BULLETIN DE L'INSTITUT ROYAL DES SCIENCES NATURELLES DE BELGIQUE SCIENCES DE LA TERRE, 69-SUPP. A: 55-65, 1999
BULLETIN VAN HET KONINKLIJK BELGISCH INSTITUUT VOOR NATUURWETENSCHAPPEN AARDWETENSCHAPPEN, 69-SUPP. A: 55-65, 1999

Upper Maastrichtian bivalve faunas from the Crimea, Maastricht and Mangyshlak

by Annie V. DHONDT

Abstract

Upper (but not uppermost) Maastrichtian bivalve faunas in the stratotypical Maastrichtian area and in the Crimea are extremely diverse and species rich, and represent a very littoral shallow and warm environment. Uppermost Maastrichtian bivalve faunas and in the Maastrichtian stratotypical area and in the Crimea indicate a somewhat deeper, cooler environment. The Upper Maastrichtian bivalves from Mangyshlak are much less diversified and indicate a cold environment, comparable with the ''upper shelf'' in today's seas.

Key-words: Upper Cretaceous, Bivalves, Maastricht, Crimea, Mangyshlak.

Résumé

Les faunes de bivalves du Maastrichtien supérieur (mais non terminal) dans la région stratotypique de l'étage Maastrichtien et de la Crimée sont très diversifiées et riches en espèces. Elles représentent un environnement littoral, chaud et peu profond.

Les bivalves du Maastrichtien terminal des mêmes régions indiquent un environnement plus profond et plus froid.

Les bivalves du Maastrichtien supérieur du Mangyshlak sont moins diversifiés et indiquent un environnement de ''shelf'', franchement plus profond.

Mots-clefs: Crétacé supérieur, Bivalves, Maastricht, Crimée, Mangyshlak.

Резюме

Фауны двухстворчатых верхнего (но не высшего) Маастрихта в статотипичной области Маастрихтского яруса и в Крыму невероятно разнообразны и богаты породами. Они представляют теплую и мелководную прибрежную фацию. Фауны двухстворчатых высшего Маастрихта в статотипичной области Маастрихтского яруса и в Крыму указывают на более глубокую и холодную фацию. Фауны двухстворчатых верхнего Маастрихта Мангышлака менее разнообразны и указывают на холодную фацию, сравнимую с «верхним шельфом» современных морей.

Ключевые слова: Верхний мел, двухстворчатые, Маастрихт, Крым, Мангышлак

Introduction

The Campanian represents possibly the moment of widest marine expansion in Europe (ZIEGLER, 1990). In the Lower Maastrichtian marine strata are still very widely distributed — from England to the Aral Sea in Kazakhstan — but on average they represent a somewhat shallower facies than in the Campanian. During the Upper Maastrichtian large areas, which were still marine in the Lower Maastrichtian, had become continental. This was especially true in extensive Tethyan areas of southern Europe with the development of the Garumnian facies.

In western, northern and eastern Europe, and into western Asia, the white chalk facies is found in the Campanian and Maastrichtian (Fig. 1). In this ''White Chalk Sea'' a fairly homogenous fauna is found. Specifically, the Upper Maastrichtian strata which were deposited by this white chalk, still represent a fairly deep marine facies.

On the southern border of this white chalk sea, well-developed, very fossiliferous Upper Maastrichtian deposits exist, sometimes overlain by Danian deposits. Across the K/T boundary sedimentation was only rarely continuous, and the Upper (uppermost) Maastrichtian sea was relatively shallow in this southern part. In three areas [(1) the Maastrichtian stratotypical area, Limburg, The Netherlands-Belgium; (2) south western Crimea, The Ukraine; (3) Mangyshlak Peninsula, W. Kazakhstan] which knew a more or less continuous sedimentation across the K/T boundary, the faunal evolution of the bivalves in the uppermost Maastrichtian and near the K/T boundary was followed.

