AMERICAN MUSEUM NOVITATES

Number 135 Published by THE AMERICAN MUSEUM OF NATURAL HISTORY New York City October 14, 1924

55.1,8(51.7)

STRUCTURAL ELEMENTS OF THE OLDROCK FLOOR OF THE GOBI REGION[1]

BY CHARLES P. BERKEY AND FREDERICK K. MORRIS

INTRODUCTORY STATEMENT

Reference has been made in several preceding articles on the Gobi region to the ancient rock floor, on which the so-called later sediments were laid down. The break between these two groups of formations separates comparatively simple strata above from very complexly interrelated series of much more ancient and obscure formations below. In the structural units of this complex floor is recorded all of the pre-Cretaceous history that is now readable in this portion of the Asiatic continent. The major structural elements of it have been indicated without special comment, in connection with other problems, and it has already been pointed out that a wide range of geologic time is represented, stretching from the Jurassic back to very early pre-Cambrian time. Nowhere, however, has there been any adequate description defining the chief field units. This paper is directed particularly to these elements of the ancient floor.

TWO MAJOR DIVISIONS OF ROCK FORMATIONS

Very large areas in the Gobi region are covered with younger sediments that lie nearly flat. The strata themselves are simple and, wherever they are disturbed, the deformation is of comparatively simple type also,—either gentle warping or, somewhat more rarely, sharp flexure and actual normal faulting.

In all other areas, much more complex rock formations are exposed, representing a more ancient floor which is doubtless continuous beneath all of the sediments. Wherever the old-floor rocks are encountered, the type of deformation and the degree of internal modification exhibited by them are very different from those of the simpler overlying strata. Everywhere these floor rocks are folded, often are cut by igneous intrusives, and to a marked degree are metamorphosed. These features are, of course, more pronounced in the older members.

Wherever the rocks of these two very different types of formations, the sedimentary cover and the floor, are seen in contact, or where their

[1]Publications of the Asiatic Expeditions of the American Museum of Natural History, Contribution No. 20.

structural relations can be determined, a very great unconformity is found between them. The hiatus is so great that mountain-folding and erosion of thousands of feet of material were accomplished before the first basin sediments were laid down. Furthermore, it appears that during this interval an entire change in the diastrophic habit of north central Asia came about. Mountain-folding characterized the deformations that took place before that time, whereas warping and block faulting, without mountain-folding, characterized subsequent epochs.

Late Mesozoic and Tertiary continental sediments carrying a remarkable new fauna constitute the formations developed above the unconformity. The rocks below, representing together all the ages preceding the Lower Cretaceous, form the floor immediately beneath these sediments wherever they occur, and form the present surface in other parts of the region. The overlying sediments are at best but a thin veneer with many interruptions, and the dominant structural foundation for the whole of Mongolia is the ancient rock series below the great Mesozoic unconformity.

Traces of the peneplane developed at that time still form major elements of the topography, and surprisingly large tracts of this old floor are to-day entirely bare. Many of these bare areas have been covered at one time or another by later sediments, only to be denuded subsequently to some of the minor warpings of Tertiary time. In the more elevated areas, of course, agents of erosion working toward a new level have dissected this old surface, leaving only upland remnants of the former peneplane, whereas in well-protected areas little change has been effected in all the intervening time.

SUBDIVISION OF THE ANCIENT FLOOR

From the great variety of rocks noted as belonging to this ancient floor, and the very great differences of physical condition represented by them, it is evident that this floor is of compound make-up. It has been possible to distinguish several sharply defined series of sedimentary strata, other more obscure metamorphosed formations and definite igneous units. These have, in some cases, prominent structural breaks between them, or have structural relations characteristic of important differences either in age or in origin. Some are strictly igneous types of large extent and evident structural importance; some, on the other hand, are profoundly metamorphosed and have taken on all the complexities usually characterizing the crystalline gneisses and schists of very ancient time; still others are only moderately affected by such internal and modi-

