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Upper Cretaceous Djadokhta, Barun Goyot and Nemegt formations of Mongolia, including remarks on previous subdivisions

ABSTRACT: Upper Cretaceous Djadokhta, Barun Goyot and Nemegt formations are discussed and their diagnoses refined. Columnar sections of type and references localities and lists of fossils are given. It is shown that three formations represent different lithological and faunistic units. Except for *Deltatheridium pretrituberculare*, represented in the Djadokhta and Barun Goyot formations by different subspecies, no other vertebrate species yet described are common to any two formations. The only dinosaur and mammal genera known to be common to Upper Cretaceous deposits of Asia and North America are *Saurolophus* (a hadrosaur) and *Catopsalis* (a multituberculate). Several dinasaur and mammal families are endemic to Asia or North America. As "best guesses" the estimated stages are: Djadokhta Formation — ?upper Santonian and/or ?lower Campanian; Barun Goyot Formation — ?middle Campanian; Nemegt Formation — ?upper Campanian and ?lower Maastrichtian. Confusion in the stratigraphic division of Upper Cretaceous rocks of Mongolia has resulted partly from considering the Soviet stritigraphic unit *svita* to be synonymous with formation.

INTRODUCTION

The stratigraphy of Upper Cretaceous rocks of the southern part of Mongolia [1] was first discussed in geological and palaeontological literature in a note by Charles P. Berkey (*in* Granger & Gregory 1923). More detailed results of stratigraphic studies accomplished by members of

[1] The term Mongolia, for purposes of brevity, shall be used in this paper as a synonym of the Mongolian People's Republic.

the Central Asiatic Expeditions sponsored by the American Museum of Natural History were given by Berkey & Morris (1927).

Members of the Mongolian Palaeontological Expeditions, organized through the Palaeontological Institute of the USSR Academy of Sciences, conducted exploration in Mongolia between 1946 and 1949. The most important excavations were made in southern Mongolia, and important papers on the stratigraphy of the Upper Cretaceous beds resulted (*e.g.* Efremov 1954, 1955; Novozhilov 1954a; Rozhdestvensky 1957, 1965, 1971, 1974; Maleev 1952, 1955a, 1956; see also Marinov & al. 1973, for review).

Members of the Polish-Mongolian Palaeontological Expeditions between 1963 and 1971 also explored parts of southern Mongolia. Geological results of the expeditions were discussed mainly by Gradziński & al. (1969), Gradziński (1970), Gradziński & Jerzykiewicz (1972, 1974a), Kielan-Jaworowska (1974a, 1975a, 1975c), Lefeld (1965, 1971), and Maryańska & Osmólska (1974, 1975).

Renewed Soviet interest in the area began in 1967 and 1969, respectively, through the Soviet-Mongolian Geological Expeditions (as main references, see Barsbold 1972, Martinson & al. 1969, Martinson 1975, Martinson & Shuvalov 1975, Sochava 1975, and Shuvalov 1975) and Soviet-Mongolian Palaeontological Expeditions (*e.g.* Kramarenko 1974, Beliajeva & al. 1974, and Rozhdestvensky 1974). The Soviet-Mongolian expeditions continued researches in the southern Gobi Desert through 1976, with the likelihood of further continuation.

Additionally, the area has been studied by individual Mongolian workers (*e.g.* Dashzeveg 1975) and some occasional European geologists (*e.g.* Nikoloff & von Huene 1966). Various stratigraphic comments or conclusions have been also published by paleontologists who have not actually worked in Mongolia (*e.g.* McKenna 1969, and Fox 1972a, 1974).

General reviews of the stratigraphy of Mongolian Upper Cretaceous deposits were provided by Marinov (1957), Vasiliev & al., (1959), Marinov & al. (1973) and Martinson (1975).

Nevertheless, some nomenclatorial confusion persists. The most important sources of the difficulty are due to: (1) use of units belonging to categories of stratigraphic nomenclature that are not comparable with one another (e.g. *„svita"* is sometimes synonymized with a „formation", a unit based on a quite different concept), and (2) incomplete diagnoses of stratigraphic units.

We have refined the diagnoses of three important rock units (Djadokhta Formation, Barun Goyot Formation and Nemegt Formation), presented lists of fossils as completely as possible for each formation and have reconsidered the bases of age determinations. We believe that the scheme of lithostratigraphic subdivision used herein for Upper

Cretaceous deposits of southern Mongolia will not only provide a useful framework for future stratigraphic work, but when combined with palaeontological data will become an essential tool to the study of continental Asiatic life during the Late Cretaceous.

The formations discussed below do not represent all mapable Upper Cretaceous rock units of southern Mongolia; further field investigations will certainly reveal others.

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LITHOSTRATIGRAPHY

GENERAL REMARKS

Upper Cretaceous strata of southern Mongolia are found mainly within large, post-Oligocene tectonic depressions. The rocks are exclusively red beds of continental origin, most of which have great lateral and vertical variability. Marker beds of an extent greater than a few tens (exceptionally few hundreds) of meters have not been recognized. Exposures are scarce but large, and are found in isolated groups referred to in the present paper as „localities" (*cf.* Fig. 1). Usually, only parts of formations are exposed at any one locality. Formational boundaries are only rarely exposed, thus posing serious

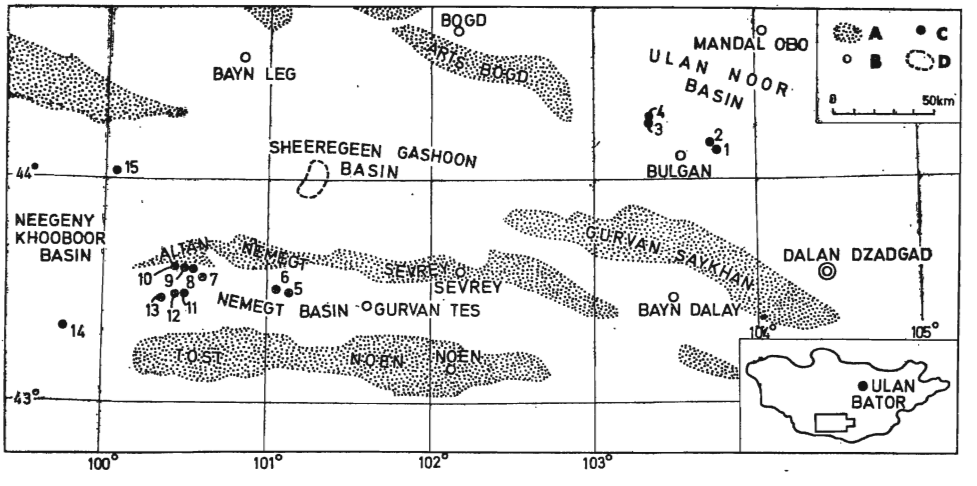

Fig. 1. Sketch-map of southern Mongolia
A massifs; *B* settlements; *C* localities discussed in the text (**1** Khashaat, **2** Bayn Dzak, **3** Toogreeg, **4** Alag Teg, **5** Khulsan, **6** Nemegt, **7** Altan Ula *I*, **8** Altan Ula *II*, **9** Altan Ula *III*, **10** Altan Ula *IV*, **11** Ulan Bulak, **12** Naran Bulak, **13** Tsagan Khushu, **14** Khermeen Tsav *I* & *II*, **15** Bugeen Tsav); *D* area of main exposures in Sheeregeen Gashoon Basin

difficulties to defining the limits of lithostratigraphic units and recognizing them away from type and reference localities.

The original formational names are maintained in the diagnoses given below, as are the kind, rank, and general concept involved at the time of establishment of each unit. The changes introduced by us are mainly of subordinate importance; they are intended merely to refine the characteristics of the formations and to adjust the diagnoses to better comformity with international standards.

Descriptions and sketch-maps of the localities mentioned in the text are given by Gradziński & al. (1969) and Gradziński & Jerzykiewicz (1972).

DJADOKHTA FORMATION

NAME

Introduced as „Dja-doch-ta" by Berkey (in Granger & Gregory 1923, p. 8), then modified to „Djadokhta" (Berkey & Morris 1927). According to Dr. R. Barsbold (see Lefeld 1971, p. 101), the term „Djadokhta" is a result of the incorrect spelling and transliteration of a local Mongolian geographic name.

GENERAL LITHOLOGY

Dominant lithology (Pl. 1; Pl. 2, Fig. 1) is a poorly cemented, fine-grained arkosic sandstone of reddish-orange to brick-orange color. Conglomeratic beds, only few decimetres thick, composed of light-colored calcareous concretions, occur subordinately, mainly in upper parts of the section; some are firmly cemented toward the tops of beds, displaying caliche features. Sandstones are massive and usually grossly appear structureless; poorly visible cross-stratification of a very large scale can be observed locally. Occurrences of numerous dikaka-like structures are found in some places and other tubular structures, supposed to be burrows, occur sporadically. Small calcareous concretions are irregularly common in sandstones. Large isolated zones of stronger calcareous cementation occur in lower part of the section; they are of irregular shape and occasionally of inclined attitudes which gives the impression of inclined bedding.

HISTORICAL BACKGROUND, SYNONYMY

The formation was established in the early 1920's by geologists with the American Central Asiatic Expedition at the Flaming Cliffs, in the area of Shabarakh Usu (present name, „Bayn Dzak"). Since then, the term „Djadokhta Formation" has been widely used in paleon-

tological and geological publications. The terms „sandstones of Bayn Dzak" or „deposits of Bayn Dzak" have been used synonymously by many Soviet and Mongolian authors for the past 25 years.

TYPE LOCALITY

Locality Bayn Dzak (lat. 44°12′N, long. 103°44′E). The best and most representative section is in the sharp escarpment at the Flaming Cliffs (Pl. 1, Fig. 1) and the continuation to the north-east, in the central part of the locality (Figs 2—3).

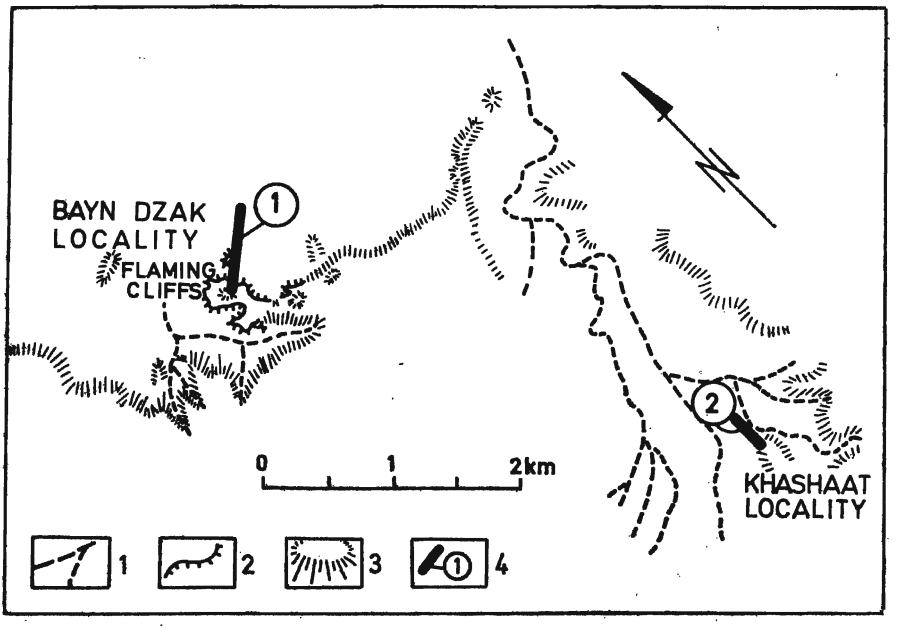

Fig. 2. Sketch-map of localities Bayn Dzak and Khashaat (N part)
1 sayrs (ueds), *2* escarpment with larger cliffs, *3* escarpment, *4* placement and number of columnar section

The same symbols are used in Text-figs 4, 7, 8 and 11

BOUNDARIES

The lower boundary of the formation is not exposed. The upper boundary is exposed in the Khashaat (Gashato) locality (for placement of section, see Fig. 2; boundary stratotype, see Fig. 3). It is marked by an erosional surface overlain by the Paleocene Khashaat (Gashato) Formation (dominantly of sandy clays and sands with common intercalations of coarse gravel, most sediments being deep red and chocolate brown in color). The interformational contact was variously described by Berkey & Morris (1927, p. 358), Novozhilov (1954a, pp. 42—43),

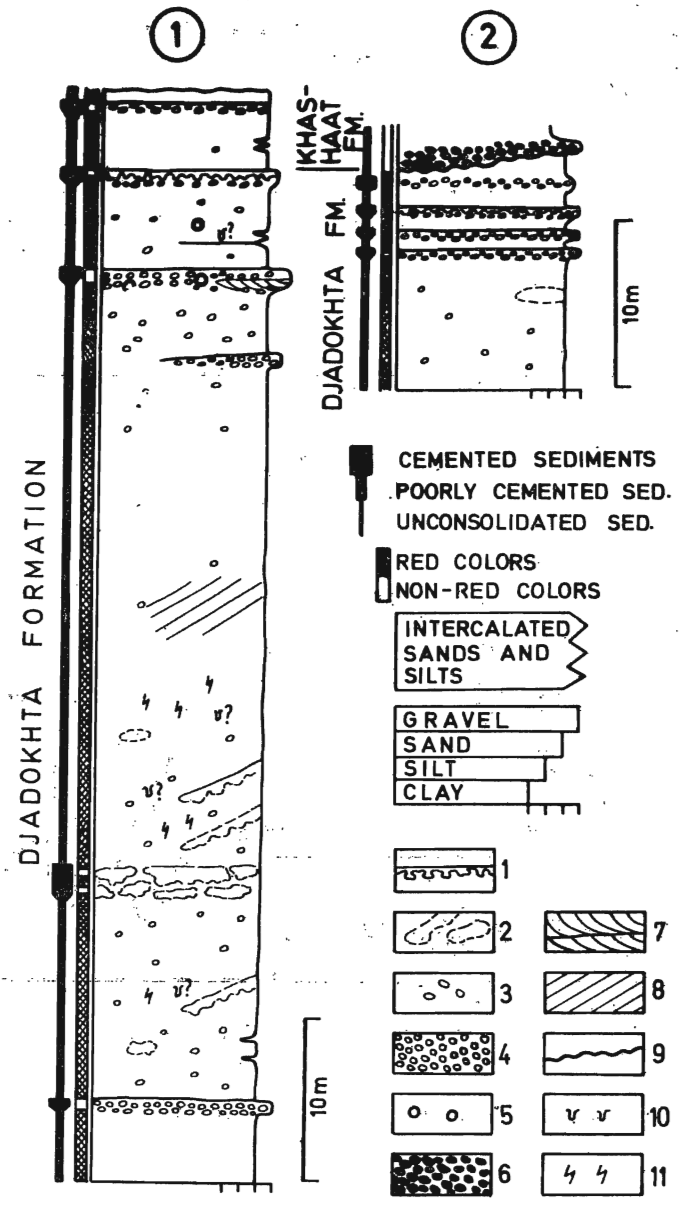

Fig. 3. Columnar sections of the Djadokhta Formation (1 Flaming Cliffs, Bayn Dzak locality; 2 upper-boundary stratotype at Khashaat locality). For placement of the sections see Text-fig. 2

1 caliche, *2* isolated zones of stronger calcareous cementation, *3* scattered calcareous concretions, *4* conglomerate composed of calcareous concretions, *5* exotic pebbles, *6* coarse gravels, *7* large-scale cross-lamination, *8* very large-scale cross-lamination (sets thicker than 1 m), *9* erosional surface, *10* burrows, *11* dikaka-like structures; red colors = hue values (5 R, 10 R, 5 YR; according to *Rock Color Chart* of Godward, 1970)

Symbols for cementation, colors and grade types of sediments are also used in Figs 5, 6, 9 and 10

Lefeld (1971, p. 106), and by Zhegallo & Shevyreva (1976, pp. 269—270).