Stratigraphy

In the Maastricht area (Limburg, Belgium-The Netherlands) the Upper Maastrichtian is mainly represented by the generally calcarenitic Maastricht Fm. (Figs. 1, 2 and map in JAGT, this volume, p. 104). Stratigraphically most of the Maastricht Fm. is part of the *junior* Zone. Only the uppermost member (Meerssen Chalk) belongs partially to the *kazimiroviensis* Zone (JAGT, 1996). At the quarry Curfs-Ankerpoort (near Geulhem, Zuid Limburg, The Netherlands) the Meerssen Chalk contains a clearly marked thin layer the ''Berg en Terblijt Horizon'' (formal

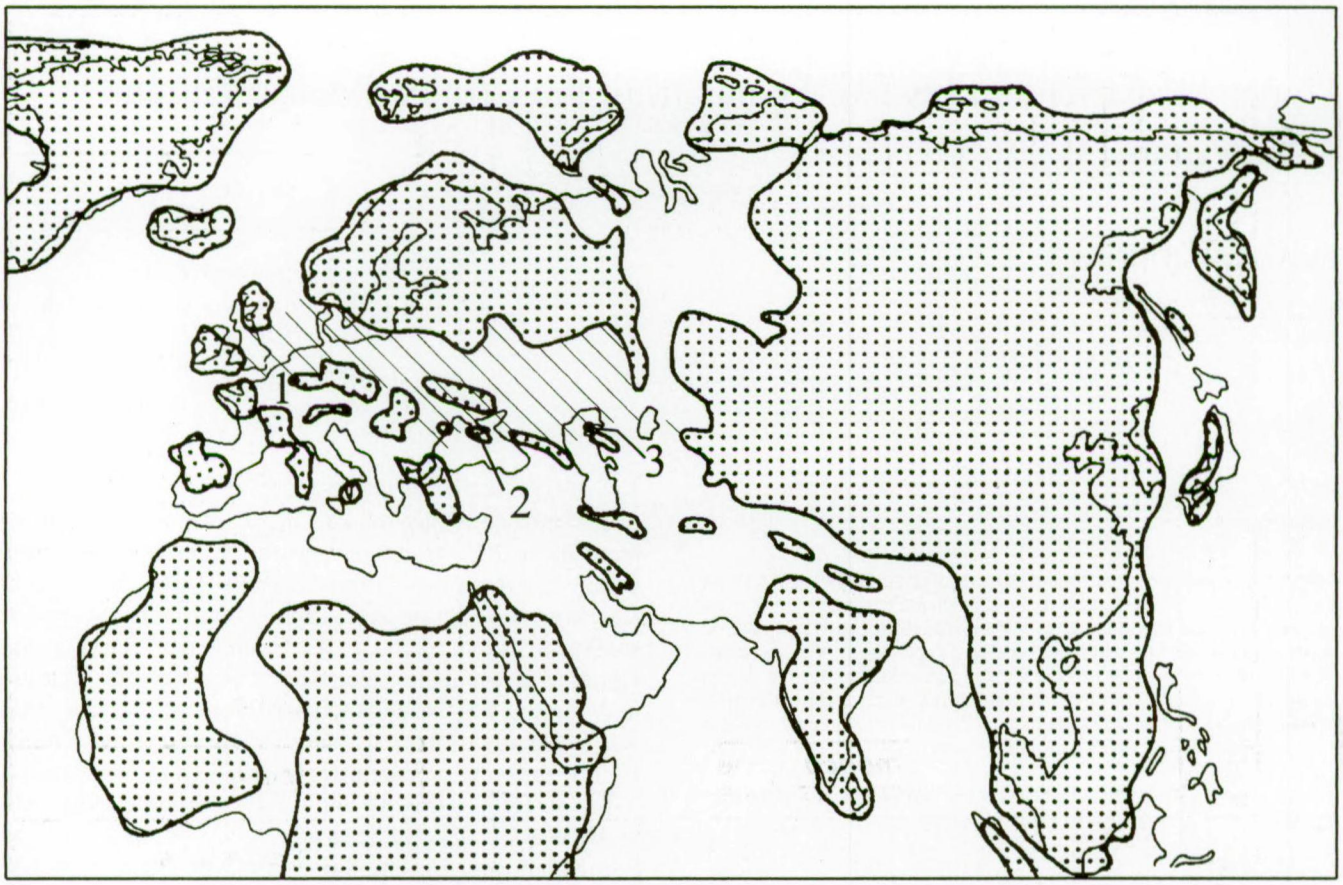


Figure 1 — Distribution of the White Chalk Sea (map from DHONDT *et al.*, 1996); the "white chalk sea" is shaded; 1: Maastrichtian stratotypical area; 2: Upper Cretaceous of Crimea; 3: Mangyshlak.

