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AGE OF THE UPPER CRETACEOUS NEMEGT FORMATION
(MONGOLIA) ON CHAROPHYTAN EVIDENCE

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The assemblages of Charophyta from the Nemegt Formation (Upper Cretaceous) and some Paleocene deposits of Mongolia are compared to those from China, Europe and America. It appears that Charophyta are useful in stratigraphy of continental deposits. The present investigations provided new evidence of the age of the Nemegt Formation from Mongolia. The assemblage of this formation is intermediate between two Upper Cretaceous assemblages from the "Red Beds" from China. Comparisons with the Chinese, European and American assemblages indicate that the Nemegt Formation is not younger than the Lower Campanian, thus is older than it was supposed before. The state of preservation of the oogonia permit to draw some ecological conclusions.

Key words: Charophyta, Upper Cretaceous, stratigraphy, Gobi Desert.

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Upper Cretaceous Charophyta are known from Europe, Asia, North America, South America and Africa. The most diversified and abundant assemblages are those from Asia. The first of these were described in the sixties from China (Wang Shui 1965). Then the work on them was undertaken again in 1976 (Huang Ren-jin 1979; Wang Zhen 1978; Wang Zhen *et al.* 1976; Wang Zhen *et al.* 1979).

Owing to the Polish-Mongolian Palaeontological Expeditions to the Gobi Desert rich collections of fossils have been gathered, which has permitted to learn about several groups of continental organisms of the Upper Cretaceous of Mongolia. Among these are the Charophyta, the oogonia of which were found in Mongolia in 1969. At first, the material was scarce and therefore we described (Karczewska and Ziemińska-Tworzydło 1970) only thirteen species of oogonia belonging to ten genera.

The Charophyta of Mongolia were also studied by Kyansep-Romaschkina (1975).

In our recent paper based on the abundant material we have described thirty-three species of oogonia belonging to seventeen genera (Karczewska and Ziemińska-Tworzydło 1981).

The diversity of the Upper Cretaceous assemblage of Charophyta from Mongolia suggests the most favourable conditions for the development of this group of algae in the area of our research. This is striking because the data on the Upper Cretaceous Charophyta from other regions of the World are rather scarce, with the exception of China.

In the seventies, the palaeontological investigations on the continental deposits of the so called "Red Beds" from southern and middle China were well in progress. These deposits seem to represent similar facies as those from the Nemegt Basin in Mongolia. Their age is estimated by the Chinese geologists as the Upper Cretaceous to Eocene. Charophyta occur frequently in the "Red Beds" and are, beside ostracods, the best tool in stratigraphy of these deposits.

In a synthetic paper concerning Southern China, the Chinese authors (Wang Zhen, Lu Hui-nan and Huang Ren-jin 1979) distinguished two assemblages of Charophyta differing in age. The older one, called the assemblage "2" is supposed to represent the lower part of the Upper Cretaceous (Aptian — Cenomanian). It contains several Lower Cretaceous elements such as *Flabellochara*, *Atopochara trivolvis* and *Euaclistochara mundula*. The younger assemblage ("3") considered to be of the uppermost Cretaceous age (Turonian — Maastrichtian) includes several Tertiary elements such as *Tectochara*, *Nemegtichara* etc.

Table 1 shows the World distribution of the Upper Cretaceous genera of Charophyta. It is apparent that our Mongolian assemblage is most similar to those from China. Its character is intermediate between the assemblage "2" and "3" of the "Red Beds". The taxa common to our assemblage and the older one from China are: *Mesochara*, *Atopochara* and *Euaclistochara mundula*. The latter species occurs abundantly in both assemblages. It has not been recorded in uppermost Cretaceous and is also absent in the younger Chinese assemblage. In the lower part of China the genus *Atopochara* is represented by *Atopochara trivolvis* while in the Nemegt Formation by *A. ulanensis*. This genus described by Peck from the Cretaceous deposits of North America was represented there by *A. trivolvis*, the species indicative of the Lower Cretaceous (Aptian) and *A. multivolvis* indicative of the Cenomanian-Turonian (Peck 1957). The Mongolian species *A. ulanensis* Kyansep-Romaschkina, 1975, in our opinion is identical with *A. restricta* Grambast from the Albian of Portugal. This species was included by Grambast (1974) in the *Perimneste-Atopochara* lineage, but was formally described by Grambast-Fessard only in 1980 as *A. restricta* sp.n., therefore *A. ulanensis* Kyansep-Romaschkina

Table 1

Distribution of the genera and selected species of the Charophyta in Upper Cretaceous deposits of the World