Thickness: Not less than 70 m.

Fossils: See Tables 3—4.

Age and correlation: The estimated age of the formation is ?upper Santonian and/or ?lower Campanian[2]; for correlation see below.

BARUN GOYOT FORMATION

NAME

Derived from an ancient settlement situated in the Nemegt Basin near the eastern part of the Nemegt Massif.

GENERAL LITHOLOGY

Lithology dominated (Pl. 2, Fig. 2; Pls 3—5; Pl. 6, Fig. 1) by red and red-brown, poorly cemented sandstones that are usually either fine- or medium-grained. Subordinate beds of sandy mudstones (claystones) of more intense red-brown color exist, and rare intercalations of sandy siltstones occur locally. The beds of the massive sandstones are either devoid of internal stratification or display a very large-scale cross-lamination. Erosional channels, cut-and-fill structures, and horizontal lamination are seen in places. Intraformational conglomerates occur irregularly, and they fill small pockets. Flat-bedded sandstones intercalated with mudstones and/or siltstones become dominant in the uppermost part of the section; most beds in this part enjoy a relatively great persistence laterally. Tubular structures resembling burrows are rather common in the uppermost part of the formation.

HISTORICAL BACKGROUND, SYNONYMY

The rock unit now known as the Barun Goyot Formation was first described by Efremov (1950, 1954, 1955), who used the names „unfossiliferous lacustrine sandstones" and „barren deposits" without clearly defining their limit. The „Lower Nemegt Beds" were named by Gradziński & al. (1969), but were redefined and emended as the Barun Goyot Formation by Gradziński & Jerzykiewicz (1974a, p. 116).

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[2] The terms *upper* and *lower* Campanian, Santonian etc. are not capitalized herein, as these parts of the stages may not correspond closely to the substages commonly refferred to as Lower and Upper.

TYPE LOCALITY

Locality Khulsan (lat. 43°30′—43°15′ N, long. 101°07′—101°08′ E; Pl. 6, Fig. 1) in the Nemegt Basin, *c.* 15 km S from the eastern part of the Nemegt Massif, and *c.* 8 km N from the morphological axis of the basin (for columnar sections see Fig. 5, for placement of sections see Fig. 4).

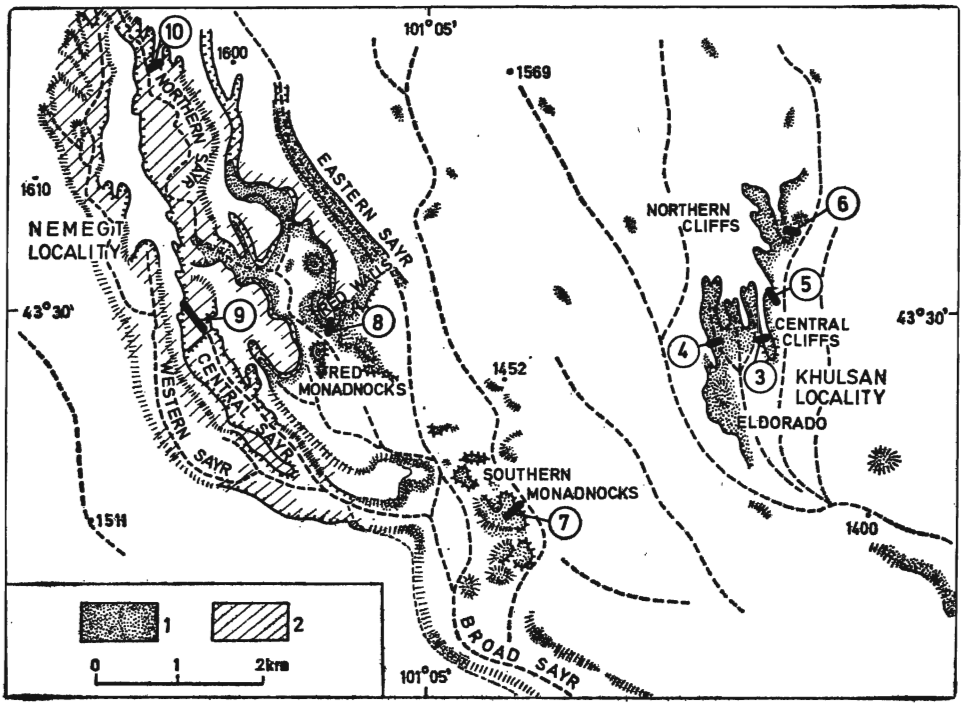

Fig. 4. Sketch-map of localities Nemegt and Khulsan
1 exposures of the Barun Goyot Formation, *2* exposures of the Nemegt Formation; other symbols as in Text-fig. 2

REFERENCE LOCALITY

SE part of the Nemegt locality area: Southern Monadnocks and Red Walls (see Fig. 4; columnar sections are in Fig. 6).

BOUNDARIES

The lower boundary of the formation is covered and thus is unknown. The upper boundary is exposed in the eastern part of the Nemegt locality (Red Walls and vicinity) and is placed at the top of the interrupted sequence of the typical Barun Goyot lithology. It is directly overlain (see boundary stratotype, Fig. 6) by a distinct layer of conglomerate composed of reworked calcareous concrections and

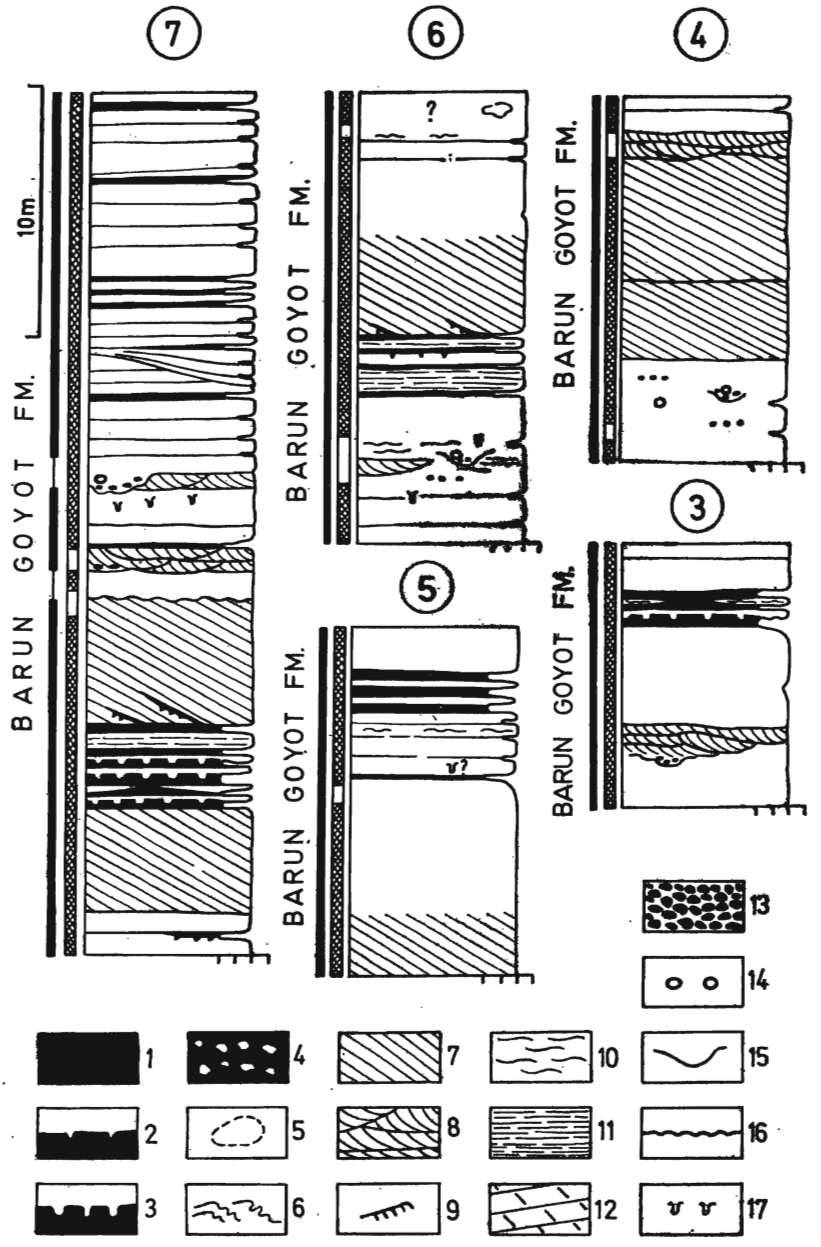

Fig. 5. Columnar sections of the Barun Goyot Formation (3 Central Cliffs, Khulsan southern locality; 4 Western Sayr, Khulsan locality; 5 Central Cliffs, Khulsan northern locality; 6 Northern Cliffs, Khulsan locality; 7 Southern Monadnocks, Nemegt locality). For placement of the sections see Text-fig. 4

1 mudstone, *2* mud cracks, *3* load casts, *4* calcareous concretions in mudstone, *5* large calcareous concretion, *6* deformational structures, *7* very large-scale cross-lamination, *8* large scale cross-lamination, *9* small-scale cross-lamination, *10* wavy lamination, *11* horizontal lamination, *12* inclined bedding with internal structures, *13* intraformational conglomerate, *14* exotic pebbles, *15* erosional pocket, *16* extensive erosional surface, *17* burrows; other symbols as in Text-fig. 3

mudstone fragments. The conglomerate is superposed by the light-colored, poorly cemented sands of the Nemegt Formation. The contact, when traced laterally, can be shown to involve interfingering litho-

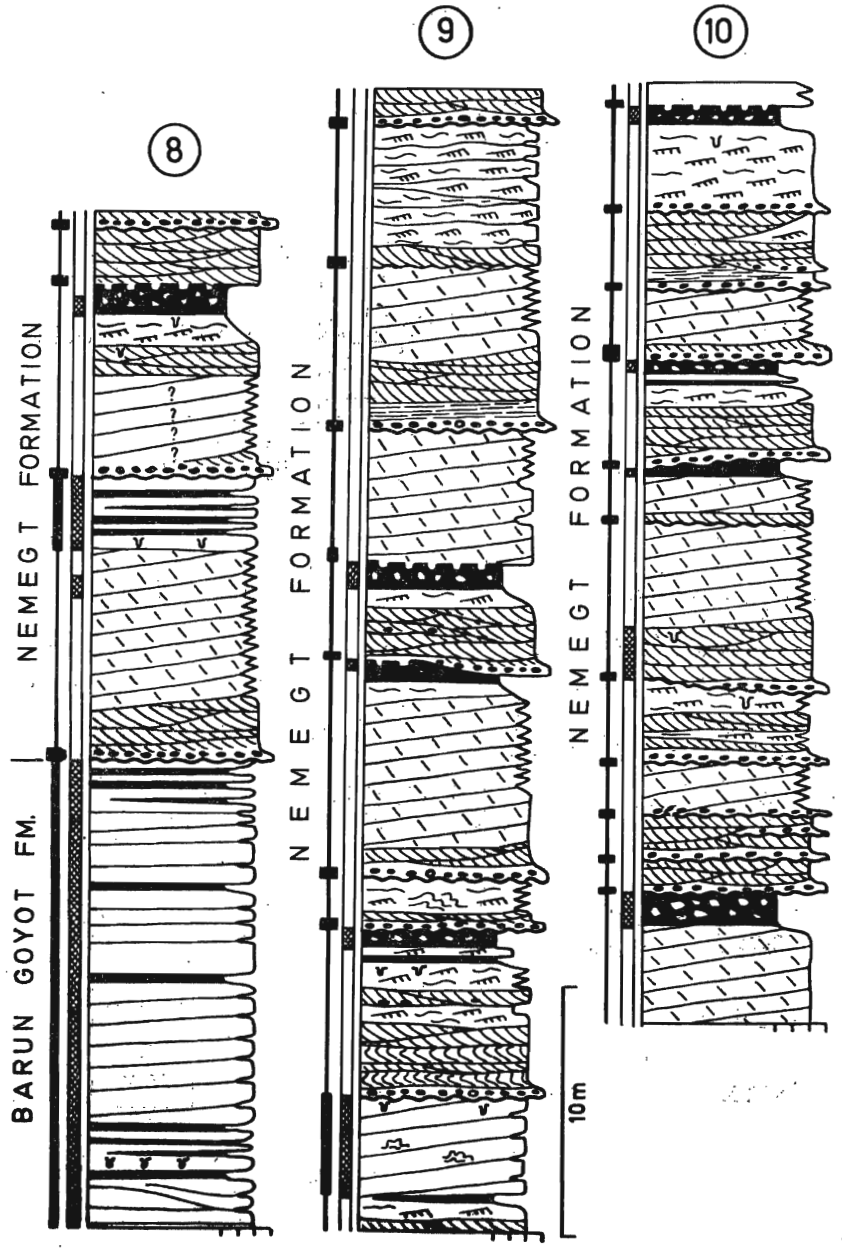

Fig. 6. Columnar sections of the Barun Goyot and Nemegt formations (8 boundary stratotype, SW part of Red Walls, Nemegt locality; 9 Central Sayr, N part, Nemegt locality; 10 Northern Sayr, N part, Nemegt locality). For placement of the sections see Text-fig. 4; symbols as in Text-figs 3 and 5

logies characteristic of the Barun Goyot and Nemegt formations. The Nemegt Formation usually begins with a basal conglomerate bed. There are sandstones similar to those of the Barun Goyot Formation interbedded within the Nemegt Formation, but no Nemegt-like lithologies are known from the Barun Goyot Formation. The stratotype for the upper boundary has been designated as the section exposed in the SW part of the Red Walls at the Nemegt locality (for placement, see Fig. 4 and Pl. 3, Fig. 2; for columnar section, see Fig. 6).