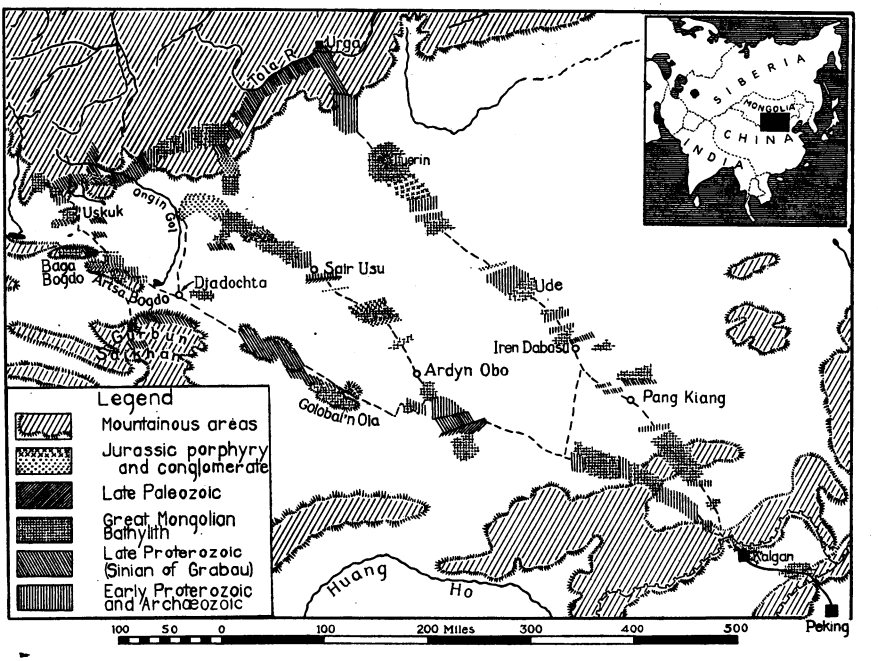

Fig. 1. Sketch map of central Mongolia, showing general geology of the rock floor along the route traversed by the Expedition.

Mountain areas are shaded by coarse slanting lines. An attempt has been made to distinguish the major groups of floor rocks along the route by different patterns. The younger basin sediments along the same lines of march are left white.

fying processes, and consequently are regarded as of much later age, corresponding in some degree to their greater simplicity.

At least six great groups are thus distinguished, some of which are capable of additional subdivision (Fig. 1). This is true particularly of the lowest, most ancient one, where for present purposes all the strongly metamorphosed units are grouped together. These major groups, in descending order, are as follows:

6. Mesozoic porphyry intrusives, cutting all formations up to and including the sedimentary series involved in the last folding of the region previous to the development of the great Mesozoic unconformity.

5. A great series of folded conglomerates and sandstones of continental type, considered to be of Jurassic age.

4. Strongly folded, fossiliferous Paleozoic strata of marine origin.

3. An extensive underlying and invading mass of granite, described as the Great Mongolian Bathylith.

2. A very thick and widely extended series of folded, unfossiliferous graywackes and slates, older then the granite bathylith and only moderately metamorphosed. We have called this the Khangai series, and consider it to be of late pre-Cambrian age.

1. Still more ancient, underlying complex groups of quartzites, slates, phyllites, schists, gneisses, crystalline limestones and other associated metamorphic rocks. This complex is made up undoubtedly of more than one series. The upper members are judged to belong to the division distinguished in China as the Wu T'ai system, and the oldest members are regarded as local representatives of the T'ai Shan complex.

Mesozoic Intrusives

A very great variety of porphyries, occurring both in dikes and in irregular forms of much larger extent, have been seen at many places. Typically, they are associated with and cut the latest sedimentary series preceding the great unconformity. This clearly establishes the fact that they are the youngest of the formations of the ancient floor. The strata above the unconformity are now regarded as of earliest Lower Cretaceous age, whereas those immediately below are judged on rather obscure grounds to be Jurassic. These intrusives, therefore, must also be of Jurassic age.

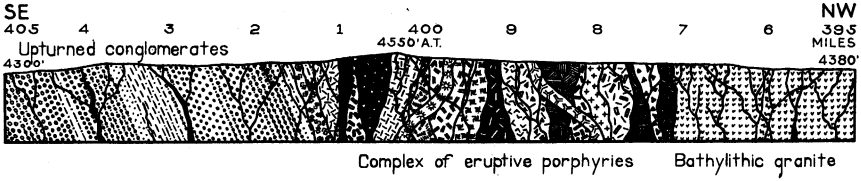

Fig. 2. Reproduction of ten miles of structure-section from the geologist's field notebook, 70 to 80 miles southeast of Sair Usu on the Uliassutai trail.

Chiefly Mesozoic rocks. Folded Jurassic conglomerates are seen at the left, cut by dikes. A complex of eruptive porphyries, probably also Jurassic, occupies the center. Both rest unconformably upon the Great Mongolian Bathylith, which occupies the right-hand end of the diagram. The extreme simplicity of the desert peneplane is well shown, contrasting with the complex underground structure.

Representatives of this group are very widely distributed, and in places exhibit a formidable complexity of relations. So many different units are represented, and they cut one another in so irregular a way, that in certain areas they form a veritable igneous complex (Fig. 2).

The commonest type is an acid porphyry, ranging in minor character from that of a simple quartz porphyry to granophyre and granite porphyry of comparatively massive habit. Intermediate composition is common also, and occasionally there are more basic types, so that the

compositional and structural range is very great indeed. The most constant characters are fine grain, dense texture, only moderately porphyritic habit. These rocks are brittle and exhibit a very broken condition, due apparently to their deformation. This physical condition, together with the great irregularity of form and occurrence as part of a confused complex, is not so strikingly exhibited by any other series of rocks.