Localisation	N. AMERICA	CHINA	MONGOLIA	CHINA	N. EUROPE	S. AMERICA	N. AMERICA
Stratigraphy	L. Cretaceous	Aptian-Cenom. "Assemblage 2"	U. Cretaceous	Turon.-Maestr. "Assemblage 3"	U. Cretaceous	U. Cretaceous	U. Cretaceous
Genera							
<i>Platellochara</i>							
<i>Atopochara trilobata</i>							
<i>Atopochara ulanensis</i> (= <i>A. restricta</i>)							
<i>Atopochara multilobata</i>							
<i>Eusolistochara mundula</i>							
<i>Eusolistochara</i>							
<i>Mesochara</i>							
<i>Sphaerochara</i>							
<i>Obtusochara</i>							
<i>Maedlerisphaera</i>							
<i>Latochara</i>							
<i>Harrisiachara</i>							
<i>Stephanochara</i>							
<i>Peckichara</i>							
<i>Grumbastichara</i>							
<i>Mongolichara</i>							
<i>Saportanella</i>							
<i>Gobiichara</i>							
<i>Microchara</i>							
<i>Lamprothamnia</i> (= <i>Stothochara</i>)							
<i>Maedlerella</i>							
<i>Arblychara</i>							
<i>Baekyachara</i>							
<i>Turbochara</i>							
<i>Charites</i>							
<i>Gruvestichara</i>							
<i>Croftia</i>							
<i>Aclistochara</i>							
<i>Collichara</i>							
<i>Tectochara</i>							
<i>Pseudolatochara</i>							
<i>Nemegtichara</i>							
<i>Platychara</i> (= <i>Gyrogonia</i>)							
<i>Porochara</i>							
<i>Septoria</i>							
<i>Peckisphaera</i>							
<i>Strobilochara</i>							
<i>Bysmochara</i>							
<i>Retusochara</i>							
<i>Dughiella</i>							
<i>Tolyella</i>							
<i>Pseudoharrisiachara</i>							

has priority. According to Grambast (1974), in the *Atopochara* lineage *A. restricta* (= *A. ulanensis*) is intermediate between *A. trivolvis* and *A. multivolvis*. According to Grambast, *A. trivolvis* is indicative of the Upper Barremian-Aptian, *A. restricta* of Albian and *A. multivolvis* of Cenomanian-Turonian. Genus *Atopochara* is absent in the rich and diversified assemblage of the uppermost Cretaceous deposits of China and is rare in Mongolia.

The third genus present in the assemblage "2" of China, and in our assemblage is *Mesochara*. In North America the species of *Mesochara* occur in the deposits from the Middle Jurassic to the Aptian. Especially characteristic is *M. voluta*, which has been also recorded in Mongolia. *Mesochara* is absent in the assemblage "3" of China as well as in the Upper Cretaceous deposits of Europe and America, while in the Upper Cretaceous deposits of Mongolia this genus is still present and is represented by numerous specimens and taxa.

The species belonging to *Obtusochara*, *Sphaerochara* and *Maedlerisphaera* are recorded in both Chinese assemblages and in the Mongolian one.

The genera *Amblyochara*, *Harrisichara*, *Latochara*, *Peckichara*, *Stephanochara* and *Grambastichara* are common to the Upper Cretaceous assemblage of Mongolia and assemblage "3" of China (uppermost Cretaceous).

Some genera recorded in the Upper Cretaceous deposits of Mongolia have not been found in China. These are: *Mongolichara*, *Saportanella*, *Lamprothamnium* and *Microchara*. *Mongolichara* is the most characteristic genus of the Upper Cretaceous of Mongolia and is characterized by considerable variability; it occurs in abundance in these deposits.

Beside *Mongolichara*, also *Saportanella* is an important component of the assemblage of Charophyta from Mongolia. It is represented by *S. nana* and *S. romashkinae*, both species occurring abundantly. *Saportanella* was described from Upper Cretaceous deposits of Europe and, according to Grambast (1964), is characteristic of this period.

The third well represented genus is *Lamprothamnium*. It has not been recorded in China but possibly it is identical to *Turbochara* Wang Zhen, 1978. It seems, in our opinion, that also some other genera of Charophyta created by the Chinese palaeontologists are younger synonymes of those from other regions, but this cannot be proved without examination of the original material.

The two remaining genera occurring in the Upper Cretaceous deposits of Mongolia, i.e. *Gobichara* and *Maedleriella*, appear in China only in the Paleocene.

In the Upper Cretaceous deposits of China there occur some genera which have not been found in Mongolia. These are: *Porochara*, *Raskyechara*, *Charites*, *Turbochara*, *Croftiella*, *Tectochara*, *Aclistochara*, *Colli-*

chara, *Pseudolatochara* and *Nemegtichara*. The genera *Charites*, *Gyrogona*, *Grovesichara* and *Nemegtichara* appear in Mongolia only in Paleocene. Especially significant is the lack of the genus *Porochara* in the Upper Cretaceous deposits of Mongolia, which is well represented in the upper part of the Upper Cretaceous sediments of China. This genus is also characteristic of the Maastrichtian of Western Europe (Feist 1979) and America (Peck 1957), and have also been recorded in the Maastrichtian of Africa (Feist 1979).