definition in FELDER & BOSCH, in press); this horizon is now considered the K/T boundary (JAGT *et al.*, 1996, Fig. 3). The upper Meerssen Chalk, above this horizon, is lowermost Danian. It is unconformably overlain by younger Palaeocene calcarenites. The Houthem Fm. of early to late Danian age (? Thanetian), is outcropping also as a calcarenite. The age of the Geulhem Member is Middle Danian (JAGT, 1996 & 1999). In the Geulhemmerberg section the K/T transition is more complete and the transitionary clay forms the Berg en Terblijt Horizon, which is a little older than the Vroenhoven Horizon at the top of the Meerssen Chalk. The Vroenhoven Horizon was previously considered to equate with the K/T boundary in that area (JAGT *et al.*, 1996).

Near Bakhchisaray and near Belogorsk (S. Crimea, the Ukraine), extensive Maastrichtian chalks (sometimes marly sandstones) are overlain generally unconformably by Palaeocene and/or Eocene limestones (sandstones) (NAIDIN *et al.*, 1984; NIKISHIN *et al.*, 1993; ALEKSEEV & KOPAEVICH, 1997; Fig. 4). Further east on the Crimean Peninsula (near Topolevka Koktebel) the Maastrichtian is present in a flysch facies, deposited in deep water.

The zonation generally used for the Maastrichtian is based on belemnites (macrofauna) and on planktonic Foraminifera and calcareous nannofossils (microfauna) (NIKISHIN *et al.*, 1993; ALEKSEEV & KOPAEVICH, 1997, p. 110, fig. 6). Also used are "units" representing faunal assemblages (ALEKSEEV, 1989).

It must be noted that the *kazimiroviensis* Zone in Crimea comprises a large part of the Upper Maastrichtian, overlying a thin *junior* Zone.

In Mangyshlak the complete Upper Maastrichtian, as was already noted by NAIDIN (1973), belongs to the *kazimiroviensis* Zone. For details on the stratigraphy see NAIDIN (1986, 1987) and NAIDIN *et al.* (1990a, b; 1996).

Faunas and environment

MATERIAL AND METHODS

The taxonomy used for bivalves herein is based on the "Treatise", but changes introduced by WALLER (1978) for the pteriomorphs and by MALCHUS (1990) for the oysters, have been taken into account. The material studied in personal or museum collections was in all three regions complemented by fieldwork.