Wherever such an igneous complex intrudes the Jurassic strata, the original sediments are entirely displaced and none of the original structural trend is preserved. Areas represented by such rocks, observed at several points, cover many square miles. The best examples are those seen at Tsetsenwan, at Sain Noin, in the Mt. Uskuk district, in the Artsa Bogdo range, on the Sair Usu trail east of the Ongin Gol, and on the trail southeast of Sair Usu. It is worth noting that igneous activity of a somewhat similar sort is prominent in China also, in association with exactly the same sorts of sedimentary formations. The type is constant enough in character, no matter how widely the occurrences are separated, to warrant the belief that some very widespread general source for these intrusions must have existed, operating under regional rather than very local control. We are inclined to the belief that the active history of the great granite bathylith, in spite of its much greater age, is in some way tied up with the genesis of the Mesozoic intrusions. There is a certain difference of habit, one age after another, that makes the whole lot look like a genetic succession, as if they all, from beginning to end, represented only stages in the active history of a single great, slowly differentiating and repeatedly rejuvenated bathylithic mass. Perhaps these peculiar porphyries are only the normal product of a particular stage from this master source (Fig. 7).

Jurassic Sediments

The youngest of the sedimentary groups forming the old floor is a great series of conglomerates and sandstones of continental type, simply folded or sometimes block-faulted, and quite free from important metamorphism. A great proportion of the material is coarse-grained, and considerable thicknesses are strictly conglomerates. Other great thicknesses are simple, well-bedded sandstones. Occasionally interbedded finer sandstones occur in considerable prominence, but as far as noted there are no large developments of shale or limestones in this series. Nowhere is there any evidence of marine conditions. The entire series consists of stream deposits. The only fossils seen are plant remains,

chiefly stems, very poorly preserved. In certain portions of the series, however, there are thin beds of coal of very low grade. Even in these beds, the original fossil forms are poorly preserved, and are nearly destroyed by deformation, so that the fossil content has proved thus far to be quite inadequate to determine the age of the beds (Fig. 3).

The material of these sediments is largely quartzose or at least very siliceous, and the forms of the fragments indicate much wear. The three striking features are the enormous thickness of the series, its wide distribution and the abundance of quartz pebbles and grains.

These rocks were found at several widely separated localities, the principal ones being at "Camp Jurassic," 50 miles north of Ude; at Tsetsenwan, 125 miles west of Urga; at Sain Noin, 300 miles west of Urga; in the Mt. Uskuk region, 40 miles north of the Altai Mountains;

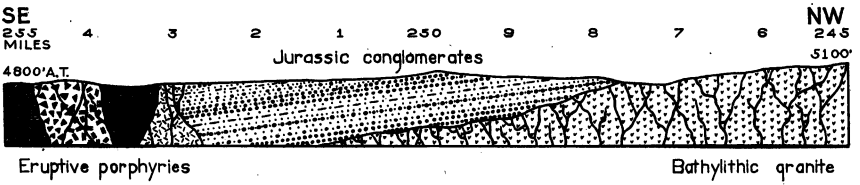

Fig. 3. Typical section of rock floor.

One of the important rock-floor formations is the Jurassic conglomerates. This series itself lies unconformably on other older groups, and is commonly cut by a great complex of intrusive porphyries. The section used here is a reproduction of ten miles of field traverse on the Uliassutai trail, 80 miles northwest of Sair Usu.

in the Artsa Bogdo range; on the trail midway between Sair Usu and Ardyn Obo, and at a few other spots where field relations and evidence were too obscure to determine the extent and local importance. As a matter of fact, there is evidence that strata of this series formerly extended over a much greater area than that covered by the Expedition.

Almost everywhere these strata stand on edge, or at least are strongly folded,—more seldom they are mashed and faulted, while occasional synclinal remnants show little disturbance. The total thickness in the district where this point could be best determined, is no less than 25,000 feet, and at several other places great thickness is indicated, although estimates were not made. Doubtless these strata form the floor beneath the covering of simple sediments at many places, but it appears that erosion has cut so deep into the geologic structure of that time that only the lowest portions of the synclinal folds and the bases of fault blocks are preserved. South of Tsetsenwan, we observed a vast series of surface volcanic rocks,—flows, ash and tuff beds, all of which shared the deformation of the Jurassic conglomerates. They range, like

the intrusive rocks, from rhyolitic through andesitic types, though basalts are present in minor proportion. They are regarded as a surface-flow expression of the same magmas that penetrated the Jurassic, and are now found as intrusive bodies cutting the conglomerate series.