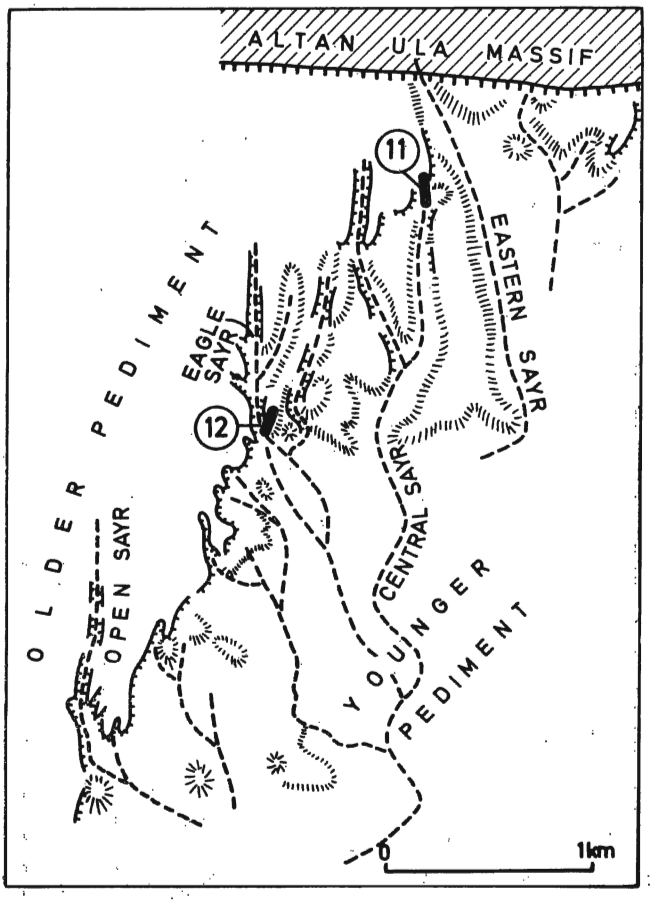

Fig. 7. Sketch-map of Altan Ula *IV* locality; symbols as in Text-fig. 2

Thickness: The total thickness of the formation was determined only by the spatial interpolation of the individual locality-sections (see Gradziński & Jerzykiewicz 1974a, p. 118); it is not less than 110 m.

Fossils: See Tables 2—4.

Age and correlation: The estimated age of the formation is ?middle Campanian; for correlation see below.

NEMEGT FORMATION

NAME

Derived from the Nemegt Massif.

GENERAL LITHOLOGY

The dominant lithology (Pl. 6, Fig. 1; Pls. 7—8) is poorly cemented light colored sands that vary from yellowish to grey-brown, and rarely red and orange. Numerous, but volumetrically less significant, are intercalations of sandy mudstones of red or olive color, sandstones, and intraformational conglomerates or gravels, composed of fine-grained rock fragments and/or reworked calcareous concretions. Fining-upwards cyclothems, 2—9 meters thick, with extensive erosional surfaces at their bases are distinctive for the whole formation. Inclined bedding, due to lateral accretionary development, and internal cross-laminations within the inclined beds are common. Erosional channels abound. The formation is characterized by great variability, both vertically and laterally.

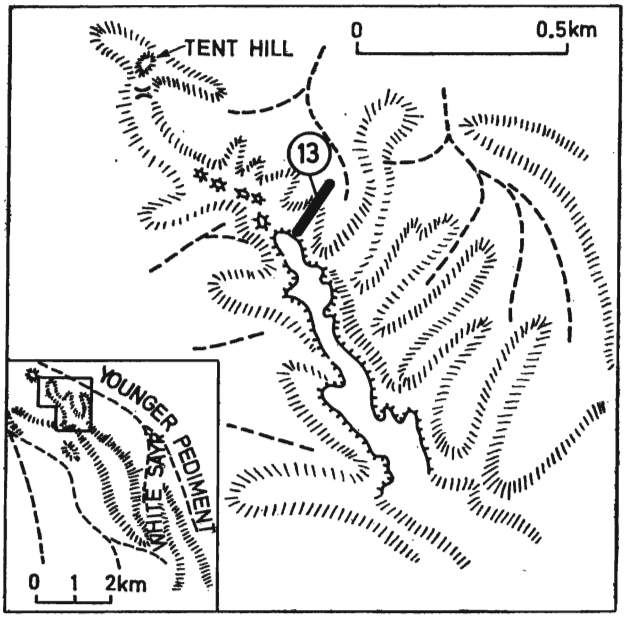

Fig. 8. Sketch-map of Tsagan Khushu locality; symbols as in Text-fig. 2

HISTORICAL BACKGROUND, SYNONYMY

The rock unit now known as the Nemegt Formation was described first by Efremov (1950, 1954), who used the names „fossiliferous series" and „subaqueous deltaic-channel deposits" without clearly definning

them. The „Upper Nemegt Beds" were named by Gradziński & al. (1969), but were redefined and emended by Gradziński & Jerzykiewicz (1974a, p. 116) as the Nemegt Formation.

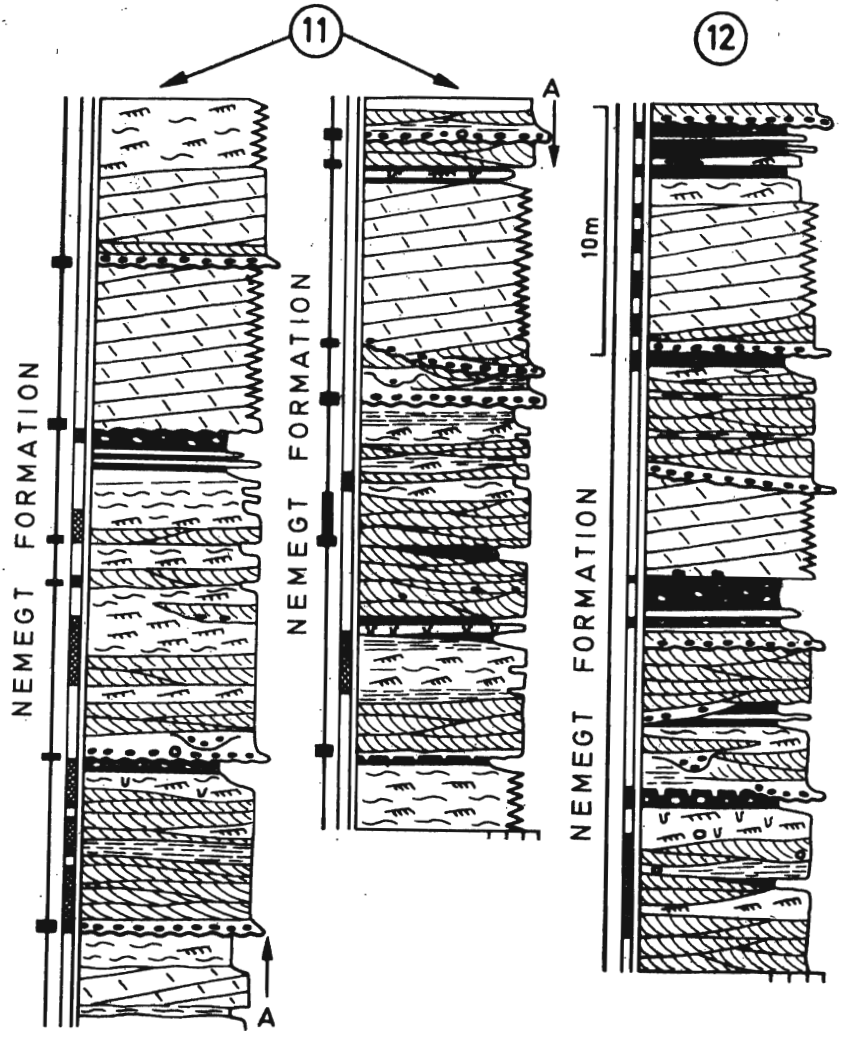

Fig. 9. Columnar sections of the Nemegt Formation at locality Altan Ula *IV* (**11** Central Sayr, N part; **12** Eagle Sayr). For placement of the sections see Text-fig. 7; symbols as in Text-figs 3 and 5

TYPE LOCALITY

North-western part of the Nemegt locality area (lat. 43°29′30″—43°32′N, long. 101°02′—101°03°30″E; for placement see Fig. 4, for columnar sections, see Fig. 6), about 15—20 km S of the central part of the Nemegt Massif.

REFERENCE LOCALITIES

1) Locality Altan Ula *IV* (lat. 43°34′—43°36′N, long. 100°26′—100°28′E; for placement see Fig. 7, and columnar sections, see Fig. 9).

2) Locality Tsagan Khushu (lat. 43°28′—43°29′20″N, long. 100°26′—100°23′30″E; for placement, see Fig. 8, and columnar section, see Fig. 10).

BOUNDARIES

The lower boundary of the unit can be seen only at the Nemegt locality (see section above on upper boundary of the Barun Goyot Formation, and Fig. 6). The upper boundary is marked by an erosional unconformity, above which are Paleocene deposits. The contact is exposed at localities Tsagan Khushu (SE part), Naran Bulak (W part),

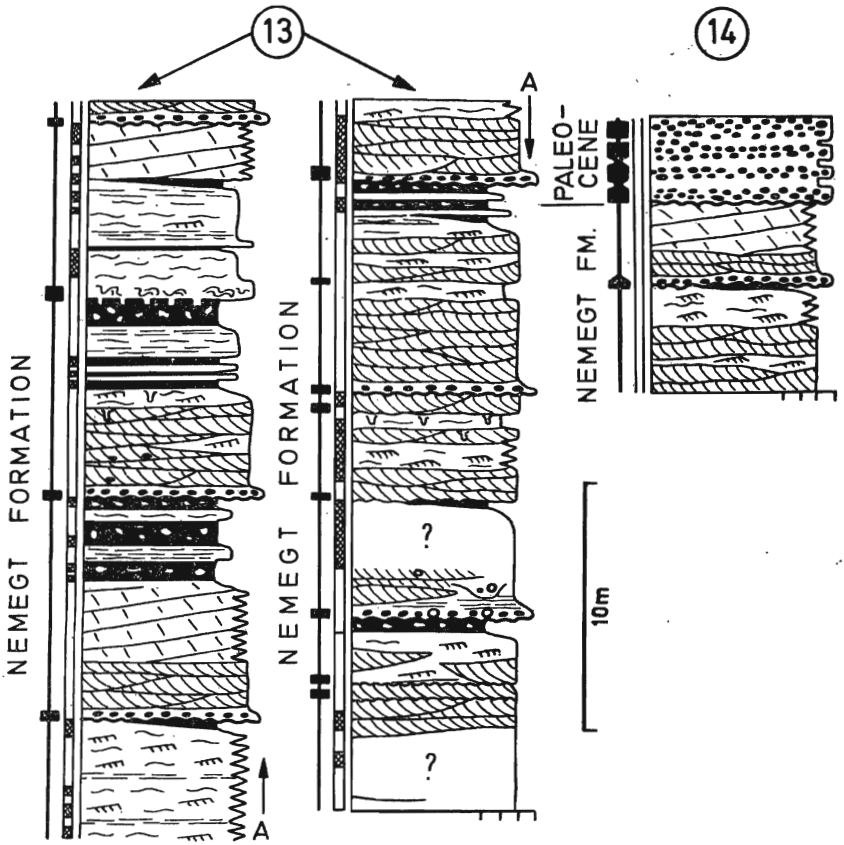

Fig. 10. Columnar sections of the Nemegt Formation (13 Tsagan Khushu locality; 14 upper-boundary stratotype at locality Naran Bulak, N part). For placement of the sections see Text-figs 8 and 11; symbols as in Text-figs 3 and 5

and Ulan Bulak (N part). The stratotype of the upper boundary is here placed at the Naran Bulak locality (see Figs. 10—11). Basal Paleocene rocks begin with a 2—5 m thick, pinkish-colored conglomerate layer that is overlain by red mudstones with subordinate intercalations of sand and gravel (Gradziński & al. 1969; Shishkin 1975).

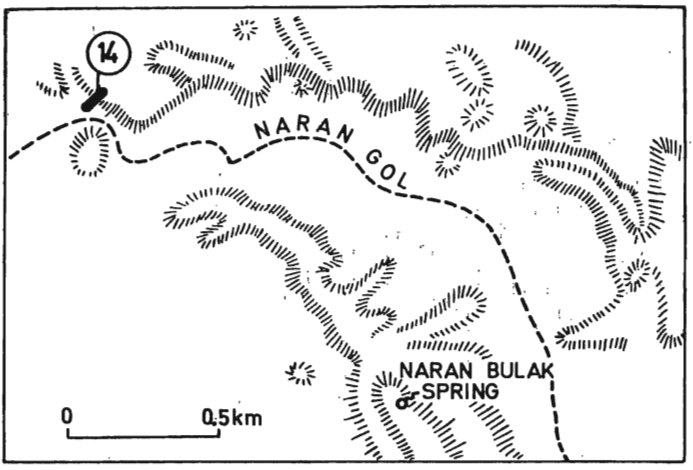

Fig. 11. Sketch-map of Naran Bulak locality; symbols as in Text-fig. 2

Thickness: The total thickness of the formation was determined only by the spatial interpolation of the individual locality-sections (see Gradziński 1970, pp. 156—157); it amounts to c. 400 m.
Fossils: see Tables 1—4.
Age and correlation: The estimated age of the formation is ?upper Campanian and ?lower Maastrichtian; for correlation see below.

SEDIMENTARY ENVIRONMENTS

Data useful to interpretation of the depositional environment of the Djadokhta Formation are the least complete for these rock units under study. It may be inferred from observations of Berkey & Morris (1927), Cayeux & Deviatkin (1969), Lefeld (1971), and Sochava (1975) that sedimentation took place in eolian dunes and, to some extent, in small lakes; there occurred some periods of caliche formation.

The geological history of the Barun Goyot Formation was interpreted by Gradziński & Jerzykiewicz (1974a, b) in terms of intertonguing and/or alternating eolian dune and interdune deposits, sediments of intermittent small lakes and streams, and deposits of playas.

The Nemegt Formation was built of alluvial plain deposits, with

the channel sediments dominating in preservation; rocks representing sedimentation in overbanks and flood-basin lakes are subordinate (Gradziński 1970).