I have studied the bivalves from the Maastrichtian

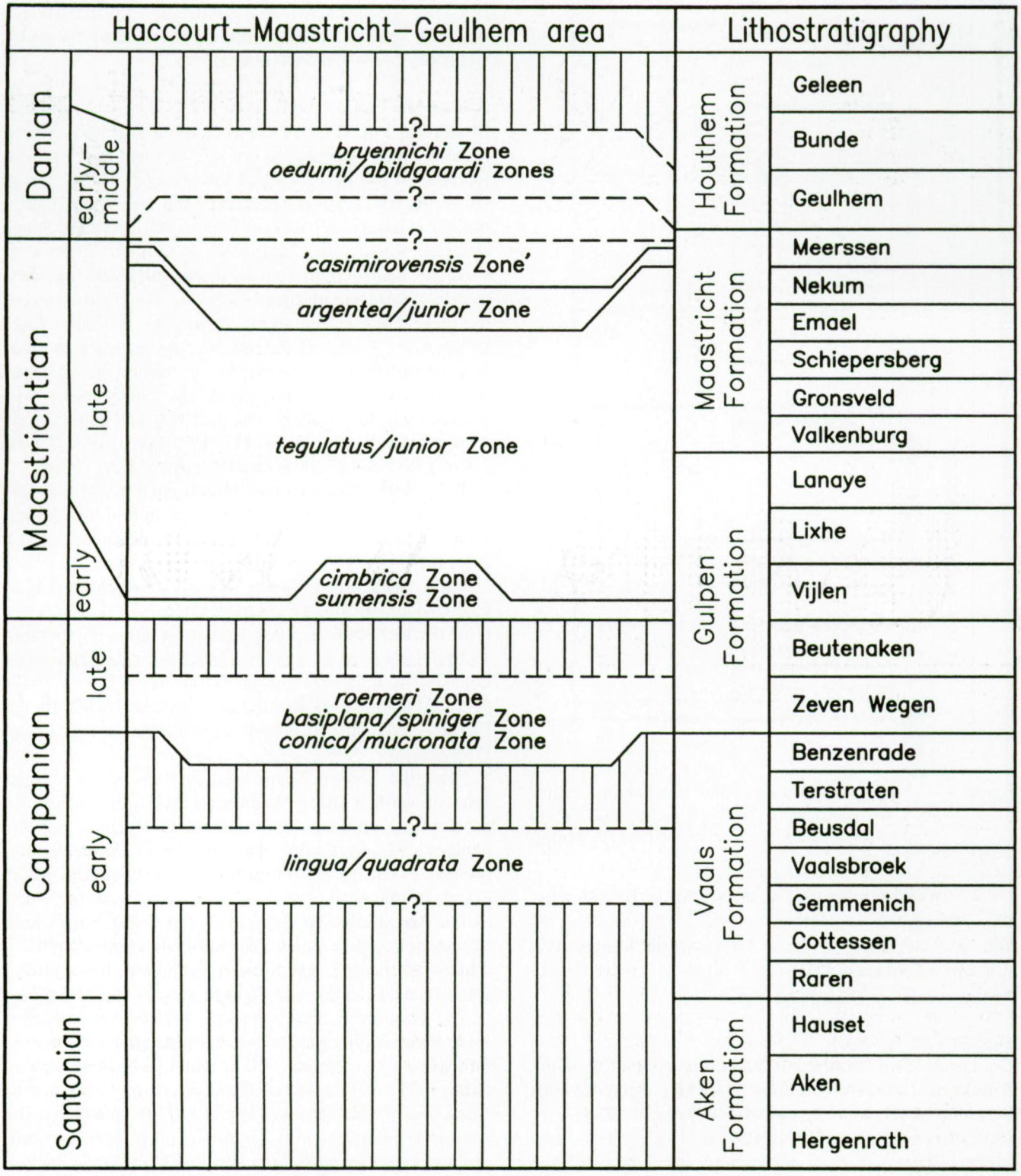


Figure 2 — Lithostratigraphy and biozonation of Campanian, Maastrichtian an Danian strata in the stratotypical region of the Maastrichtian Stage (after JAGT, this volume).

stratotypical part for the last 35 years mainly in the collections of the Royal Belgian Institute of Natural Sciences; in the list provided herein the taxa in steinkern preservation are not taken into consideration.

Bivalves from the Crimean outcrops have been mainly studied in the personal collection of Prof. D. P. Naidin at the MGU, in the collections of the late V. A. Sobetski at the PIN, and in the collections at the Baza MGU at Prokhladnoe in the Crimea.