In age the whole series is pre-Cretaceous and precedes the general peneplanation. On the other hand, the series lies above another unconformity, the exact position of which in the geologic scale is undetermined, except that it lies above the latest Paleozoic sediments. These strata, therefore, are apparently mid-Mesozoic, and are in all essential respects analogous to and in many important features similar to the Lower Jurassic strata of China proper. The fossil evidence for age determination is inadequate, but there are enough points of similarity in type of strata, character of content and deformation history to warrant tentative assignment to the same age. No fossils other than plant remains are found in either. On this basis we are referring to this series as wholly of Jurassic age, although there is no good evidence against the presence of representatives of the Triassic also. In any case, the series must be regarded as a unit, in which the only breaks of consequence are those marked by the great igneous intrusions, described under the preceding heading.

These intrusions occur at so many places, where they are associated with the Jurassic sediments directly, that one is impressed with the necessity of accounting in some way for this close association. It may very well be that the deformation that accomplished the foldings and faultings of Jurassic time was connected with and occasioned by igneous activities in the depths beneath, one expression of which is marked by these intrusives. Down-faulting blocks, therefore, or very deep down-foldings may mark the places of weakness which guided the outbreak, and thus both the sedimentary remnants and the associated intrusives are now preserved together. Other higher portions were more successfully removed by erosion.

Paleozoic Strata

It is a most striking fact that all the sediments thus far found in central Mongolia, from the present back to the break at the close of Paleozoic time, are of continental type. But beneath the unconformity, at the base of the so-called Jurassic sediments, there is a great series of strata of marine origin, carrying abundant and characteristic fossils. These beds include basal sandstones of only moderate development, with much greater thicknesses of limestones and shales preserved in down-

folded remnants. Several thousand feet in thickness have been seen, but the actual total or maximum thickness is unknown.

Strata of this age have been found in only two areas, both southeast of Sair Usu. Undoubtedly they constitute an eastward extension of the ancient folded Altaides of Suess, but the Tertiary faulting that has raised the modern Altai ranges did not extend into this portion of the desert; so that the representatives of the folded Paleozoic strata have not been uplifted, and are still simply part of the peneplaned floor.

The larger proportion of the strata is judged by Dr. A. W. Grabau, from fossil collections made during the first season of the Expedition's work, to be of Permian age, but there is a continuation downward into a still earlier period, at least into the Pennsylvanian. Curiously enough, no representatives of these strata were seen in the Altai Mountains them-

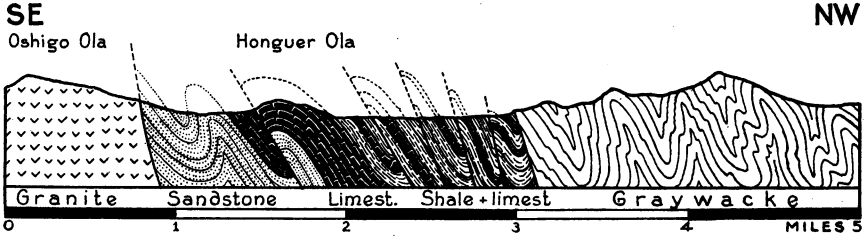

Fig. 4. Cross section of an area of marine Permian beds, noted on the Uliassutai trail, about 120 miles southwest of Iren Dabasu.

The complexly folded and faulted sandstones, shales and limestones now occupy a graben between a broad area of granite hills on the southeast and a broad area of the Khangai graywackes and other old rocks on the northeast.

selves, either in the Artsa Bogdo or the Baga Bogdo districts, although a single hand specimen carrying fossils of Paleozoic age was found loose on the northerly flanks of the Gurbun Saikhan. From this it seems probable that representatives of Paleozoic age are to be found somewhere to the south in that region. Probably marine Paleozoic strata were formerly extensively distributed in this central Asiatic region, but the early Mesozoic or mid-Mesozoic epochs of diastrophism and erosion wrought such havoc that now only a few remnants are preserved (Fig. 4).

These rocks are all closely folded, and, although considerably deformed, the fossil content is fairly well preserved. The strike is nearly east and west, conforming in this respect to the average structural trend of the other elements of the ancient floor. Nowhere have we seen the exact relations between this series and the Jurassic above or the graywackes below. But the relative position in the scale can be inferred, and

the general nature of the relation is reasonably well determined by differences of structural habit and physical condition. There is clearly an important break indicated between the Paleozoic sediments and the Jurassic series, since these strata are marine, whereas the Jurassic beds are strictly continental.