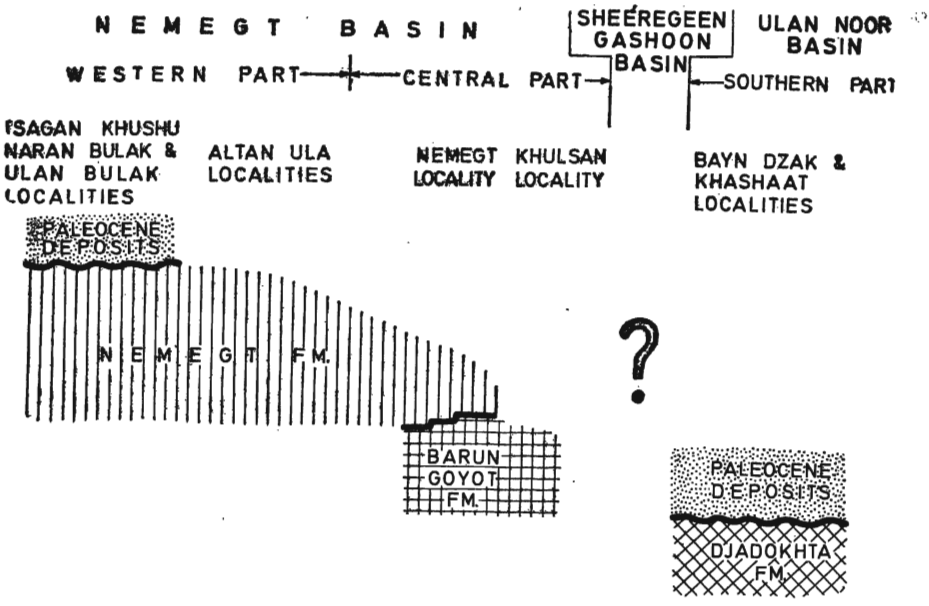

Fig. 12. Synthetic diagram (not to scale) showing distribution and relations between Upper Cretaceous formations in southern Mongolia

It may be concluded that the first two formations were deposited under conditions of hot and semi-arid climate, in areas lacking a permanent fluvial-drained system, while the Nemegt Formation had a typical fluviatile development.

REGIONAL ASPECTS

The Djadokhta Formation is known to be exposed only in a small area NE of the Bulgan settlement, in the localities of Bayn Dzak and Khashaat (N part; *cf.* Figs 1 and 12). It is presumed on palaeontological evidence *(see below)* to be roughly time-equivalent of deposits of the Toogreeg (Toogreegeen Shireh, Tugrikiin-Us) area and perhaps with deposits at the Alag Teg (Alag-Taag) localities (*cf.* Sochava 1975, p. 114; Shuvalov 1975, p. 106). It is important to note that the rocks at Toogreeg are distinctive because of very large-scale cross-laminations. Tverdochlebov & Tsybin (1974) attributed these sedimentary structures to deposition within the fronts of irregularly growing deltas entering into intermittent lakes. It is our opinion, however, that these structures are typical of eolian dune slipfaces.

The Barun Goyot Formation is exposed in the SE part of the Nemegt locality, in the Khulsan locality, and in several smaller localities as far as 20 km to NE. Its deposition was probably time-equivalent with sediments forming the red beds of the Khermeen Tsav I and II localities (see Gradziński & Jerzykiewicz 1972) [1].

The Nemegt Formation is exposed in the NE part of the Nemegt locality and in other localities farther to the W in the Nemegt Basin at Altan Ula *II*, Altan Ula *III*, Altan Ula *IV*, Tsagan Khushu, Naran Bulak (W and N part), Ulan Bulak (N part), and probably in the Altan Ula *I* locality, not yet investigated in detail. It is suggested herein that the formation also crops out toward the SW and NW from the Nemegt Basin, in the localities explored by Soviet and Mongolian geologists and paleontologists (e.g. upper white beds of Khermeen Tsav, see Gradziński & Jerzykiewicz 1972, and Sochava 1975; and Bugeen Tsav locality, see Tshudinov 1966, and Sochava 1975).

It is evident from the data gathered so far that the Paleocene Khashaat Formation directly overlies the Djadokhta Formation with an important time-break in the S part of the Ulan Noor Basin (*cf.* Figs 1 and 12). Paleocene deposits in the W part of the Nemegt Basin are underlain by the Nemegt Formation. An unconformity involving a lesser hiatus of time is suggested in this area by field observation (Gradziński & al. 1969, p. 37) and by the analysis of mapped contacts (see Gradziński 1970, Fig. 1, and p. 156). There are also other indications to the extent of erosion and to break in sedimentation near the end of Cretaceous in the wide distribution of horizons of pink conglomerates that were developed during the Paleocene (Gradziński & al. 1969; Shishkin 1975). It is also important that in the Paleocene deposits there are great quantities of poorly rounded gravels, quite different in petrographic composition from those occurring in the Nemegt Formation. These peculiar gravels were probably derived from a different source area early in Paleocene time.

SHEEREGEEN GASHOON BASIN

The Sheeregeen Gashoon Basin is situated near the center of the discussed area (*cf.* Figs 1 and 12) and its Cretaceous rocks are poorly known. They are lithologically strongly diversified (*cf.* Sochava 1975, and Shuvalov & Ckhikvadze 1975). Fossils from the Sheeregeen Gashoon

[1] The red beds of Khermeen Tsav *I* and *II* have been previously referred to (e.g. Kielan-Jaworowska 1974a) as Khermeen Tsav formation. It should be also explained that the localities designated Khermeen Tsav *I* and Khermeen Tsav *II* are recognized only within the area of occurrence of the red beds in Khermeen Tsav region, while the dinosaur bearing white beds of the same region are referred to as upper white beds of Khermeen Tsav, without further qualification.

Basin were excavated by members of various expeditions and were described by Konzhukova (1954), Maleev (1954), Barsbold (1972), Martinson (1975), Shuvalov & Ckhikvadze (1975), Maryańska & Osmólska 1975), and Maryańska (1977). No detailed maps of the basin have yet been published and the pinpointing of exposures known to yield fossils cannot be done.

On the basis of differentiation of described fossils one can conclude that the Sheeregeen Gashoon beds embrace diverse Cretaceous rocks, equivalent to various Upper Cretaceous stages. Further discussion is deferred until more data are available.

FOSSILS

The complete lists of fossils described from the three formations discussed (Djadokhta, Barun Goyot and Nemegt), as well as from other Upper Cretaceous beds of the same region (beds of Toogreeg, beds of Alag Teg, red beds of Khermeen Tsav *I* and *II*, upper white beds of Khermeen Tsav, and beds of Bugeen Tsav) are given in Tables 1—4. The probable biostratigraphic equivalency of these beds with those

Table 1

Charophytes from the Nemegt Formation

After: Karczewska & Ziembińska-Tworzydło 1970, and Kyansep-Romaschkina 1975

Species	N Nemegt Nemegt Fm.	Altan Ula Nemegt Fm.	Beds of Bugeen Tsav
CHAROPHYTES			
Tectochara gobica Karczewska & Ziembińska	+	+	
Harrisichara cretacea Karczewska & Ziembińska	+	+	
Tectochara altanulaensis Karczewska & Ziembińska	+	+	
Grambastichara sp.	+		
Saportanella nana Karczewska & Ziembińska	+	+	
Obtusochara madleri Peck	+		
Mesochara voluta (Peck) Karczewska & Ziembińska	+		
Aclistochara cf. *bransoni* Peck	+		
Sphaerochara verticillata Peck	+		
Maedleriella monilifera (Peck & Reker) Grambast	+		
Maedlerisphaera pseudoulmensis Karczewska & Ziembińska	+	+	
Mesochara mongolica Karczewska & Ziembińska	.	+	
Tectochara aurea Karczewska & Ziembińska	.	+	
Mongolichara deplanata Kyansep-Romaschkina	.	+	+
Mongolichara costulata Kyansep-Romaschkina	.	+	+
Mongolichara bugintsavica Kyansep-Romaschkina	.	+	+
Mesochara oviformis Kyansep-Romaschkina	.	+	+
Mesochara stankevitchii Kyansep-Romaschkina	.	+	+
Mesochara texensis (Groves) Kyansep-Romaschkina	.	+	+

Table 2

Invertebrates from the Barun Goyot and Nemegt formations, and some other Upper Cretaceous localities

After: Barsbold 1971, 1972; Dzik 1975; Khand 1974, 1976; Martinson 1975; Martinson & Kolesnikov 1974; Novojilov 1954b; Sochava 1975; Stankevitch & Sochava 1974; and Stankevitch & Khand 1976

Species	Beds of Toogreeg	Khulsan Barun Goyot Fm.	Red beds of Khermeen Tsav I	N Nemegt Nemegt Fm.	Altan Ula Nemegt Fm.	Tsagan Khushu Nemegt Fm.	Beds of Bugeen Tsav	Upper white beds of Khermeen Tsav
DIPLOPODS								
Gobiulus sabulosus Dzik	.	+						
OSTRACODES								
Gobiocypris tugrigensis Khand	+							
Ilyocypris proteus Khand	+							
Limnocythere ulannurensis Khand	+							
Limnocythere aspera Schneider	+							
Limnocythere proprius (Stankevitch)	+	.	.	.	.	.	+	
Limnocythere ingenicus (Stankevitch)	+	.	.	.	+	+	+	
Limnocythere barungoiotensis Khand	+	.	+					
Cypridea cavernosa Galeeva	.	.	+	+	+	.	+	
Eucypris? elata Stankevitch & Khand	.	.	+	+	+	.	+	
Cypridea obliquecostae Szczechura & Błaszyk	.	.	+	+				
Cypridea profusa Lubimova	.	.	+					
Cypridea ex gr. *fracta* Lubimova	.	.	+					
Cypridea ex gr. *rostrata* Galeeva	.	.	+					
Mongolianella cuspidigera Stankevitch	.	.	+	+	.	.	+	
Cypridea biformata Szczechura & Błaszyk	.	.	.	+	+	+	+	
Cypridea punctilataeformis Lubimova	.	.	.	+	+			
Cypridea sp. 1 Szczechura & Błaszyk, 1970	.	.	.	+				
Cypridea sp. 3 Szczechura & Błaszyk, 1970	.	.	.	+				
Candona altanulaensis Szczechura & Błaszyk	.	.	.	+	+	.	+	
Candoniella mordvilkoi Mandelstam	.	.	.	.	+			
Timiriasevia sp.	.	.	.	.	+			
Cypridea distributa Stankevitch	.	.	.	+	+	+	+	
Cypridea szczechurae Stankevitch	.	.	.	.	+	+	+	
Cypridea barsboldi Stankevitch	.	.	.	.	+	.	+	
Cypridea fracta Lubimova	.	.	.	.	+	.	+	
Mongolianella ex gr. *palmosa* Mandelstam	.	.	.	+	+	.	+	
Mongolianella khamariniensis Galeeva	.	.	.	+	.	.	+	
Lycopterocypris altanicus Stankevitch	.	.	.	.	+	.	+	
Lycopterocypris? bugintsavicus Stankevitch	.	.	.	.	+	.	+	
Timiriasevia minuscula Stankevitch	.	.	.	+	+	+	+	
Timiriasevia aff. *costata* Galeeva	.	.	.	.	.	.	+	
Timiriasevia polymorpha Mandelstam	.	.	.	.	+	.	+	
Timiriasevia? transitoria Stankevitch	.	.	.	+	.	.	+	
Palaeocytheridea ectypa Stankevitch	.	.	.	.	+	.	+	
PHYLLOPODS								
Trigonestheria perennis Novojilov	.	.	.	.	+			
Estheriina ulashandica Novojilov	.	.	.	.	+			
Pseudestheria nemegetica Novojilov	.	.	.	.	+			
Paleoleptestheria ichechongolica Novojilov	.	.	.	.	+			
Paleoleptestheria parmiformis Novojilov	.	.	.	.	+	+		
Notocrypta altissima Novojilov	.	.	.	.	.	+		
Rhombograpta rhombica Novojilov	.	.	.	.	+			
Liograpta danzani Novojilov	.	.	.	.	.	+		
Liograpta mongolica Novojilov	.	.	.	.	.	+		
Liograpta naranensis Novojilov	.	.	.	.	.	+		
GASTROPODS								
Mesolanites efremovi (Martinson)	.	.	.	+	+	+	+	
Mesolanites mongoliensis (Martinson)	.	.	.	+	.	+	+	
Mesolanites bajanchongorensis Barsbold	.	.	.	.	.	+	+	
Hydrobia nemegetica Martinson	.	.	.	+	.	+	+	
PELECYPODS								
Buginella buginica buginica Barsbold	.	.	.	.	.	.	+	
Buginella buginica gigantea Barsbold	.	.	.	.	+	.	+	
Buginella elongata Barsbold	.	.	.	.	.	.	+	
Buginella laevivalvata Barsbold	.	.	.	+	.	+		
Buginella autochtonica Barsbold	.	.	.	.	+	+	+	+
Pseudohyria buginzabica Martinson & Kolesnikov	.	.	.	.	+	+	+	
Pseudohyria posterior Barsbold	.	.	.	.	.	.	+	
Pseudohyria kozlovi (Barsbold)	.	.	.	+	.	+	+	
Pseudohyria debilicostata (Barsbold)	.	.	.	+	.	+	+	
Pseudohyria pseudoanadontoides (Martinson)	.	.	.	.	.	+	+	

of the Djadokhta, Barun Goyot and Nemegt formations is discussed below. The fossil eggs which occur in beds of three formations have not been so far identified and therefore are not included into the tables. In the Nemegt Formation commonly occurs fossilized wood, belonging to Araucariaceae, absent from beds of other two formations.

Table 3

Diverse vertebrates (dinosaurs and mammals excluded) from the Djadokhta, Barun Goyot and Nemegt formations, and some other Upper Cretaceous localities

After: Elżanowski 1974; Gilmore 1931, 1943; Konzhukova 1954; Khosatzky & Młynarski 1971; Młynarski 1972; Młynarski & Narmandakh 1972; Mook 1924; Osmólska 1972; Shuvalov & Ckhikvadze 1975; and Sulimski 1972, 1975.

