range, a single sauropod bone was found, indicating either the Lower Cretaceous or the Upper Jurassic age of the sediments. Beginning with conglomerates, the section passes into redbeds, chiefly clays, about 1,000 feet thick. They are succeeded by gray beds, more than 1,000 feet thick, consisting chiefly of clays, with thin sandy layers and minor limestone lenses. Many of the beds are limy and hard; some are shattered, and the fractures are healed with carbonate veins. The strata are tilted along the mountain front, dipping as much as 48°. Dips of 40° continue for over 2,000 feet out from the mountain face, and minor faults traverse the formation.

The prevailing fineness of grain, and the regular and thin bedding, render it quite impossible for the Gurbun Saikhan ranges to have been prominent when these beds were laid down. It is more probable that much, if not all, of the site of the present mountains was covered by the deposits of later Mesozoic time, a suggestion that is strengthened by the great thickness of the upturned beds. In other reports[2] we have postulated a sedimentary cover of the Gurbun Saikhan during Lower Creta-

[1]Cockerell, T. D. A. 1924. 'Fossils in the Ondai Sair Formation, Mongolia.' Bull. Amer. Mus. Nat. Hist., Vol. LI, Art. VI, pp. 129–144. Berkey, C. P., and Morris, F. K. 1927. Geology of Mongolia, pp. 230, 354.

[2]Berkey, C. P., and Morris, F. K. 1924. 'Basin Structures in Mongolia.' Bull. Amer. Mus. Nat. Hist., Vol. LI, Art. V, p. 118. Berkey, C. P., and Morris, F. K. 1927. Geology of Mongolia, pp. 316–317.

ceous time, basing the inference chiefly upon studies of the Djadokhta and Gashato beds.

The base of the Ochungchelo rests directly upon the complex oldrocks of the Gurbun Saikhan. The edges of the tilted strata are smoothly beveled by the Gobi erosion plane. The northward dip, if the formation continues far out into the basin, would carry it underneath the Djadokhta and Gashato formations. It may, therefore, be essentially equivalent to the Dubshih formation next to be mentioned, which certainly lies immediately beneath the Djadokhta formation at the westerly border of the district.

DUBSHIH.—About 14 miles west of our camp at Shabarakh Usu in the Djadokhta district, there is a broad dry valley called Baron Ghi Usu, tributary to the still larger Shabarakh valley. On the east side of the channel a mesa of rhyolite and basalt, called Dubshih, forms the most prominent landmark for many miles. The name, Dubshih Gashuin Bologai, is given to an important spring on the main caravan trail, three miles east of the mesa. In the dissected ground between Dubshih mesa and the spring, Dubshih Gashuin Bologai, there is a series of tilted strata which forms a stratigraphic unit, and which has been designated as the Dubshih formation.

The beds dip eastward at angles varying up to 20°. The steepest dips are found in the western, or lower, beds, near the mesa, but in the mesa itself the lava flows lie horizontally. The higher beds dip at progressively smaller angles until they become sensibly horizontal. It is estimated that the thickness cannot be less than 1,000 feet, and it is probably more, since the base of the formation is not exposed and the nearest exposure of the oldrock floor is fifteen miles to the northwest.

The sediments here include two members: a lower group of pebble conglomerates, sandstones, and thin white limestones, all together totaling at least 530 feet; and an upper group, made up chiefly of coarse rubble, rhyolitic tuff and ash but including also conglomerates with pebbles derived from older sediments and porphyries. This member is nearly 300 feet thick.

In the lower conglomerates the pebbles are chiefly of fine-grained phyllite, with fairly abundant limestone pebbles, some of which bear Palæozoic fossils. Less abundant are quartz, jasper, graywacke, and silicified ash, or argillite. The limestones consist of a fine-grained white lime mud, like marl, which includes varying amounts of sand. Dense white marly masses like concretions are present in some layers. The white lime beds contain shells of a small pelecypod and a gastropod.

Our collection has been sent to Professor Grabau for study. No reptile bones were found.

The base of the Dubshih is not exposed; its top passes under the typical fine red sands of the D'adokhta formation, marking an abrupt change in the character of the sediments. The entire exposure of the Dubshih formation occupies but twelve square miles. The faulting and tilting indicate a history similar to that of the Ochungchelo, Oshih and Ondai Sair units; and the position of the Dubshih beneath the Djadokhta formation suggests that it belongs to the Lower rather than to the Upper Cretaceous. It is, in part at least, equivalent to the Ochungchelo, but it is more complex and quite different in physical character as well as in fossil content. On these counts, it deserves special definition.