It is worth noting that *Septorella*, the genus indicative of the Maastrichtian in Western Europe (Grambast 1962, 1971) is absent in the Upper Cretaceous deposits of Mongolia and China. Also *Platychara*, the characteristic Upper Cretaceous (Maastrichtian) genus recorded in Europe (Grambast et Guttiérrez 1977) and America (Peck 1979) has not been found in Asia.

According to Wang Zhen (1978), in the Upper Cretaceous deposits of China occur numerous species of the genus *Gyrogona*. In his opinion *Gyrogona* is distinct from *Platychara* in spite of the similarity between these two genera. In this author's opinion, the important feature of *Gyrogona*, the genus including also *G. compressa*, is the internal structure of the oogonia and the morphology of their apical part. According to Grambast (1962) and Peck (1979), *G. compressa* is the type species of *Platychara*. Thus, the apparent absence of *Platychara* in China is due to the different taxonomical approach of the Chinese authors. On the other hand, *Platychara* is definitely absent from the Upper Cretaceous assemblage of Charophyta from Mongolia.

The genera common to the Upper Cretaceous assemblages of Charophyta of Mongolia and Europe are: *Atopochara*, *Amblyochara*, *Peckichara*, *Saportanella*, *Microchara* and *Maedleriella*.

The comparison between our assemblage and those of Upper Cretaceous from North America is difficult as the latter are very poor in taxa. The common genus is *Atopochara* (Peck 1957) while the other American genera i.e. *Porochara* and *Platychara* do not occur in Mongolia.

More similar are the assemblages of Charophyta from South America (Musacchio 1973, 1978). The common genera are *Amblyochara*, *Microchara*, *Maedleriella*, *Grambastichara* and *Gobichara*. It seems that *Notochara* from Argentina (Musacchio 1973, 1978) is identical with *Lamprothamnium*, and the oldest species of this genus is *L. altanulaensis* from the Upper Cretaceous deposits of Mongolia.

In some areas of the Nemegt Basin, the red beds of the Upper Cretaceous are overlain unconformably by white, strongly calcareous sediment of the Lower Tertiary. From these beds we described (Karczewska and Ziemińska-Tworzydło 1972) the second assemblage of Charophyta. Due to the unconformity we were not able to trace the transition between the Upper Cretaceous and Tertiary assemblages. The comparison between

the Upper Cretaceous assemblage of Charophyta from Mongolia and those of other regions indicates that the Mongolian assemblage does not represent the uppermost Cretaceous. This is supported by comparison between the Cretaceous and Tertiary assemblages of Mongolia. Only four genera are common to both assemblages: *Grambastichara*, *Mesochara*, *Peckichara* and *Gobichara*. Beside the genera common to the Upper Cretaceous and Paleogene assemblages of Mongolia, there occur in the Paleogene: *Nemegtichara*, *Grovesichara*, *Charites*, and *Gyrogonia*. The most characteristic component of the Mongolian Paleogene assemblage are: *Nemegtichara*, *Gobichara* and *Grovesichara*, especially *G. kielani*.

REMARKS ON ECOLOGY

The study on the Upper Cretaceous assemblage of the Charophyta from the Nemegt Formation implies some ecological conclusions. The deposits of this formation are mostly fine to very coarse-grained sandstones. The oogonia of Charophyta occur exclusively in fine-grained sandstones and light gray mudstones in which the content of calcium carbonate is up to 42% (Gradziński 1970). The high content of calcium carbonate is probably due to drying up of the sedimentary basin, which is implied also by the specific state of preservation of the oogonia. The cortical cells of these are very strongly calcified and inside the spiral cells there occur additional ridges.

It is believed generally that Charophyta are connected with freshwater basins, but the investigations on Recent Charophyta of Australia (Burne *et al.* 1980) indicate that they may adapt to high salinity in periodically evaporating inland basins. According to the authors mentioned above, such phenomena are common in ephemeral basins in areas of arid climate.

The fact, that the Upper Cretaceous basins of Mongolia were isolated from flowing waters is implied by the fact, that the oogonia of Charophyta present a wide variety of size, including also the very small ones (200 to 300 μm), suggesting lack of sorting. The very small oogonia are an interesting assemblage of specimens with strongly thickened walls and characteristic microstructure of the surface. They seem to represent not fully matured oogonia which developed in very unfavorable conditions.

CONCLUSIONS

The investigations on the Upper Cretaceous and Paleogene Charophyta from the Nemegt Basin in Mongolia revealed that there is a strong difference between the two assemblages. This is due to the unconformity between the Nemegt Formation and the overlying "White Beds". Thus,

it was not possible to indicate the Cretaceous/Tertiary boundary on the basis of change in assemblages of the Charophyta.