Species	Bayn Dzak Djadokhta Fm.	Beds of Toogreeg	Beds of Alag Teg	Khulsan Barun Goyot Fm.	SE Nemegt Barun Goyot Fm.	Red beds of Khermeen Tsav I	Red beds of Khermeen Tsav II	N Nemegt Nemegt Fm.	Altan Ula Nemegt Fm.	Tsagan Khushu Nemegt Fm.	Beds of Bugeen Tsav	Upper white beds of Khermeen Tsav
BIRDS												
Gobipteryx minuta Elżanowski	.	.	.	+								
CROCODILES												
Schamosuchus djadochtaensis Mook	+											
Gobiosuchus kielanae Osmólska	+											
Paralligator ancestralis Konzhukova	.	.	.	.	.	.	.	+				
TURTLES												
Dermatemydidae indet.	+											
Zangerlia testudinimorpha Młynarski	.	.	.	+	+							
Mongolemys elegans Khosatzky & Młynarski	.	.	.	.	.	.	.	+	.	+	+	?+
Mongolemys sp.	.	.	.	.	.	.	.	+	.	+	.	+
Trionyx sp.	.	.	.	.	.	.	.	+	.	.	.	+
Trionyx sp. *a* Młynarski & Narmandach	.	.	.	.	.	.	.	+				
Trionyx sp. *b* Młynarski & Narmandach	.	.	.	.	.	.	.	+				
?*Zangerlia* sp.	.	.	.	.	.	.	.	+				
"*Neurankylus*" sp.	.	.	.	.	.	.	.	+	.	+	.	+
unidentified turtles	.	+	+	.	.	+	+	.	+			
LIZARDS AND OTHER SQUAMATES												
Adamisaurus magnidentatus Sulimski	+											
Conicodontosaurus djadochtaensis Gilmore	+											
Isodontosaurus gracilis Gilmore	+											
Macrocephalosaurus ferrugenous Gilmore	+											
Mimeosaurus crassus Gilmore	+											
Telmasaurus grangeri Gilmore	+											
Cherminsaurus kozlowskii Sulimski	.	.	.	.	.	+						
Darchansaurus estesi Sulimski	.	.	.	.	.	+						
Erdenetesaurus robinsonae Sulimski	.	.	.	.	.	.	+					
Macrocephalosaurus chulsanensis Sulimski	.	.	.	+	+							
Macrocephalosaurus gilmorei Sulimski	.	.	.	.	?+							
undescribed lizards belonging to various families	+	+	.	+	+	+	+					

It is interesting to note that the vertebrates are represented by different species assemblages in three formations; except *Deltatheridium pretrituberculare* (represented in the Djadokhta and Barun Goyot formations by different subspecies), no other species yet described has been found in common between any two formations.

Not all vertebrate fossil species known to occur in Upper Cretaceous rocks of the region have yet been described. Therefore, we do not designate formal biostratigraphic units. In the description that follow we only present index fossil assemblages for each formation.

Table 4

Mammals and dinosaurs from the Djadokhta, Barun Goyot and Nemegt formations, and some other Upper Cretaceous localities

After: Barsbold 1974, 1976a, b; Borsuk-Białynicka 1977; Gilmore 1933; Granger & Gregory 1923; Kielan-Jaworowska 1969, 1974a, 1975a, b, c; Maleev 1954, 1955a, b, 1956; Maryańska 1970, 1977; Maryańska & Osmólska 1974, 1975; Nowiński 1971; Osmólska 1976; Osmólska & Roniewicz 1970; Osmólska & al. 1972; Osborn 1924; and Rozhdestvensky 1957, 1965, 1971.

Species	Bayn Dzak Djadokhta Fm.	Beds of Toogreeg	Beds of Alag Teg	Khulsan Barun Goyot Fm.	SE Nemegt Barun Goyot Fm.	Red beds of Khermeen Tsav I	Red beds of Khermeen Tsav II	N Nemegt Nemegt Fm.	Altan Ula Nemegt Fm.	Tsagan Khushu Nemegt Fm.	Beds of Bugeen Tsav	Upper white beds of Khermeen Tsav
MAMMALS												
Gobibaatar parvus Kielan-Jaworowska	+											
Bulganbaatar nemegtbaataroides Kielan-Jaworowska	+											
Kryptobaatar dashzevegi Kielan-Jaworowska	+	+										
undescribed new eucosmodontid genus and species	+											
Catopsalis matthewi (Kielan-Jaworowska)	+											
Kamptobaatar kuczynskii Kielan-Jaworowska	+											
Sloanbaatar mirabilis Kielan-Jaworowska	+											
undescribed new genus and species	+											
Nyctheridium dobsoni Gregory & Simpson	+											
Deltatheroides cretacicus Gregory & Simpson	+											
Deltatheridium pretrituberculare pretrituberculare Gregory & Simpson	+											
Kennalestes gobiensis Kielan-Jaworowska	+											
Zalambdalestes lechei Gregory & Simpson	+											
Nemegtbaatar gobiensis Kielan-Jaworowska	.	.	.	+	+		+					
Catopsalis catopsaloides (Kielan-Jaworowska)	.	.	.	+	.	+	+					
undescribed poorly known new species of *Kamptobaatar* or a new genus	.	.	.	.	+							
Chulsanbaatar vulgaris Kielan-Jaworowska	.	.	.	+	+	.	+					
Deltatheridium pretrituberculare tardum Kielan-Jaworowska	.	.	.	+	+	.	+					
Asioryctes nemegetensis Kielan-Jaworowska	.	.	.	+	+	.	+					
Barunlestes butleri Kielan-Jaworowska	.	.	.	+	+	.	+					
DINOSAURS												
Velociraptor mongoliensis Osborn	+	+										
Saurornithoides mongoliensis Osborn	+											
Oviraptor philoceratops Osborn	+											
Carnosauria indet.	+	.	+									
Sauropoda indet.	+	.	+									
Protoceratops andrewsi Granger & Gregory	+	+	+									
Pinacosaurus grangeri Gilmore	+	.	+									
Hadrosauridae indet.	+											
Velociraptor sp.	.	.	.	+	.	+	+					
Oviraptor sp.	.	.	.	+	+	+	+					
small unidentified theropods	.	.	.	+	+	.	.					
Carnosauria indet.	.	.	.	+	.	+	+					
Sauropoda indet.	.	.	.	+	.	.	.					
?Protoceratops kozlowskii Maryańska & Osmólska	.	.	.	+	.	.	.					
Bagaceratops rozhdestvenskyi Maryańska & Osmólska	.	.	.	.	.	+	+					
Tylocephale gilmorei Maryańska & Osmólska	.	.	.	+	.	.	.					
Saichania chulsanensis Maryańska	.	.	.	+	.	.	.					
Tarchia kielanae Maryańska	.	.	.	+	.	+	+					
Tarbosaurus bataar (Maleev)	.	.	.	.	.	.	.	+	+	?	+	+
Gorgosaurus novojilovi Maleev	.	.	.	.	.	.	.	+	.	?	.	
Therizinosaurus cheloniformis Maleev	.	.	.	.	.	.	.	+	+	.	.	+
Deinocheirus mirificus Osmólska & Roniewicz	.	.	.	.	.	.	.	.	+			
Saurornithoides junior Barsbold	.	.	.	.	.	.	.	.	.	.	+	
Oviraptor sp.	.	.	.	.	.	.	.	+				
Gallimimus bullatus Osmólska, Roniewicz & Barsbold	.	.	.	.	.	.	.	+	+	+		
Nemegtosaurus mongoliensis Nowiński	.	.	.	.	.	.	.	+				
Opisthocoelicaudia skarzynskii Borsuk-Białynicka	.	.	.	.	.	.	.	.	+			
Theropoda indet.	.	.	.	.	.	.	.	+	+	+	.	+
Saurolophus angustirostris Rozhdestvensky	.	.	.	.	.	.	.	+	+	+	?	+
Hadrosauridae indet.	.	.	.	.	.	.	.	+				
Prenocephale prenes Maryańska & Osmólska	.	.	.	.	.	.	.	+				
Homalocephale calathocercos Maryańska & Osmólska	.	.	.	.	.	.	.	+				
"Dyoplosaurus" giganteus (Maleev)	.	.	.	.	.	.	.	+	+	.	?	+

DJADOKHTA FORMATION

Index fossil assemblage: **Kryptobaatar dashzevegi, Catopsalis matthewi, Kennalestes gobiensis, Zalambdalestes lechei, Protoceratops andrewsi,** and **Pinacosaurus grangeri.**

All vertebrates known from Toogreeg and Alag Teg (Table 4) are also known from Bayn Dzak (Djadokhta Fm.), but the ostracodes known from Toogreeg have not yet been discovered at Bayn Dzak. Nevertheless, on the basis of similar assemblages of vertebrates (less abundant at Toogreeg and Alag Teg than at Bayn Dzak), the Toogreeg and Alag Teg beds are biostratigraphic equivalents of the Djadokhta Formation.

BARUN GOYOT FORMATION

Index fossil assemblage: **Nemegtbaatar gobiensis, Catopsalis catopsaloides, Asioryctes nemegetensis, Barunlestes butleri, ?Protoceratops kozlowskii, Saichania chulsanensis, Macrocephalosaurus chulsanensis,** and **Macrocephalosaurus gilmorei.**

Most species of vertebrates found in the red beds of Khermeen Tsav *I* and *II* (Tables 3 and 4) also occur either at SE part of Nemegt or in Khulsan in beds of the Barun Goyot Formation. The only exceptions are *Bagaceratops rozhdestvenskyi* and some lizards found at Khermeen Tsav *I* and/or Khermeen Tsav *II* that are not yet known at Khulsan or SE Nemegt. The red beds of Khermeen Tsav *I* and *II* are therefore biostratigraphic equivalents of the Barun Goyot Formation.

NEMEGT FORMATION

Index fossil assemblage: **Tarbosaurus bataar, Gallimimus bullatus, Saurolophus angustirostris, „Dyoplosaurus" giganteus, Mesolanites efremovi,** and **Mesolanites mongoliensis.**

On the basis of the fossil content (*cf.* Table 4), it seems completely justified to regard the beds of Bugeen Tsav and the upper white beds of Khermeen Tsav as biostratigraphic equivalents of the Nemegt Formation. The data on the vertebrate assemblages of the beds at Bugeen Tsav are from preliminary information provided by Tshudinov (1966).

ESTIMATED AGES

When discussing ages of the Djadokhta, Barun Goyot and Nemegt formations we will also consider the ages of their probable equivalents (i.e. beds of Toogreeg and Alag Teg, red beds of Khermeen Tsav, beds of Bugeen Tsav and white beds of Khermeen Tsav).

There are not radiometric age data available and the localities are exclusively of continental origin. All fossils discovered so far are endemic at the specific level, and most of them at the generic level. In this situation, evaluation of formational ages as based up on „stages of evolution" of vertebrate or invertebrate assemblages, or

upon correlation with European or North American fossil range zones must be regarded as tentative. Therefore, in our estimations of the ages of the discussed formations, a query prefaces all presumed ages.

COMPARISONS OF LATE CRETACEOUS DINOSAURS FROM MONGOLIA AND NORTH AMERICA

Comparison of known Late Cretaceous dinosaur faunas of Mongolia and North America does not cast much light upon the ages of the Mongolian formations discussed herein. Part of the problem is that only a small percentage of the Asiatic dinosaur species has been compared directly and in detail.

A list of dinosaur species known from selected localities (Table 4) shows that representatives of the following families were found in common between Mongolia and North America: Tyrannosauridae, Dromeosauridae (including parts of Troodontidae of Russell 1969, Saurornithoididae of Barsbold 1974, and Oviraptoridae of Barsbold 1976a), Ornithomimidae, Atlantosauridae, Camarasauridae, Protoceratopsidae, Pachycephalosauridae, Ankylosauridae and Hadrosauridae. Only two families, the Deinocheiridae and Therizinosauridae, are endemic to Asia. Some families that are commonly represented in Upper Cretaceous rocks of North America are as yet unknown from Asia; these include the Hypsilophodontidae, Ceratopsidae, Pachyrhinosauridae and Panoplosauridae (referred to as Nodosauridae by Coombs 1974). The absence of ceratopsids and some ankylosaurs in Mongolia may have been a result of differences in environmental conditions between North America and Asia (Maryańska & Osmólska 1975). The Hadrosauridae, strongly diversified in the Upper Cretaceous beds of North America, are represented in Mongolia by only one genus, *Saurolophus*. This is the only known Late Cretaceous dinosaur genus common to Mongolia and North America. In spite of these important faunal differences, some comparisons can be made between Upper Cretaceous dinosaur assemblages of Mongolia with those of North America found in rocks correlated with the Campanian and Maastrichtian stages of Europe.

According to Rozhdestvensky, the fauna of the Djadokhta Formation is contemporaneous with those of the upper part of Niobara Formation and the Belly River Formation (Rozhdestvensky 1971) or with the fauna of Belly River Formation (Rozhdestvensky 1974) and is correlated with the upper Santonian and Campanian of Europe. The Nemegt Formation according to Rozhdestvensky (1971, 1974) is contemporaneous with the lower part of the Edmonton Formation (this part being referred by him to the whole Edmonton Fm.) which corresponds to the Maastrichtian stage. Uppermost Maastrichtian (or Danian) sediments are, according to him, unknown in Mongolia.

According to Maryańska & Osmólska (1975) and Maryańska (1977), analysis of the protoceratopsid and ankylosaurid faunas occurring in the Djadokhta Formation indicates that their enclosing rocks are older than Two Medicine Formation of Alberta and Montana that has yielded *Leptoceratops* and *Euoplocephalus*.

Rozhdestvensky's conclusion (1971 and 1974) on the age of the Nemegt was based upon the comparison of *Saurolophus angustirostris* with *S. osborni*, the latter of which occurs in the lower part of the Edmonton Formation. Rozhdestvensky (1965) concluded that *S. angustirostris* was more advanced than *S. osborni*. Rozhdestvensky (1965) also compared *Tarbosaurus bataar* with *Tyrannosaurus rex* (which occurs in the upper part of the Edmonton Formation and its equivalents) and concluded that *Tarbosaurus bataar* is more primitive than *Tyrannosaurus rex*.

Maleev (1955a, b) named and described four species of tyrannosaurids, assigned to three genera, from localities at Nemegt and Altan Ula (both assigned in the present paper to the Nemegt Formation). These are: *Tyrannosaurus bataar, Tarbosaurus efremovi, Gorgosaurus lancinator,* and *Gorgosaurus novojilovi*. Rozhdestvensky (1965) considered all of these to be conspecific, and assigned them to *Tarbosaurus bataar*. It is our belief that the unification of all of Maleev's species with *Tarbosaurus bataar* is not justified. The specimen of *G. novojilovi* illustrated in the posthumous paper by Maleev (1974), appears to be significantly different from equivalent parts of *T. bataar* (= *T. efremovi*). The left foot of *T. efremovi* (see Maleev 1974, Fig. 43) differs from that of *G. novojilovi* (see Maleev, 1974, Fig. 62) in having a relatively larger matatarsal *3*. If one accepts Rozhdestvensky's (1965) interpretation that *G. novojilovi* represents a young individual of *T. bataar*, one must also accept the idea that young individuals had relatively more strongly reduced third metatarsal than adults.