DOHOIN USU.—In 1925 Granger discovered a large basin of Cretaceous beds near the well, Dohoin Usu, at approximately Lat. 44° 14′ N., Long. 104° 19′ E., or 40 miles northeast of the eastern end of the Gurbun Saikhan range. He estimates that at least 300 feet of beds are exposed. The base of the formation was not seen, and the upper limit is the Gobi erosion plane, so that the original thickness must be greater than the present exposures. The sediments are chiefly brick red, sandy clays, exposed in badland bluffs along two promontories that front one another across a narrow intervening lowland.

The only fossils were found in a flat lens of bluish gray, sandy clay, 10 to 50 feet thick, in the red clay of the northern promontory. Granger collected pelecypod shells and bones of turtles, crocodilians and iguanodont dinosaurs—clearly a water-loving fauna. No sauropods were found, and the presence of iguanodonts suggests a relation with the Iren Dabasu biota rather than with that of Ondai Sair, Oshih, or Baiying Bologai. For this slender reason, and until the bones shall have been studied, we would place the Dohoin Usu formation near the Iren Dabasu in the column, without attempting any definite correlation.

TERTIARY FORMATIONS

In discussing the newer Tertiary deposits, it seems advisable to depart from the order of time sequence in a few cases so as to emphasize the structural relations of a locality. The individual formations are given their proper position in the geologic column, page 3. The first of the complex localities is the valley of Khunuk, east of the lake, Kholobolchi Nor.

THE KHOLOBOLCHI LAKE DISTRICT

KHOLOBOLCHI.—Possibly the oldest true Eocene beds thus far

found belong to the Kholobolchi formation, outcropping at several places in the Khunuk Valley (Fig. 2).

The first section studied lies at the southern end of the Khunuk valley. Here a series of white and yellow arkosic sands and drab clays