It is particularly disappointing that these Paleozoic beds have not been seen in direct sedimentary contact with the graywacke-slate series beneath. This leaves some uncertainty about structural relation and relative age. It is clear that the graywackes are older, and, in view of the fact that they are unfossiliferous, somewhat more metamorphosed and of an entirely different petrographic habit, we are inclined to believe that the graywackes are much older and are probably separated from the Paleozoic strata by an unconformity as pronounced as either of those above. There is abundant evidence that the Great Mongolian Bathylith, described as the next unit under the following heading, is later than the graywacke series, and is very much older than the Jurassic sediments, which in some places lie on an erosion floor of granite (Fig. 3). But it is not entirely clear, from any relation yet observed, whether the Paleozoic sediments are younger or older than the maximum invasion stage of the bathylith. All the early and mid-Paleozoic strata are missing, so that there are no representatives yet found from Cambrian to Mississippian time. Apparently the Paleozoic era is the most defective one, as indicated by the few sedimentary remnants still preserved. The Paleozoic rocks mark a transient marine history between two very long epochs of continental control.

The Great Mongolian Bathylith

Between the sedimentary series just described and the older ones to follow, there developed in central Asia a great granite bathylith, exposures of which can be seen at various places over a very large territory. The formations existing at that time, including the Archæan crystalline rocks and the graywacke-slate series, are invaded by the granite, and at many places where subsequent erosion has been deep enough, remnants of these earlier formations are preserved as roof pendants. The granite appears as large areas of massive rock, and also as smaller intrusive masses, even dikes, which cut all the formations up to and including the graywackes. It is not so clear what its relations are to the Paleozoic series, but in one place the granite appeared to be faulted against the Paleozoic strata (Fig. 4, Oshigo Ola). As the Permian beds near the contact are not metamorphosed, and as no granite dikes are seen

cutting them, it seems fair to infer that these Permian sediments are younger than the granite.

It is possible, of course, that even the later intrusives, such as those which cut the Jurassic series, are products of the same great bathylithic magma, but if so, they belong to a much later stage in its own development than that represented by the great areas of true granite. That stage, the stage of massive granite solidification which was also the stage of maximum invasion, is probably pre-Pennsylvanian, and certainly later than the Khangai graywacke. It is entirely possible that every igneous unit in the region, no matter what its age, is genetically connected with this immense bathylith. Its early developmental stages may have been responsible for the injection phenomena of the ancient gneisses; its maximum encroachment was attained in Paleozoic time, and its old age rejuvenations may in this view be recorded in the outbreaks of later periods (Fig. 7).

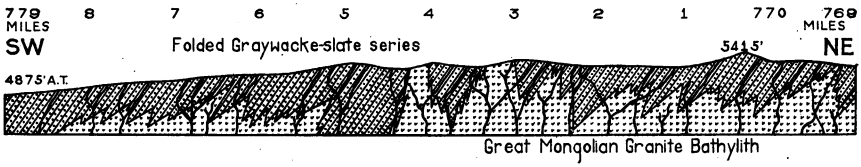

Fig. 5. Typical section of the Khangai graywacke series. This section is from Five-Antelope Camp, 100 miles southwest of Urga.

The simply folded graywacke-slate series is undercut and penetrated by the Great Mongolian Bathylith, and locally metamorphosed by contact influence over a very wide territory. This section reproduces a ten-mile stretch along the route followed by the Expedition within the northern mountain area.

These granites show considerable variety of composition and minor habit, but the dominant type is a biotite granite of medium coarse texture and massive structure. It has produced an extraordinary variety of end-product effects, and considerable contact metamorphism. Its relations and distribution and special features are made the subject of a separate paper already published.[1]

The Khangai Graywacke Series

A very extensive series of graywacke sandstones and interbedded shale or slate rocks is widely distributed in Mongolia. This series forms the major composition of the mountains of the Arctic divide, and constitutes the country rock of the Urga-Tola River-Tsetsenwan region, as well as the Khangai mountain range through the province of Sain Noin

[1]Berkey, Charles P., and Morris, Frederick K. 1924. "The Great Bathylith of Central Mongolia." Amer. Mus. Novitates, No. 119.

toward Uliassutai. These rocks are particularly well exhibited in the Gurbun Saikhan and in the small mountain tract 20 miles east of the Mt. Uskuk block, as well as in the Ude region along the Urga trail. Representatives of the same formation are found in many other areas.

In the Tola River region and at Tsetsenwan and westward, graywackes dominate, whereas southward and eastward a greater proportion of shales is interbedded. Neither the top nor the bottom of the series has been determined, but it is certain that it is of very great thickness,—probably at least 20,000 feet.

As far as observed, these strata are unfossiliferous throughout. Diligent search was made for possible fossil content, and, in the general Uskuk region, slates were found with obscure markings that are believed to represent imprints of some simple organic form, probably algæ. A striking thing, of course, is the unfossiliferous nature of these rocks in spite of their simple sedimentation structure, in strong contrast to the richly fossiliferous habit of the Upper Paleozoic strata. It is not believed possible that these graywackes and slates, with their splendid bedding structure and abundance of original shales, could be of Paleozoic age without bearing better evidence in the form of fossil content.