Kurzanov (1976) described *Alioramus remotus*, as a new species of tyrannosaurid from a locality at Nogon Tsav (possibly contemporaneous with the Nemegt Fm.). It is likely that the Asiatic tyrannosaurid fauna was, at the time of deposition of the Nemegt Formation, taxonomically more diversified than has been accepted by Rozhdestvensky (1965). Future comparisons of tyrannosaurid material from the Nemegt Formation (and its equivalents) in Mongolia with tyrannosaurids of Campanian and Maastrichtian formations in North America may cast more light on the age of the Nemegt Formation.

The other theropod families known from the Nemegt Formation: Saurornithoididae and Oviraptoridae (see Barsbold 1974, 1976a), do not help much in dating this rock unit. The genus *Saurornithoides*, which is represented in the rocks of Bugeen Tsav (probable age equivalent

of the Nemegt Fm.) by *S. junior* (see Barbold 1974), is also known from the Djadokhta Formation *(S. mongoliensis).* The genus is very similar to *Stenonychosaurus,* known from the Belly River and Oldman Formations of North America. However, on the basis of known skeletal material, the question of possible congenerity cannot be unequivocally answered. Species of *Oviraptor,* which occur in all three Mongolian formations discussed herein, show similarities with *Coenagnathus,* occurring in the Oldman Formation. According to Osmólska (1976), *Oviraptor* and *Coenagnathus* should be assigned to the same family Coenagnathidae, while Barsbold (1976a) split *Oviraptor* to a separate family Oviraptoridae.

Comparisons must also be made among the ornithischian dinosaurs. The ankylosaurid *Dyoplosaurus* has been cited as a representative common between Asia and North America during the Late Cretaceous. It appears from study of new materials from Mongolia (Maryańska 1977), however, that *Dyoplosaurus* reported by Maleev (1956) and Maryańska (1970) from the Nemegt Formation is not congeneric with North American type material from the Belly River and Two Medicine formations. Other ankylosaurid genera from the Djadokhta Formation *(Pinacosaurus)* and from Barun Goyot Formation *(Saichania* and *Tarchia)* differ markedly from those known to occur in North American strata correlated with Campanian and Maastrichtian stages (Maryańska 1977).

The Protoceratopsidae are represented in Mongolia by three genera: *Protoceratops* (Djadokhta and Barun Goyot formations), *Bagaceratops* (red beds of Khermeen Tsav, probable age equivalent to Barun Goyot Fm.), and *Microceratops* (beds of Sheeregeen Gashoon, that are older according to Maryańska & Osmólska 1975, than the rocks of the Djadokhta Fm.). The North American protoceratopsids *Leptoceratops* and *Montanoceratops* are structurally very different from the known Mongolian forms (Maryańska & Osmólska 1975). Similarly Mongolian and North American Pachycephalosauridae are represented by different genera (Maryańska & Osmólska 1974).

Unfortunately, comparisons completed to date of Late Cretaceous dinosaurs from Mongolia and North America do not significantly aid in recognition of detailed ages of Djadokhta, Barun Goyot and Nemegt formations.

COMPARISONS OF LATE CRETACEOUS MAMMALS FROM MONGOLIA AND NORTH AMERICA

The marsupials which are important elements of practically all adequately known North American Late Cretaceous faunas (see Fox 1971, 1972a; Clemens 1966; Sloan & Van Valen 1965; Lillegraven 1969),

are unknown from rocks of Late Cretaceous age in Asia. Although Deltatheridiidae of the Djadokhta and Barun Goyot formations possess some similarities in dental formula with the marsupials, they are regarded as Theria of metatherian-eutherian grade (*cf.* Butler & Kielan-Jaworowska 1973; Kielan-Jaworowska 1975b).

Triconodonta and Symmetrodonta, known to occur in the Upper Cretaceous strata of the Milk River Formation in Alberta, Canada (Fox 1972a, b) have not been found in Upper Cretaceous rocks of Asia. Eutherian mammals are first known from rocks of Early Cretaceous (?Albian) age at Khovboor, Mongolia (Beliajeva & al. 1974) and are present in the Djadokhta and Barun Goyot formations. They first appear (in form of a single upper molar) in the fossil record of North America in the Milk River Formation, correlated with the lower Campanian stage (Fox 1970). Eutherian mammals are extremely rare in rocks equivalent to the Campanian stage in North America and the therian faunas are dominated by marsupials. The oldest named North American eutherian genus *Gypsonictops* appears in the Judith River Formation (Sahni 1972) that is correlated with the middle Campanian stage. Relationships between the oldest known North American palaeoryctid *(Cimolestes,* which made its appearance during the Maastrichtian) and the Mongolian palaeoryctid *Asioryctes* are not clear (Kielan-Jaworowska 1975a). All other known Asian eutherian mammals belong to the Zalambdalestidae, which were apparently endemic.

The most commonly found group of mammals in the Upper Cretaceous rocks of Mongolia and North America is the Multituberculata. Most genera from the two continents, however, belong to different families. According to work in preparation by Clemens & Kielan-Jaworowska, *Gobibaatar* from Asia and *Cimexomys* from North America should be removed from the Neoplagiaulacidae and considered for the time being with a status of *incertae sedis.* Such an action eliminates the record of the neoplagiaulacids from Asia, although members of this family were common during the Late Cretaceous in North America. Two other Late Cretaceous families, that were apparently endemic to North America were the Ptilodontidae and the Cimolomyidae. The Chulsanbaataridae and Sloanbaataridae seem to have been endemic to Asia. The only families known to have been common to the two regions are the Eucosmodontidae and Taeniolabididae. The Asian Late Cretaceous representatives of both families are, as demonstrated by Kielan-Jaworowska (1974b), more primitive than the earliest known representatives of either family in North America. The oldest known North American taeniolabidid is *Catopsalis joyneri* from the Bug Creek Formation (Maastrichtian stage). Kielan-Jaworowska & Sloan *(in press)* demonstrated that *Djadochtatherium* (from Mongolia) and *Catopsalis* (from North America) are congeneric, with the former name thus

being a junior synonym. The genus *Catopsalis* is the only Late Cretaceous mammalian genus known to be common to two continents.

A likely evolutionary sequence of *Catopsalis matthewi* (a primitive species from the Djadokhta Fm.) to more specialized North American species has been suggested by Kielan-Jaworowska & Sloan *(in press)*. They concluded that the Djadokhta and the Barun Goyot formations (yielding *C. matthewi* and *C. catopsaloides* respectively) are older than the Hell Creek Formation (with *C. joyneri*), but the ages cannot be shown on this basis in terms of real time. The evolution of the multituberculate family Eucosmodontidae cannot be followed in such detail. The oldest described North American specimen that could be a eucosmodontid is a single upper molar, identified as *Stygimys* sp. by Lillegraven (1972) from „El Gallo Formation", probably correlating with the late Campanian stage. Relationships between eucosmodontids from the Barun Goyot Formation and *Stygimys* sp. from „El Gallo Formation" are uncertain. Thus comparisons of Late Cretaceous mammalian faunas of Asia and North America do not allow unequivocal evaluation of ages of the Djadokhta, Barun Goyot or Nemegt formations.

RELATIONSHIP OF DJADOKHTA FORMATION TO BARUN GOYOT FORMATION

No physical contact between the Djadokhta and Barun Goyot formations has yet been discovered. The studies of mammals (Kielan-Jaworowska 1969, 1970, 1974a, 1975a, b) and dinosaurs (Maryańska & Osmólska 1975, Maryańska 1977) suggest that the Djadokhta Formation is older than the Barun Goyot Formation.

The species *Catopsalis matthewi* from the Djadokhta Formation may be regarded as a close ancestor of *C. catopsaloides* from the Barun Goyot Formation. The species *Deltatheridium pretrituberculare* differs only at the subspecific level from the form in the Barun Goyot Formation. The species *Zalambdalestes lechei* from the Djadokhta Formation was probably ancestral to *Barunlestes butleri* from the Barun Goyot Formation, whereas *Velociraptor* sp. from the Barun Goyot Formation was similar to *V. mongoliensis* from the Djadokhta Formation (personal information from Dr. H. Osmólska). The genera *Protoceratops* and *Oviraptor* occur in both formations but are represented in each by markedly different species. The species *P. andrewsi* from the Djadokhta Formation, however, may be regarded a likely ancestor of *?P. kozlowskii* from the Barun Goyot Formation (see Maryańska & Osmólska 1975, and Osmólska 1976). Of the few lizards described to date that occur in both rock units, *Macrocephalosaurus gilmorei* of the Djadokhta Formation is closely similar to *M. ferrungenous* of the Barun Goyot Formation (Sulimski 1975).

Sediment types between the two formations are quite distinct, with no intermediate lithofacies yet recognized. The above faunal comparisons, however, suggest that any time gap between rocks representing the Djadokhta and Barun Goyot formations was not of long duration.

SUMMARY OF AGE DATA

Comparative studies of dinosaurs suggest that the Nemegt Formation is probably older than the Lance Formation of North America (see Rozhdestvensky 1971, 1974 and Osmólska & al. 1972), and as an approximation may embrace not only the lower Maastrichtian, but also the upper parts of Campanian stage. The probable absence of rocks representing the uppermost parts of the Maastrichtian stage at the top of Nemegt Formation is supported by the presence of marked unconformities. The freshwater pelecypods and gastropods, occurring in the Nemegt Formation are, according to Barsbold (1972) and Martinson (1975), characteristic of the Maastrichtian stage. According to Karczewska & Ziembińska (1970) and Kyansep-Romaschkina (1975), however, the charophytes suggest Campanian-Maastrichtian equivalency for the Nemegt Formation.

The Barun Goyot Formation is probably an equivalent of the Campanian, and differentiation of the multituberculates (see Kielan-Jaworowska 1974a) suggests again an estimated equivalency with middle part of the stage. Comparative studies of dinosaurs and mamals (see preceding section) suggest that the Djadokhta Formation is older than the Barun Goyot Formation.

The deposits at Bayn Dzak (Djadokhta Fm. of the present paper) are included by Soviet geologists within the *barungoyotskaya svita* (cf. Martinson 1975, Sochava 1975; and this paper below). In southeastern Mongolia, the rocks mapped as *barungoyotskaya svita* are underlain by the *bainshireinskaya svita*. The age of the latter svita has been estimated on the basis of freshwater mollusks as corresponding to the upper part of the Cenomanian and lower part of Santonian. The gastropod and pelecypod faunas of the *bainshireinskaya svita* have been compared with similar species of the Fergana and Aral regions of USSR, where fossil-bearing Cretaceous rocks are interbedded with Coniacian-Santonian marine strata (see Martinson 1975, Martinson & Kolesnikov 1974). Thus it is possible, but far from proven, that the Djadokhta Formation embraces the lower part of the Campanian stage, and perhaps the upper part of the Santonian as well. One is not certain, however, as to what extent correlation on the basis of freshwater mollusks can be considered reliable.

It follows from the foregoing discussion that as „best guesses" the estimated stages are: Djadokhta Formation — ?upper Santonian and/or ?lower Campanian; Barun Goyot Formation — ?middle Campanian; Nemegt Formation — ?upper Campanian and ?lower Maastrichtian. It is a difficult problem and it is hoped that new techniques of dating sedimentary rocks may help in future in estimation of the ages.

DISCUSSION

Soviet and Mongolian geologists generally use a nomenclature in which the fundamental stratigraphic unit is „svita". Svita belongs to a category of local stratigraphic subdivisions accepted by the Soviet system of stratigraphic classification (see Zhamoida & al. 1970, 1972). Unfortunately this category does not have an equivalent in the system utilized in the International Subcomission on Stratigraphic Classification (*cf.* Hedberg 1972, 1976). One of the features of a sivta is that the lower as well as the upper boundaries are considered to be isochronous throught the total extent of this unit. Therefore, svita is a temporal concept, not a lithostratigraphic unit (see Zhamoida & al. 1972, p. 16). Lithostratigraphic units of the Soviet classification are represented by another set of terms. The point has not generally been known to most authors, and the confusion that has resulted from considering „svita" and „formation" as more or less synonymous should be unravelled.

Division of the Upper Cretaceous deposits of Mongolia into svitas was recently done by the members of the Soviet-Mongolian Geological Expeditions (see Martinson 1975) and the dating was mainly on the basis of freshwater mollusks. Martinson (1975, Table 1) distinguishes *sainshandinskaya svita* (Lower Cenomanian), *bainshireinskaya svita* (Upper Cenomanian — Lower Santonian), *barungoyotskaya svita* (Upper Santonian — Companian), and *nemegetinskaya svita* (Maastrichtian).

The two first svitas were distinguished in southwestern Mongolia (*cf.* Marinov 1957; Vasiliev & al. 1959; Marinov & al. 1973). The other two were defined by Martinson & al. (1969) at the section of the Nemegt locality. Short diagnoses given by Martinson & al. (1969, Table 2) suggest that the *barungoyotskaya svita* and *nemegetinskaya svita* correspond, respectively, to the Lower Nemegt Beds and the Upper Nemegt Beds established earlier by Gradziński & al. (1969). The latter two lithostratigraphic units had, in fact, the status of formations (Gradziński 1970, p. 154). In the year 1969 the concepts of the *barungoyotskaya* and *nemegetinskaya svita* were similar to the concepts of the Lower and Upper Nemegt Beds respectively. For this reasons Gradziński & Jerzykiewicz (1974) accepted the geographical name „Ne-

megt" and „Barun Goyot" by the redefinition of these two lithostratigraphic units. As the both svitas were extended by subsequent authors away from stratotypes their concepts were practically changed. Therefore it is clear recently, that the mentioned svitas and formations cannot be treated as equivalents.

A review of the general principles underlying these categories is beyond the scope of the present paper; they have already been discussed by others (*e.g.* Keller 1950; Menner 1962; Sadykov 1974; O'Rourke 1976). However, we believe it necessary to discuss some specific problems arising from the use of these categories for Upper Cretaceous rocks of southern Mongolia.

The three formations described in the present paper clearly differ by lithology and fossil content, and these characters allow the recognition of the units away from their type and reference localities. It should be stressed that in southern Mongolia and/or neighboring regions there undoubtedly occur deposits entirely or partly coeval with the formations mentioned above, but which would be defined as quite different ones.

The lithologically-based formations as diagnosed in this paper have a limited areal extent. The svitas distinguished in the same region are considered to be valid over the whole area of occurrence of time-equivalent parts of deposits of Late Cretaceous age in Mongolia (e.g. Martinson 1975, Table 1; Martinson & Shuvalov 1975, p. 228), and each svita is considered both as a time unit and as a sedimentary unit deposited during that specific time. In practice, however, authors accepting the svita concept disagree in several respects on identification of beds cropping out at particular localities and assign them to different svitas.