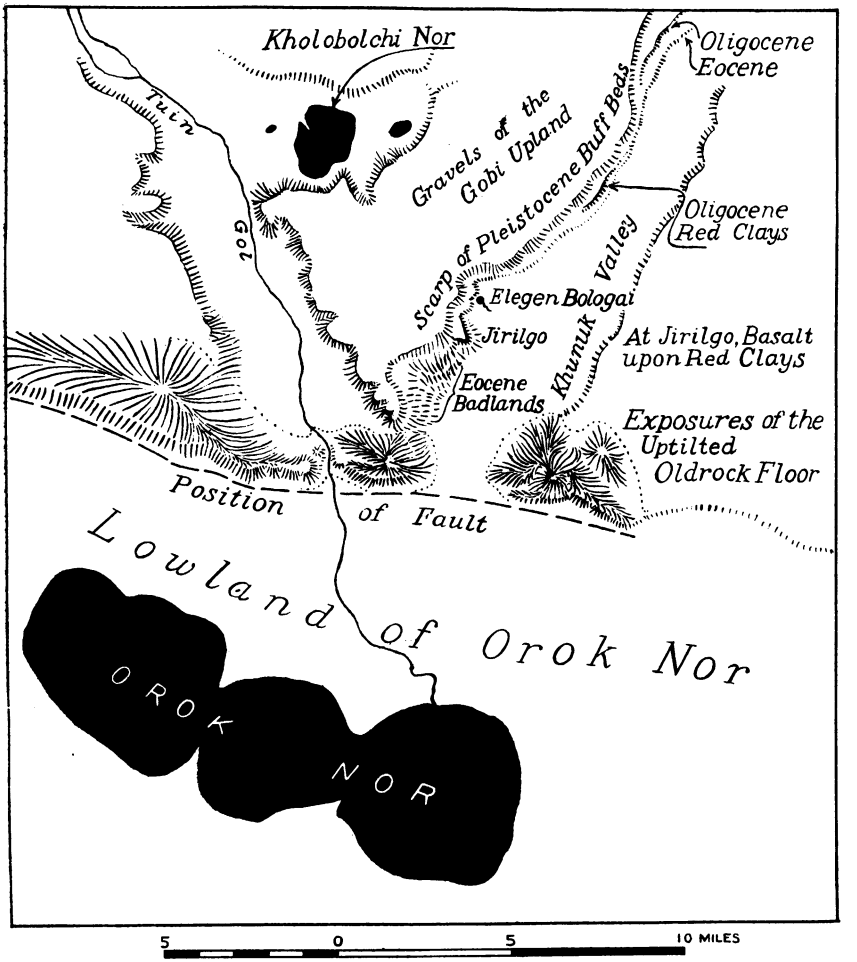

Fig. 2. Sketch map of the area between Kholobolchi Nor, Orok Nor, and Khunuk valley, showing (1) the faulted lowland or graben of Orok Nor, lying between the porphyry hills of the oldrock floor and the Altai range, Ikhe Bogdo, (2) the uptilted oldrock floor, exposed in the chain of porphyry hills; (3) the overlying Tertiary and Pleistocene sediments. (Based chiefly upon the survey by L. B. Roberts and F. B. Butler).

rests directly upon the planed surface of complexly folded rocks of undetermined age, belonging to the oldrock floor (Fig. 3). The later sediments dip northward, and are overlain by buff-colored sands, gravels and silts of Pleistocene age. The lower group of sediments is here between 200 and 300 feet thick, basing the calculation upon the dip and width of exposed outcrop. Skulls of coryphodonts and bones of other mammals were found here, indicating Eocene age, but until the bones are studied it will not be possible to compare the Kholobolchi beds with other formations. The biota is apparently different from any yet seen in Mongolia.

The same sediments can be traced northward for over 20 miles, as the lowest beds exposed in the Khunuk valley. The northern exposures, which are 157 feet thick, also yielded bones, chiefly of perissodactyls. The name, Kholobolchi formation, was assigned these beds, for, although their outcrops are several miles east of the lake, Kholobolchi Nor, the lake is known throughout the district and is the explorer's readiest guide in reaching them. The beds certainly extend beneath the lake itself.

KHUNUK.—The overlying buff beds (Fig. 3) range in thickness from 27 to 127 feet. Because they crown the bluffs along almost the entire west wall of the Khunuk valley (Fig. 2), they are called the Khunuk formation (pronounced Khoon-ook). They include fine buff silts, sandy clay or silt, and arkosic sands and gravels, commonly cross-bedded and locally cemented to form thin sandstones. The lower beds are of finer grain, while the sands and gravels increase in the higher portions. Some of the silty beds are very massive, and may well be windborne dust or loess. The cross-bedding in the sands and gravels is exclusively of stream type, with a prevailing southward dip, indicating that the source of the material was in the north—not in the Altai range to the south. Bones of horses, rhinoceros and a large mastodont clearly indicate Pleistocene age for the Khunuk formation.

OROK NOR.—The base of the Khunuk formation rests on a rolling erosion surface (Fig. 3). The top of the formation is capped by the familiar gravels of the Gobi upland, but as they are 5 to 10 feet thick here and yielded chipped flints which were studied by N. C. Nelson, it has seemed well to give them a name. Accordingly the name, Orok Nor formation, is assigned to the gravels above the Khunuk. The two are separated by a distinct plane where the contact could be seen, and the Orok Nor gravels, at least locally, show cross-bedding and channel-filling. As such washed gravels are not forming anywhere on the Gobi upland at the present time, and as the entire cutting of the Khunuk valley must have

taken place since they were laid down, we judge that the upland gravels are of Pleistocene age. They belong to an epoch of deposition, separated from the present by an epoch of stream erosion.

JIRILGO (probably equivalent to the Hsanda Gol formation).—Three miles north of the southern exposures of the Khunuk buff beds, a new formation is found, intercalated lens-like between the Khunuk and the Kholobolchi (Fig. 3). It consists of massive red clay, without visible bedding, and attains a thickness of about 40 feet, thinning out, wedge-like, within less than a mile. It is capped by a flow of basalt, about 20 feet thick at most, which likewise thins out north and south. The basalt platform, on which the buff beds rest, is called Jirilgo by the Mongols, and we at first proposed this name for the associated red clays.