Bivalves from Mangyshlak were studied in the collec-

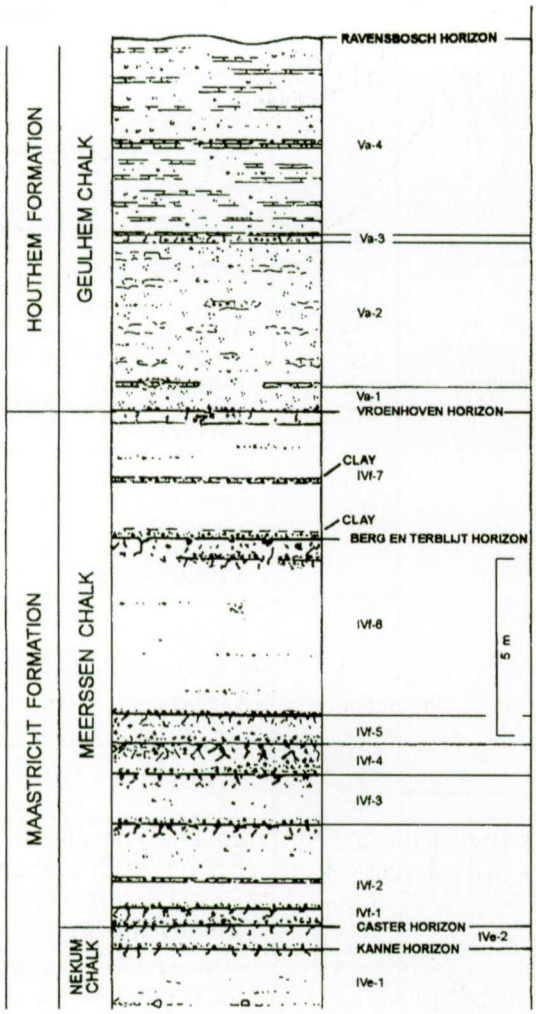


Figure 3 — Uppermost Maastrichtian section in quarry Curfs-Ankerpoort, Geulhem (after JAGT *et al.*, 1996) indicating the level of the Berg en Terblijt Horizon.

tions of Prof. D. P. Naidin at MGU. In the Mangyshlak outcrops of Maastrichtian age, bivalves are relatively rare.

MAASTRICHT

The fossils from the strata of the Maastrichtian Fm. in the stratotypical area were already described, figured and/or mentioned by FAUJAS DE SAINT FOND (1799-1802), von SCHLOTHEIM (1813, 1820), GOLDFUSS (1833-1841), d'ORBIGNY (1850). Changes throughout the faunas of the Maastricht Fm. were recognised early on (e.g. ''couche à coprolithes, couche à bryozoaires''), but detailed stratigraphical occurrences of bivalves were only rarely noted.

More recent work has clearly shown that changes within the Maastricht Fm. were important. Herein we shall try to give an account of bivalve faunas within the members of the Maastricht Fm.. From the overlying Houthem Fm. bivalves are known but they have not so far been described in detail from the Maastricht region (JAGT & JANSSEN, 1988). Faunas of similar age from the colliery shafts in nearby Belgian Limburg were last revised by GLIBERT & VAN DE POEL (1973).

Among the macrofaunas from the Upper Maastrichtian Maastricht Fm. (Fig. 2) the very numerous and diverse bivalve fauna is probably one of the most species rich. Because of the limitations of the preservation in calcarenites not all taxa were preserved but only those with a mainly calcitic shell such as Pectinidae, Limidae, Spondylidae, Anomiidae, Mytilidae, modiolids, Ostreacea, Pinnidae; also recognisable are those with a very thin shell such as Pholadomyidae, and *Liopistha*. Rarely also taxa of the genus *Glycymeris*, arcids, *Nucula* s.l., *Cucullaea* sp., ''*Trigonia*'', crassatellids, cardiids, dosiniids are more or less identifiable as steinkerns or composite external moulds. The only ''monograph'' on these faunas was written by VOGEL (1895). The pectinids and some limids were revised by DHONDT (1971; 1972a & b; 1973 a & b; 1976; 1989) and *Liopistha* by DHONDT & JAGT (1988).

This Upper Maastrichtian Maastricht Fm., in the stratotypical area is characterised by a highly diversified fauna, which is fairly different from the fauna known from the underlying strata of the Gulpen Fm.

Thus, the Lower to lower Upper Maastrichtian Vijlen Chalk Member (top of the Lower Gulpen Fm.), which is a typical white chalk deposit, contains a fauna comparable to that found in the typical Schreibkreide/ Skrivekridt deposits of northern Europe (DHONDT & JAGT, 1987) (Table 1), and also further east around Lwow in the Ukraine and on the Russian Platform, onto the Precaspian Depression.

From the Lanaye Chalk Member (top of the Gulpen Fm.) upwards a strong southerly (shallower, sublittoral, subtropical) influence is visible in the faunas: e.g. the echinoid *Hemipneustes*, the bivalve *Pinna decussata*, ostracodes (BLESS, 1989), mosasaurs and cheloniid turtles (JAGT, 1995).

The Maastricht Fm. starts with the Valkenburg Chalk Member (formerly named unit Ma - UHLENBROEK, 1912), which represents a less open environment, but with the same fauna as in the underlying Lanaye Chalk Member.