As an example of the problems one could discuss the extent of the *barungoyotskaya svita*. Martinson & al. (1969) established the *barungoyotskaya svita* and the overlying *nemegetinskaya svita* on the basis of the section at the Nemegt locality. The age of the first svita was determined as Campanian, and the age of the second one as Campanian-Maastrichtian. In the year 1969 only fragments of dinosaur eggs were known from the *barungoyotskaya svita*. Martinson & Kolesnikov (1974, p. 236) described the assemblages of mollusks characteristic of the Mongolian Upper Cretaceous svitas. Sochava (1975) included to the *barungoyotskaya svita* the major part of the deposits exposed at localities: Altan Ula *II* (erroneously referred by him as Altan Ula *I;* cf. Gradziński & al. 1969, pp. 35—36), Altan Ula *IV*, Tsagan Khushu and Bugeen Tsav. These deposits, however, differ significantly in lithology from those of the *barungoyotskaya svita* at its stratoype (i.e. Nemegt locality), but show no differences in lithology and fossil assemblage from the *nemegetinskaya svita*.

Martinson (1975, p. 23) further stated that the members of the Polish-Mongolian Paleontological Expeditions found skeletons of *Protoceratops andrewsi*, dinosaur eggs and mammals (previously known only from Bayn Dzak) in deposits of the *barungoyotskaya svita* at Nemegt. Therefore, this author regarded the deposits cropping out at Nemegt (*i.e.* SE Nemegt locality) and at Bayn Dzak as contemporaneous (*cf.* Sukhanov & Narmandakh 1975, p. 94) and attributed them to the *barungoyotskaya svita*. In fact, protoceratopsid remains were found by the Polish-Mongolian Expeditions at Khulsan in the Nemegt Basin but not in the Nemegt locality. They belong to *?Protoceratops kozlowskii*, and *P. andrewsi* has not been found in these deposits (see Maryańska & Osmólska 1975 and Table 4). Also all but one of mammals found at Khulsan and SE Nemegt localities belong to different genera than those from Bayn Dzak (see Kielan-Jaworowska 1974a, 1975a, b, and Table 4).

The deposits exposed in the Bayn Dzak area (*i.e.* Djadokhta Fm. of this paper) were attributed by Shuvalov (1975) to the *barungoyotskaya svita*, and by Sochava (1975) partly to this svita and partly to the *nemegetinskaya svita*. On the other hand, Barsbold (1972, Table 1) and Khand (1974, p. 265) reffered these deposits to the *„bayndzakskaya svita"*.

Thus, the division into svitas of the Upper Cretaceous rocks discussed herein leads to controversial and subjectively based opinions on stratigraphic position of deposits in particular localities. We hope that acceptance of a lithostratigraphically-based division will provide a more objective and practically useful approach to the solution of the complex problems of the Upper Cretaceous stratigraphy in this most important region.

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* Abbreviations used: *Results PMPE* — Results of the Polish Mongolian Paleontological Expeditions; *JSMSGE* — The Joint Soviet-Mongolian Scientific-Research Geological Expeditions; *JSMPE* — The Joint Soviet-Mongolian Paleontological Expedition.

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FORMACJE DŻADOCHTA, BARUN GOJOT I NEMEGT W GÓRNEJ KREDZIE MONGOLII

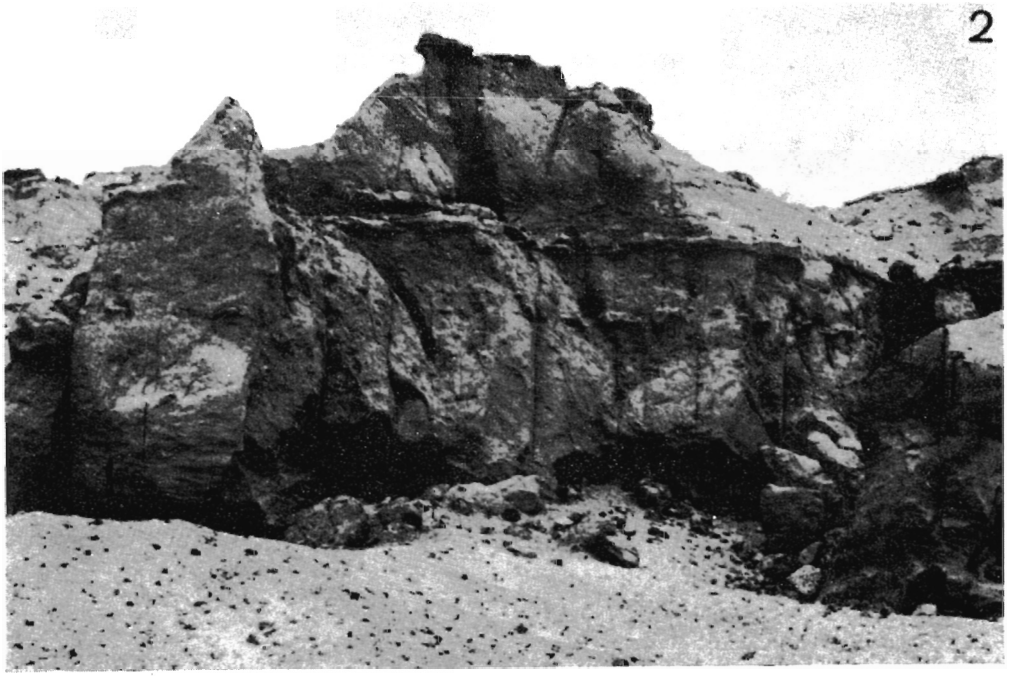
(Streszczenie)

Przedmiotem pracy jest analiza trzech górnokredowych formacji południowej Mongolii: Dżadochta, Barun Gojot oraz Nemegt. Przedstawiono profile litologicznie typowych stanowisk tych formacji, oraz szeregu stanowisk pomocniczych (patrz fig. 1—12 oraz pl. 1—8). Zestawiono też listy gatunków dotychczas opisanych z rozważanych formacji, oraz z osadów, które na podstawie składu faunistycznego można uznać za równowiekowe z tymi formacjami (tab. 1—4). Wykazano, że omawiane formacje stanowią jednostki różniące się zarówno litologią, jak i składem fauny i flory. Wśród kręgowców dotychczas opisanych z tych formacji nie stwierdzono gatunków wspólnych; jedyny wyjątek stanowi ssak *Deltatheridium pretrituberculare*, występujący w formacji Dżadochta i Barun Gojot, w których jest on jednakże reprezentowany przez różne podgatunki.

Wykazano, że fauny dinozaurów i ssaków górno-kredowych Azji oraz Ameryki Północnej reprezentowane są w większości przez różne rodzaje. Jedyne z dotychczas opisanych rodzajów wspólne dla obu kontynentów, to hadrozaur *Saurolophus* oraz multituberkulat *Catopsalis*. Kilka rodzin dinozaurów i ssaków jest endemicznych dla Azji, bądź dla Ameryki Północnej.

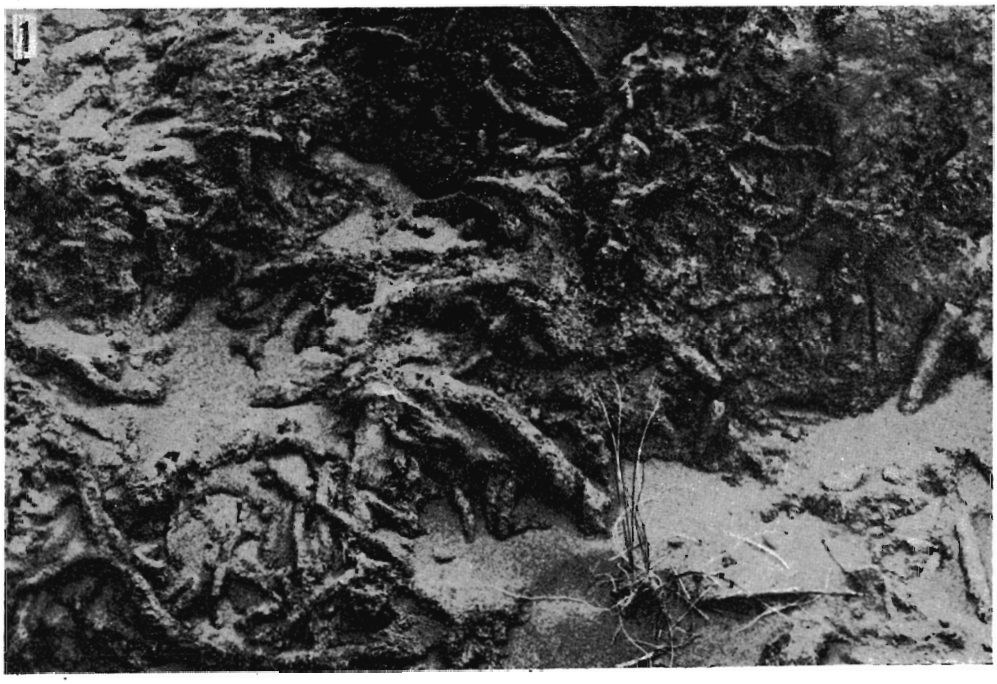
Wiek dyskutowanych formacji ustalono z wielkim przybliżeniem na: ?górny santon i/lub ?dolny kampan dla formacji Dżadochta, ?środkowy kampan dla formacji Barun Gojot, oraz ?górny kampan i ?dolny mastrycht dla formacji Nemegt.

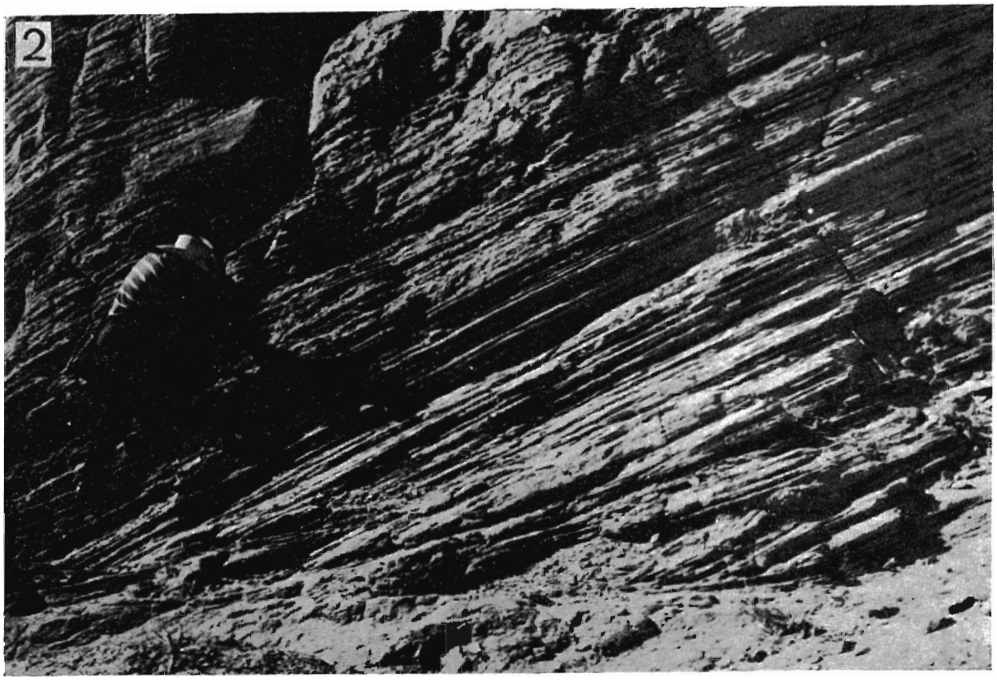
Autorzy uważają, że wprowadzenie na badanym obszarze podziału litostratygraficznego może w przyszłości doprowadzić do rozwiązania trudnych problemów stratygrafii, korelacji, oraz rozwoju facjalnego osadów górnej kredy południowej Mongolii.



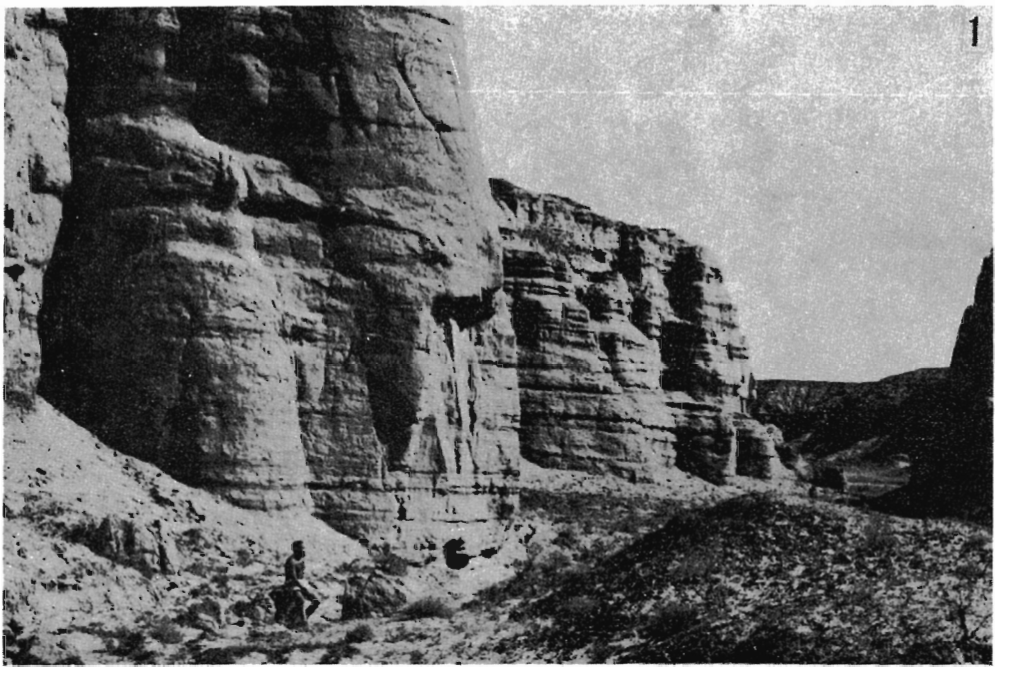
1 — Flaming Cliffs; Djadokhta Formation, Bayn Dzak locality (escarpment seen towards WNW)