A little over two miles north of the Jirilgo lens, another lens of similar clay comes in, at the same horizon but without a basalt sheet. About two miles still farther north, red clays again appear, and attain a thickness of 62 feet. Here Granger found fossils which he considers belong to the Hsanda Gol fauna. As the red outcrops were traced eastward across the valley, and as the typical Hsanda Gol fossil-beds are exposed only 20 miles farther east, Granger proposed to call these beds

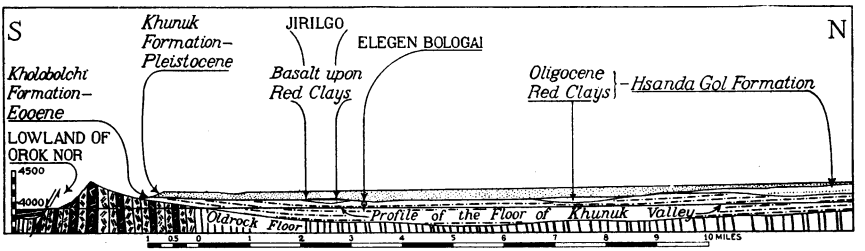

Fig. 3. Generalized geologic section along the western side of Khunuk valley. The vertical scale is five times the horizontal. The Orok Nor gravels are too thin to be plotted on this scale, and are represented by the line which bounds the top of the Khunuk formation. Where the northernmost exposure of the Hsanda Gol formation is indicated, the position of the problematic Elegen formation is indicated by a dotted line between the Hsanda Gol and the underlying Kholobolchi formations

also the Hsanda Gol, abandoning the field name of Jirilgo. But if the detailed study of the fauna should require a separate name for the red beds of Khunuk valley, the name Jirilgo should be retained as a convenient local name.

ELEGEN.—At the northern badlands, we measured 70 feet of arkosic sands, gravels and clays, chiefly of gray color, with a few red layers,

underneath the typical red Hsanda Gol clay and overlying the brown, drab clays and white and yellow sands of the Kholobolchi. No fossils were found in them, but they are sharply delimited from the Jirilgo (Hsanda Gol) red clays, and they are different from the Kholobolchi in texture, color, and details of erosion habit. In the field we considered that they might constitute a separate stratigraphic unit, and called them the Elegen formation, from the spring, Elegen Bologai.

If the beds prove to be a part of the Kholobolchi formation, the name, Elegen, must be abandoned, but we may retain it tentatively as the name for a group of beds that appears to form a distinct unit. In the field, it was the opinion of Morris that the Elegen should even include 35 feet of brown clays which lie at the top of the Kholobolchi formation. Bones were found in a channel filling of sand in the brown clays, the study of which will decide this question.

The Shara Murun District

At Shara Murun and Ula Usu, where Granger discovered fossil bones in 1922 and where the Expedition camped in 1923, two formations had been recognized—the lower Tukhum beds of hard red clay, distinguished

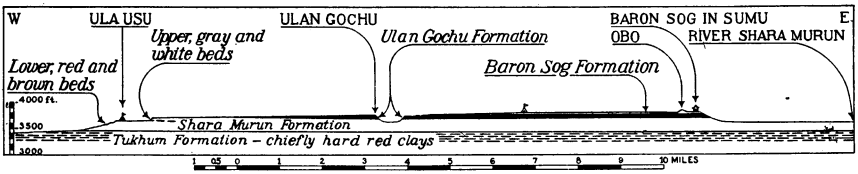

Fig. 4. Generalized cross section between Ula Usu and the Shara Murun valley. The vertical scale is five times the horizontal The upland gravels, the Joselungi formation, are too thin to be plotted separately, and are represented by the line bounding the upland from the words "upper gray and white beds" to the eastern edge of the escarpment at Baron Sog in Sumu. It will be seen that the Joselungi gravels rest successively upon the Baron Sog, Ulan Gochu and upper Shara Murun formations.

by *Teilhardia pretiosa*, and the overlying Shara Murun beds of varicolored clays with a rich Upper Eocene fauna.[1] At that time, no detailed studies had been made of the eastern bluffs north of Baron Sog temple, or of the large red mesa north of the Tukhum lowland.

The base of the Shara Murun formation rests, with a clearly defined contact, upon the hard red clays of the Tukhum formation.

[1]Matthew, W. D., and Granger, Walter. 1926. 'Two New Perissodactyls from the Arshanto Eocene of Mongolia.' Amer. Mus. Novitates, No. 208. Berkey, C. P., and Morris, F. K. 1927. Geology of Mongolia, pp. 346, 367.