The Gronsveld, Schiepersberg, and Emael Members form a virtually homogenous sediment (formerly named unit Mb - UHLENBROEK, 1912) which according to VILLAIN (1977) was deposited at a depth of 20 to 40 m, free from oceanic influences. LIEBAU (1978) considered the setting as middle sublittoral, with subtropical temperatures and with seagrass communities. These strata contain a diversified fauna in which especially the bivalves are numerous (Table 2), often largish and some typical for sea grass communities.

The Nekum Member (formerly unit Mc - UHLENBROEK, 1912) consists mainly of fairly coarse-grained biocalcarenites and contains in its lowermost part a serpulid horizon with numerous bivalves and the ammonites *Sphenodiscus binckhorsti* and *Hoploscaphites felderi*.

The upper strata of the Nekum Member contain numerous crustaceans and a coquina with tegulated inoce-

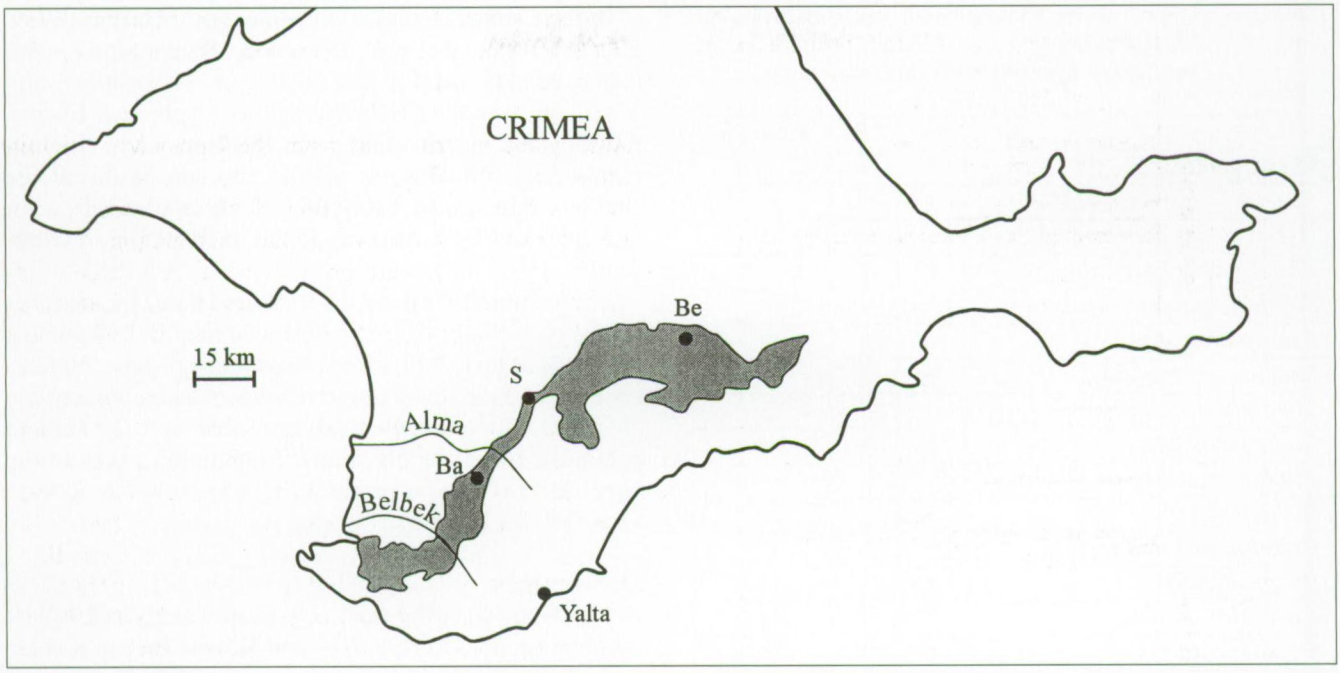


Figure 4 — Crimean Cretaceous strata. Ba: Bakhchisaray; Be: Belogorsk; S: Simferopol (from NIKISHIN *et al.*, 1993).

ramids (*Spyridoceramus tegulatus*) and *Belemnitella junior*.