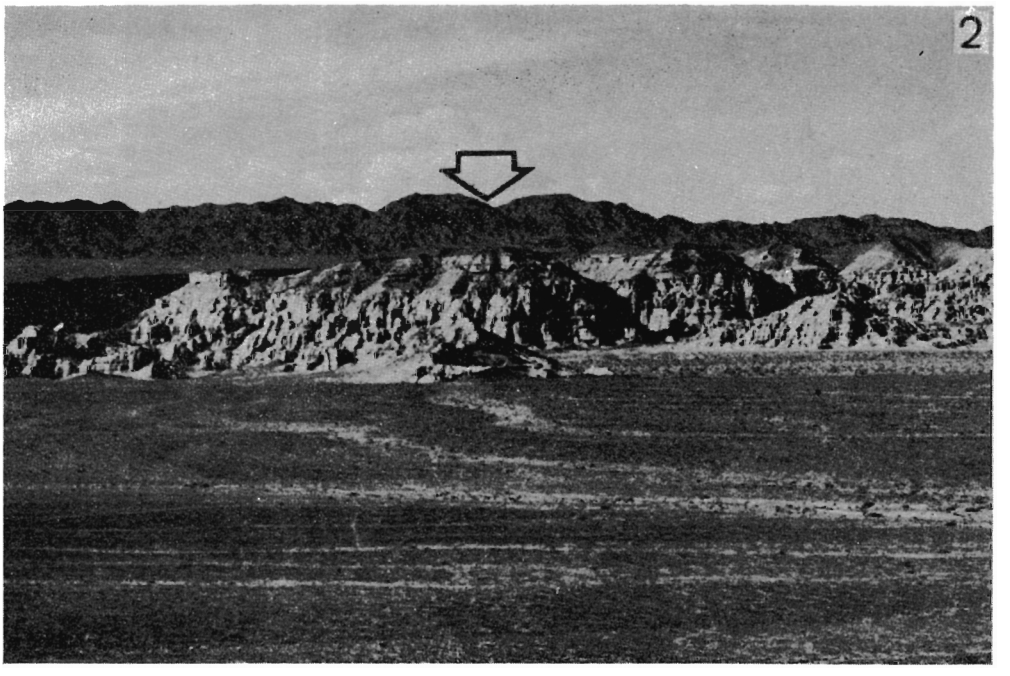
2 — Part of Flaming Cliffs (height of vertical face c 12 m)





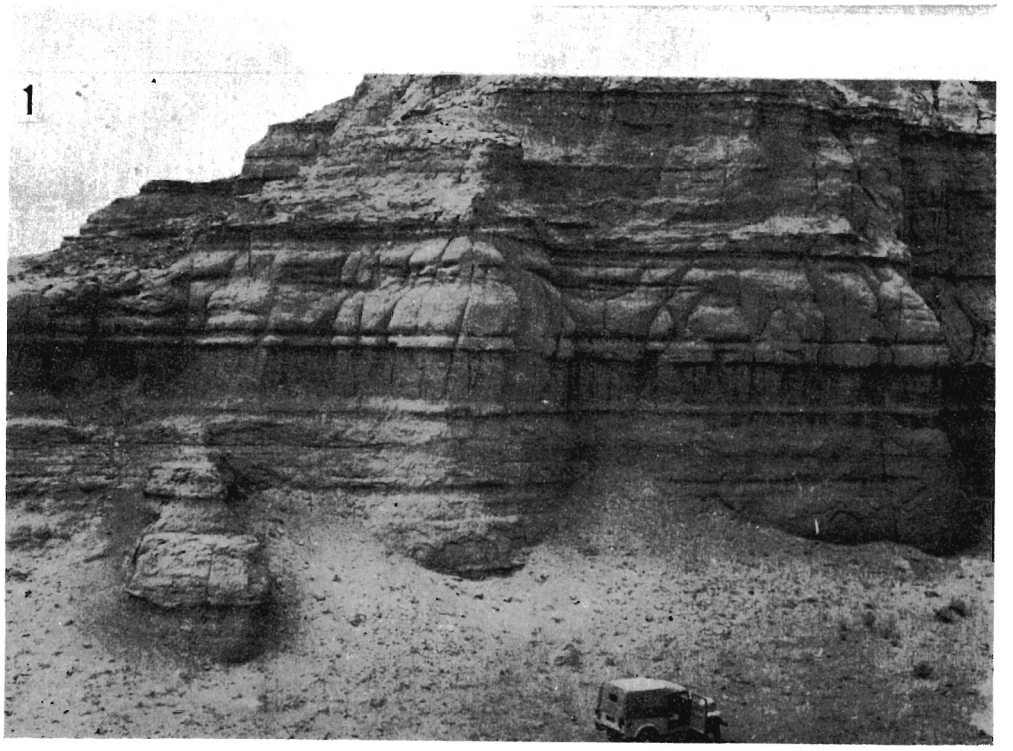
1 — Dikaka-like structures; Djadokhta Formation, Bayn Dzak locality
2 — Very large-scale cross-lamination; Barun Goyot Formation, Khulsan locality (Photograph by T. Jerzykiewicz)





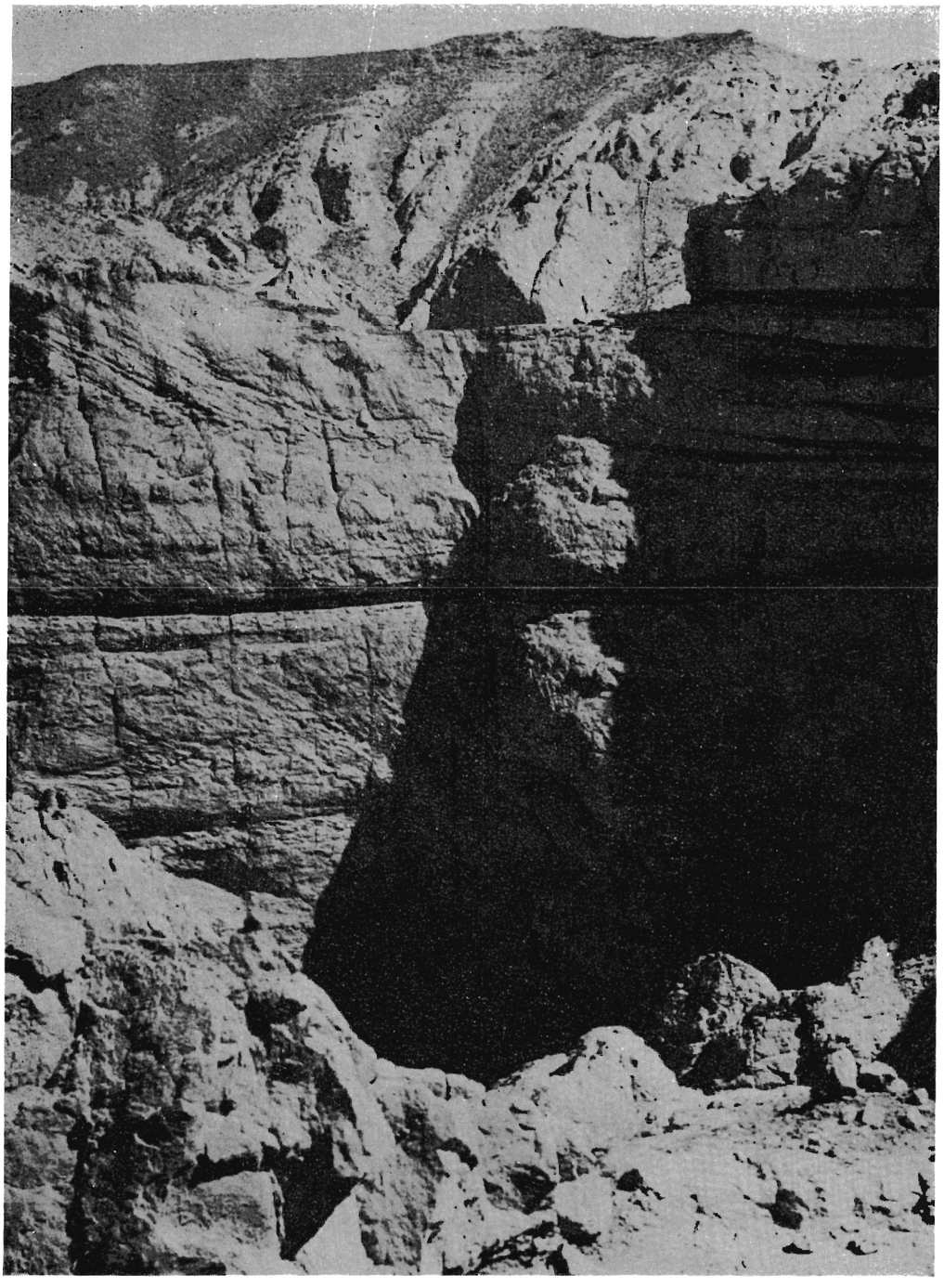
1 — Flat-bedded sandstones intercalated with mudstones and/or siltstones; Barun Goyot Formation, Nemegt locality, E part (Photograph by W. Skarżyński)

2 — Red Walls seen towards the north, Nemegt locality; Barun Goyot Formations in the lower part of the escarpment, Nemegt Formation in the upper part. Arrowed is the placement of the boundary stratotype (columnar section No 8; see Text-fig. 6)

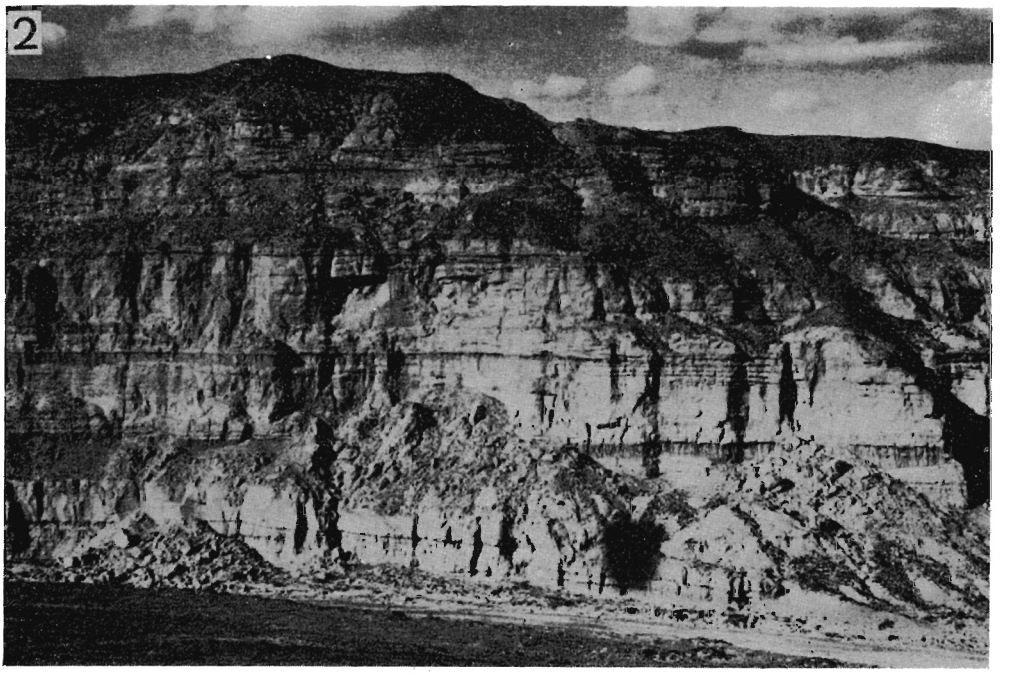


1 — Flat-bedded sandstones intercalated with mudstones and/or siltstones; Barun Goyot Formation, Nemegt locality, vicinity of Red Walls (Photograph by T. Jerzykiewicz)

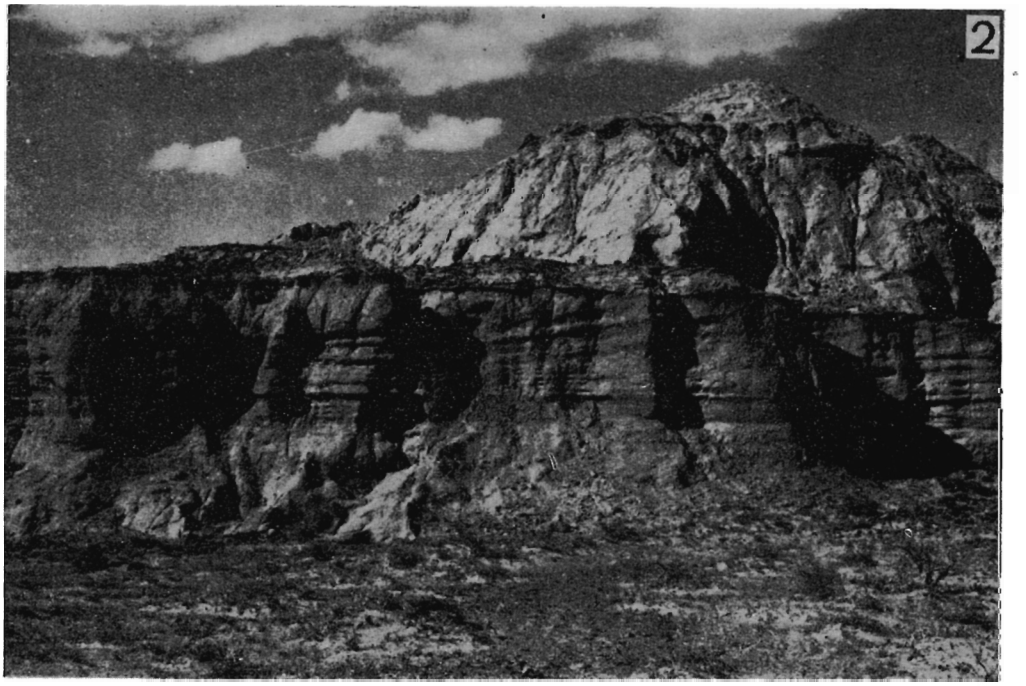
2 — Bed with very large-scale cross-lamination and overlying alternating mudstones and sandstones; Barun Goyot Formation, Nemegt locality, Southern Monadnocks (height of exposure 6 m; photograph by T. Jerzykiewicz)



Intertonguing of very large-scale cross-lamination with alternating mudstones and sandstones; Barun Goyot Formation, Khulsan locality, Northern Cliffs (height of exposure 7 m; photograph by T. Jerzykiewicz)



1 — Khulsan locality (seen towards the north), Barun Goyot Formation (Photograph by T. Jerzykiewicz)
2 — Nemegt Formation, Nemegt locality, Northern Sayr; note inclined bedding (height of exposure *c* 40 m)



1 — Nemegt Formation, locality Altan Ula *IV*, between Eagle Sayr and Central Sayr

2 — Layer with inclined bedding (lower part of the exposure), extensive erosional surface, layer of intraformational conglomerate and overlying sands. Nemegt Formation, Nemegt locality, Central Sayr (N part; height of exposure *c* 10 m)

1 — Inclined bedding with internal structures (flat- and cross-lamination); Nemegt Formation, Nemegt locality, Central Sayr (N part)
2 — Large-scale trough cross-lamination; Nemegt Formation, Tsagan Khushu locality