Siliceous limestones, of dark gray to blue color, are found associated with slates in some localities, and these also are quite without fossils so far as we have seen. Probably these limestones represent incursions of a shallow sea, and the very fact that they lack fossils so completely suggests that they are pre-Cambrian. The graywackes are probably non-marine and of the same age, and, especially in the Khangai Mountains and the region about Urga, where limestones are quite lacking, it is believed that this great series is essentially continental.

Everywhere the series is folded. In places where it is made up largely of original shales, there is much internal deformation, so that typical slates have been formed; but wherever the much more massive graywackes make up the formation, simple folding is more common, with very little internal deformation or meta-structure.

The series was invaded by the granite bathylith subsequent to its folding, and in many places over extensive areas this rock now forms the only roof. Great numbers of dikes cut through the series, and the bathylith itself is uneven enough, so that with later erosion patches of granite are exposed, alternating with patches of graywacke. In places where the granite lies close beneath, there is considerable contact metamorphic effect produced on certain qualities of the graywacke-slate series. In some places a crystalline condition and moderately schistose

structure are thus produced, whereas normally the rock is eminently granular and not schistose at all (Fig. 5).

Other observers have noted graywacke series in regions beyond the reach of the traverse of the Third Asiatic Expedition, especially in districts to the north. Some Russian geologists have classified graywackes in Siberia as of Devonian age. It does not appear, however, that there is sufficient reason to follow this classification for the Khangai series of Mongolia. A graywacke found north of Urga by J. Morgan Clements[1] is regarded by him as of pre-Cambrian age. This may correlate with the Khangai series of the Third Asiatic Expedition. Graywackes and slates also are mentioned in the region very far to the south by other observers, and again with suggestion of different age, but it is not certain, of course, that the same formation is referred to.

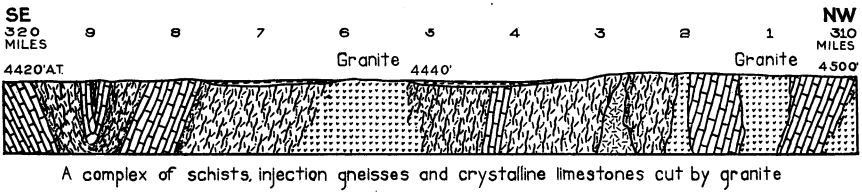

Fig. 6. Reproduction of ten miles of structure section from the geologist's field notebook, 9 to 19 miles northwest of Sair Usu on the Uliassutai trail.

The figure shows pre-Cambrian rocks of very complex structure. These have been peneplaned and two shallow basins of the later sediments overlie them. The peneplane is very well shown.

The Ancient Crystalline Complex

Clearly older than the graywacke series, as indicated not only by their structural relations but also by the much greater metamorphic modification, is a great group of formations which doubtless includes several separable series, but which together may be conveniently referred to as the ancient crystalline complex (Fig. 6). The simplest of the rocks of this class are slates, phyllites, schists, limestones and conglomerates that are clearly derived from some ancient sedimentary series, of much more variable habit and somewhat different origin from that of the overlying graywacke series. They stand everywhere on edge; they are repeatedly exposed in many places as widely separated as are the observations of the Expedition. The tracts are extensive, however, at but few places, and there are but few of these where many of the members are exposed together.

---

[1]Clements, J. Morgan. 1922. "Gold Placer Area in Mongolia, China." Department of Commerce, Trade Information Bulletin No. 4, Far Eastern Division.