The Cretaceous assemblage of the Charophyta is richer and more diversified than the Tertiary one and includes several taxa which occur also in China, Europe, Northern America and Southern America. The most similar are the assemblages of China. In Mongolia there occur ten genera and three species common with Chinese assemblages, six genera common with the European ones and four genera common with those of South America. One North American Upper Cretaceous genus and two genera recorded in the Lower Cretaceous occur also in Mongolia (Table 1).

The comparisons between the Upper Cretaceous assemblage of the Charophyta from Mongolia and those of other regions have some stratigraphic implications. When compared with the assemblages from the "Red Beds" of China, the Mongolian assemblage appears as intermediate between the assemblage "2" of lower part of the Upper Cretaceous (Aptian-Cenomanian) and assemblage "3" of the uppermost Cretaceous (Wang Zhen, Lu Hui-nan and Ren-jin 1979).

In our assemblage there are some older elements such as: *Euaclostochara mundula*, *Mesochara voluta* and *Atopochara ulanensis* (= *A. restricta*). *Euaclostochara mundula* occurs in the Lower Cretaceous (Aptian-Albian) in North America and in China and has not been, so far, recorded in the Upper Cretaceous. Similarly, *Mesochara voluta* which was described from the Jurassic and Lower Cretaceous (Albian) of North America (Peck 1957), and *Atopochara ulanensis*, identical with *A. restricta*, described from the Aptian or Albian of Portugal (Grambast-Fessard 1981).

In the Upper Cretaceous assemblage of Mongolia the species *Nemegti-chara prima* and *Grovesichara kielani* are absent; these occur in the assemblage "3" of China representing the uppermost Cretaceous. Also *Porochara* and *Platychara* (*Gyrögona* in Chinese papers) are missing.

The genus *Porochara* appears all over the World in the Middle Campanian and *Platychara* appears in the Upper Campanian and both persist throughout the Maastrichtian. Thus, the assemblage from the Nemegt Formation fills the gap between the assemblage "2" and "3" from the "Red Beds" of China.

All the above data suggest that the assemblage of the Charophyta from the Nemegt Formation can not be considered younger than the Lower Campanian. The earlier data on the age of the continental deposits of the Gobi Desert are based on some vertebrates, fresh-water invertebrates, and lithostratigraphic correlation with the Asiatic Upper Cretaceous deposits containing marine intercalations. According to Gradziński, Kielan-Jaworowska and Maryńska, 1977 the age of the Gobi Desert formations is as follows: Djadokhta Formation — ?Upper Santonian and/or Lower Campanian; Barun Goyot Formation — ?Middle Campanian; Nemegt Formation — ?Upper Campanian and/or ?Lower Maastrichtian.

Fox (1978), who compared the vertebrates of the Upper Cretaceous of Mongolia and North America, correlated these deposits from both regions which is shown in Table 2. This author placed the Djadokhta Formation above the Upper Milk River Formation and correlated it with the lowermost part of the Judith Formation. In the European scale this corresponds to the upper part of the Lower Campanian. The overlying Barun Goyot Formation extends to the bottom of the St. Mary's River Formation, which means almost to the top of the Campanian. According to Fox, the Nemegt Formation is of the uppermost Campanian to Maastrichtian age. This interpretation disagrees with our suggestion based on Charophyta from the Nemegt Formation. The occurrence of the old taxa known from Lower/Upper Cretaceous transition indicates that the Nemegt Formation is not younger than Lower Campanian. Accordingly, underlying Barun Goyot Formation and Djadokhta Formations must be older than the Lower Campanian (Table 2). The Barun Goyot Formation (and its stratigraphic equivalent red beds of Khermeen Tsav) is probably of ?Late

Table 2

Stratigraphic position of the Nemegt Formation

Stages		Formations			Charophyta assemblages	
EUROPE	N. AMERICA	N. AMERICA	GOBI Gradzinski et al., 1977	GOBI Fox, 1978		GOBI Karcz. et Ziem. this paper
Maastrichtian	Lancian	Hell Creek = Lance = Upper Edmonton				China assemblage "3"
	Edmontonian	Lower Edmonton = St. Mary River	Nemegt	Nemegt		
Campanian				?		
	Judithian	Oldman = Judith River	Barun Goyot	Barun Goyot		
				Djadokhta		
			?			
	Aquilan	Upper Milk River	Djadokhta		Nemegt	Mongolian assemblage
Santonian					Barun Goyot ? Djadokhta	China assemblage "2"

Santonian age. This agrees in general with the opinion of Kielan-Jaworowska (1974) based on the development of the multituberculates. Earlier Marinov (1957) suggested that the beds from the Nemegt Basin (Altan Ula, Tsagan Khushu and Nemegt) were older than the Campanian.

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