ULAN GOCHU.—Traced eastward along the northward-facing front of the scarp, the typical light-colored clays and sands of the upper Shara Murun formation pass beneath a wedge-shaped mass of red clay which ranges from only two feet in thickness where it first becomes visible, to 60 feet at a bold bluff called Ulan Gochu (Fig. 4). In 1925, Granger found fossils in the red clays exposed in the badlands east of Ulan Gochu. The fossils are of Oligocene age, and include titanotheres and some new perissodactyl genera. The red beds continue eastward and southward along the front of the bluff (Figs. 1 and 4) for at least four miles from Ulan Gochu.

BARON SOG.—Overlying the red clays are light gray clays and fine cross-bedded sands. Some beds contain white marly concretions. Like the Ulan Gochu, the gray beds thin out westward and disappear, while they can be traced indefinitely toward the east and south (Fig. 4). The temple, Baron Sog in Sumu, and the large obo of the same name are built upon the gray formation, and it seems well to define it as the Baron Sog formation. Granger found in this formation an Oligocene titanothere fauna of younger aspect than that of the Ulan Gochu. The greatest thickness measured by the geologists is 27 feet, but in the poorly exposed portions toward the east and south, it is probably thicker. The Baron Sog rests with a clear-cut, smooth contact upon the red Ulan Gochu, and is overlain by the gravels of the Gobi upland.

JOSELUNGI.—These Gobi upland gravels are themselves crossbedded and show channel fillings. They are clearly stream deposits, but no streams are possible on the upland now; they must have been laid down before the deep and wide lowlands of Tukhum and Shara Murun were excavated (Fig. 4).

We judge the upland gravels to be of Pleistocene and possibly in part of Pliocene age; they are locally as much as 12 feet thick. It is not impossible that fossils may be found in them and thus define them more clearly. They form a superficial structural unit for which the name of the upland, Joselungi, may be proposed. It is possible that this superficial deposit does not deserve a definite formational name.

As shown in the section (Fig. 4), the Joselungi gravels rest successively on the Baron Sog, the Ulan Gochu, and the Shara Murun formations, lying on an erosion surface that bevels them all.

ULAN SHIREH (probably equivalent to the Tukhum formation).—North of the bluffs that include the formations just mentioned, there is a system of broad lowlands which has been but slightly investigated.

The eastern portion of the streamless lowland of Tukhum is tributary to the valley of the Shara Murun, an active though shrunken river.

No fossils have been found in either lowland, although there are exposures near the foot of the bluff. North of the Tukhum lowland, there is a red-cliffed mesa called Ulan Shireh, and here, in 1925, rich fossil beds were discovered. The beds are dominantly red clays, though gray clays, sands, and gravels were seen in the western part of the mesa. They form a distinct physical unit. The visible thickness is at least 150 feet (the base has not been seen) and the upper limit is the Gobi erosion plane. Correlation with the formations of the southern bluff must await the determination of the fossils. For the present the name Ulan Shireh is proposed.

East of the Shara Murun valley the sediment basin continues for over 50 miles to the place where the granites and graywackes of the old-rock floor become visible at Boltai Urtu. Splendid exposures in cliffs have been seen at a distance, to the east. These were examined in 1928, and the sequence was found to be the same as on the Baron Sog Mesa.

TSAGAN NURU.—At the Hung Kureh, Granger reports that the huge mastodon pelvis was found in white sands and clays that fill a channel carved in the typical Hung Kureh beds. This fact of superposition indicates post-Hung Kureh age, and the mastodon, according to Granger, is of a Pleistocene type. The geologists did not visit the site of Granger's discovery, and the question of whether the channel filling is to be correlated with the Gochu remains unsolved. The bluffs are called Tsagan Nuru by the Mongols, and we, therefore, assigned this name to the Pleistocene sands and clays. The sediments are strikingly different from the heavy dark rubbles of the Gochu formation already reported, and the name, Tsagan Nuru, will probably stand the test of future investigations.

In concluding this brief review, it is noteworthy that every period except the Miocene represented by the so-called "later" sediments has added new horizons. The Miocene, as in our earlier studies, has slight representation in the record of the later sediments. Unless subsequent expeditions discover more Miocene formations, our earlier inference, that the Miocene was characterized by widespread erosion, will be strengthened.[1]

[1]Berkey, C. P., and Morris, F. K. 1927. Geology of Mongolia, pp. 346, 367.