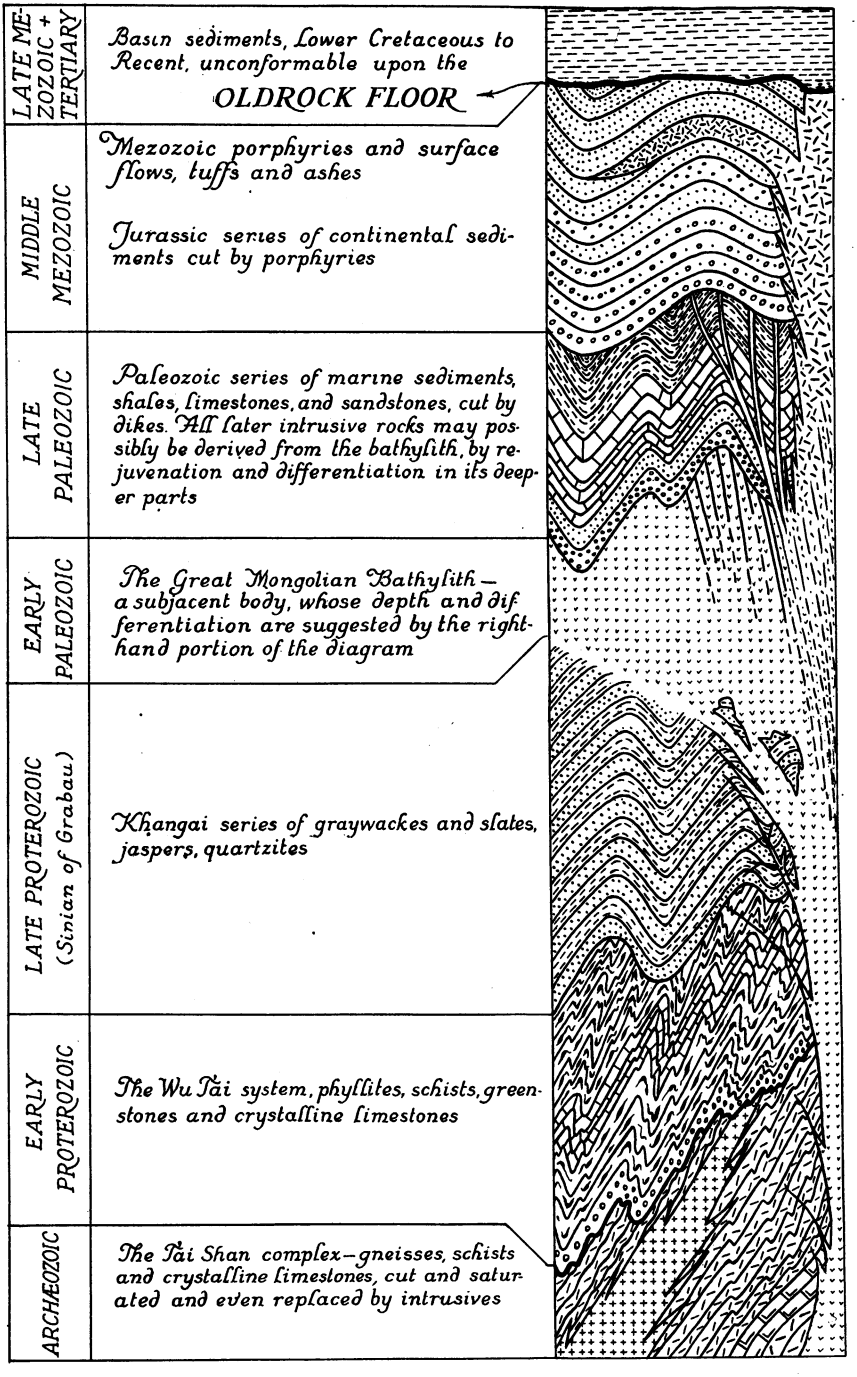
LATE MEZOZOIC + TERTIARY
Basin sediments, Lower Cretaceous to Recent, unconformable upon the
OLDROCK FLOOR
MIDDLE MEZOZOIC
Mezozoic porphyries and surface flows, tuffs and ashes
Jurassic series of continental sediments cut by porphyries
LATE PALEOZOIC
Paleozoic series of marine sediments, shales, limestones, and sandstones, cut by dikes. All later intrusive rocks may possibly be derived from the bathylith, by rejuvenation and differentiation in its deeper parts
EARLY PALEOZOIC
The Great Mongolian Bathylith — a subjacent body, whose depth and differentiation are suggested by the right-hand portion of the diagram
LATE PROTEROZOIC (Sinian of Grabau)
Khangai series of graywackes and slates, jaspers, quartzites
EARLY PROTEROZOIC
The Wu Tai system, phyllites, schists, greenstones and crystalline limestones
ARCHÆOZOIC
The Tai Shan complex—gneisses, schists and crystalline limestones, cut and saturated and even replaced by intrusives

Fig. 7.

The Wu T'ai System

Because of the fact that in certain places conglomerates are found in the midst of these series, and on account also of an observed difference in the degree of metamorphic complexity of certain members, we think the evidence favors the recognition of at least two great systems of pre-Cambrian rocks, older than the rocks of the Khangai graywacke series.

If we are right in regarding the graywackes as pre-Cambrian, they must be late pre-Cambrian, and as such they should correspond approximately to the Nan K'ou series of von Richthofen and Bailey Willis, in China, or the Sinian system of Grabau. Our next older series in Mongolia may include the greenish chloritic schists in the Artsa Bogdo range of the Altai Mountains. There is also a vast series of greenstones and chloritic phyllites in the mountains east of Ardyn Obo, which may be of igneous origin, and perhaps represent ash beds and surface flows that have undergone thorough reorganization. More data bearing on this problem may be expected when these rocks are studied with the microscope. Thin beds of limestone were found in the greenstone area. Mica schists and mica phyllites were seen on the Kalgan-Urga trail north of P'ang Kiang, and crystalline limestones are associated with these. The phyllite-schist-limestone-greenstone group occurs at many places, yet is nowhere as thoroughly pierced and saturated by invading igneous material as is the group of rocks next to be described. No better guide for these still older rocks is available than that of Bailey Willis as given in his "Research in China," where he classifies a series of phyllites, limestones, quartzites, schists and greenstones under the Wu T'ai system, and places this system as Early Proterozoic. We see no better classification for these very similar rocks in the Gobi region.

The T'ai Shan Complex

Still more complexly modified rocks are found in the Gobi region. They are largely gneisses and associated schists and crystalline limestones. The gneisses range from granitic to dioritic in general composition, but they are not simply granites and diorites. They represent a complex in which the original rock probably was a schist. This original rock has been invaded by igneous material which has penetrated and saturated the original, following in the main the structural lines of the schist. The magma has replaced as well as penetrated the host rock, so that now the igneous matter is a streaked gneiss because it has inherited the structure of the schist which it has largely destroyed and replaced. Where the

These two divisions of rock formations were recognized by earlier explorers

A floor of ancient formations, not hitherto subdivided or correlated

Overlying sediments, not hitherto subdivided

GEOLOGIC COLUMN AS WORKED OUT BY THE THIRD ASIATIC EXPEDITION

Twelve definite sedimentary formations, distinguishable on structural or paleontologic grounds, and ranging in age from Lower Cretaceous to Pleistocene time, are represented in the sediment on the ancient floor.

Mesozoic			THE GREAT MESOZOIC UNCONFORMITY		
			ALL ROCKS BELOW THIS LINE ARE FOLDED		
	Early Mesozoic	Jurassic	A great series of conglomerates, sandstones and shales, with associated lava flows, tuffs and ashes, carrying obscure plant remains and locally coal, the whole about 20,000 feet thick. Apparently corresponds to Lower Jurassic of northern China.		
			UNCONFORMITY		
Paleozoic	Late Paleozoic	Permian	Limestones, Shales, Sandstones	A series of limestones, shales and sandstones with characteristic invertebrate fossils	
		Carboniferous	Slates, Quartzites, Conglomerates		
			UNCONFORMITY COVERING EARLY PALEOZOIC TIME		
			Great Bathylithic Invasion	Mongolian granite bathylith	
Proterozoic	Late	Nan K'ou System of von Richthofen and Willis	Sinian System of Grabau	Khangai Series	Tola River graywackes and slates without fossils
	Early	Wu T'ai System as used by Willis in China			Schists, phyllites, limestones, dolomites, quartzites, greenstones
Archæozoic	Archæan	T'ai Shan Complex as used by Willis in China			Crystalline limestones, schists and complex injection-gneisses

igneous streaks are less predominant, the rocks may still be classed as schists, and among these the commonest type is a coarse-grained muscovite-biotite schist, streaked with lenses and thin sheets of granite or pegmatite. The limestones are white to blue or gray crystalline marble.

Such rocks were especially noted in the block mountain south of Tsetsenwan; in another block mountain 40 miles southwest of Tsetsenwan, and north of Kalgan on the road to the pass, as well as at many other places.

Because of the greater complexity of structural habit, these rocks are regarded as still older than those we have referred to the Wu T'ai system, and, again following the usage established by Willis in China, we have chosen to regard these oldest of the formations yet seen in the Gobi as Archæozoic and equivalent to the T'ai Shan of China.

TECTONIC LINES

All these crystalline rocks, both those of the Wu T'ai system and those of the T'ai Shan complex, are folded and sheared, and usually are found standing almost on edge with the major trend or structure running nearly east and west. Very rarely have there been great deviations from this trend, although in a minor way there is a good deal of variation. The average is about south 80° east and north 80° west. All the very ancient structural lines belong to this trend, and this is so fundamental in the floor structure that it affects even the later mountain ranges down to and including those of Jurassic time.

MISSING PARTS OF THE COLUMN

Undoubtedly there are great breaks between the principal members of the pre-Cambrian series. It is believed that the conglomerates seen on the Urga trail in the midst of these formations, and the conglomerates seen also on the Tsetsenwan-Sain Noin trail 300 miles west of Urga, mark some of these important breaks, but even without these there is sufficient evidence in the differences of the rocks themselves to warrant such subdivision as has been made, and such age differences as are indicated in the tabulation. Doubtless very much greater detail of formational make-up is actually exhibited than has been determined as yet, but the major elements of the ancient rock floor and the major characters of the individual unit series are reasonably satisfactorily represented as a working basis by the accompanying table (page 15).