The Meerssen Member (formerly unit Md - UHLENBROEK, 1912), youngest member of the Maastricht Fm., should ecologically be divided into two parts; the lower part contains a fauna similar to that of the Nekum Member and even contains rudists; the upper part (youngest Maastrichtian levels) contains a different fauna probably of cooler origin. The terminal Maastrichtian event (within the Meerssen Member of the Maastricht Fm., JAGT *et al.*, 1998) in the Maastricht area is accompanied by a cooler water fauna with rare *Neobelemnella* gr. *kazimiroviensis*, and *Tenuipteria argentea*. Among the bivalves most of the larger taxa which could live among the sea grass have gone - numerous smaller oysters and smooth pectinids remain (Table 2 and JAGT, 1996).

THE CRIMEA

The Upper Cretaceous strata from the Bakhchisaray region in the Crimea have been studied since the beginning of the 19 th century. The numerous bivalves typical for these strata immediately attracted the attention of geologists and palaeontologists. Thus FISCHER DE WALDHEIM already in 1835 described *Alectryonia deshayesi* (= *Rastellum deshayesi*) and *Pycnodonte radiata* from the Maastrichtian of ''Mountain'' Crimea. In 1842 ROUSSEAU *in* HUOT *in* DEMIDOFF described *Ostrea mirabilis* (*Pycnodonte mirabilis*) from the same area. These descriptions of Crimean Cretaceous taxa were widely known. Fossils from the uppermost Cretaceous strata in Bakhchisaray are present in the d'Orbigny collection (Institut de Paléontologie, Muséum National d'Histoire naturelle in Paris) and are mentioned in d'ORBIGNY (1850) e.g. and most museum collections contain specimens from ''Bakhshisarai''.

No monographs on these faunas were written in the 19 th century.

In the last 50 years only two papers have described Upper Cretaceous Crimean bivalves: the inoceramids were treated by DOBROV & PAVLOVA *in* MOSKVIN (1959) and many other bivalve taxa were described by SOBETSKI (1977). Danian Crimean mollusks have been studied e.g. by MAKARENKO (1961), GORBACH (1972).

Table 1 — White Chalk Sea taxa

	Vylen	Hemmoor	Crimea	Mangyshlak	Precaspia
Pseudoptera coerulescens	*		*	*	*
Limatula decussata	*	*	*		*
Pseudolimea geinitzi	*	*	*		
Microchlamys subinflexa		*	*	?	?
Mimachlamys striatissima	*	*	*		*

Table 2 — Upper Upper Maastrichtian bivalves from the Maastrichtian type area; Kunrade contains an Upper but not uppermost Maastrichtian fauna.

	Mc	Md	Kunrade
Pinna decussata	+	+	+
"Pteria" approximata	+		
Hypoxytoma danica		+	
Pseudoptera coerulescens	+	+	
Spyridoceramus tegulatus	+		
Tenuipteria argentea		+	+
Isognomon tripterus	+	+	+
Limatula decussata			+
Li. kunradensis	+	+	+
Plagiostoma hoperi		+	+
Pl. sowerbyi	+		
Pseudolimea denticulata	+	+	?
Ps. granulata	+		+
Ctenoides dunkeri	+	+	
Ct. muricata	+	+	
Ct. tecta	+	+	
Ct. vogeli	+		
Limaria ovata		+	
Pycnodonte vesicularis	+	+	+
P. vesicularis "minor"		+	
Hyotissa semiplana	+		+
Amphidonte auricularis		+	
A. decussata	+		+
Ceratostreon pliciferum	+		
Gryphaeostrea canaliculata			+
Agerostrea ungulata	+	+	
Rastellum sp.	+		
Acutostrea sp.	+	+	
Entolium membranaceum	+	+	+
Syncyclonema haeggi	+	+	
Sy. nilsoni	+	+	
Sy. semiplicata	+	+	
Camptonectes virgatus	+	+	
Microchlamys acuteplicata		+	
Mi. campaniensis	+	+	
Mi. pulchella	+		
Mi. subinflexa	+		
Lyropecten ternatus	+	+	+
Chlamys faujasi	+	+	
Mimachlamys cretosa	+	+	+
Merklinia trigeminata	+		
Me. variabilis	+	+	
Neithea quinquecostata	+		
Ne. regularis	+	+	+
Ne. sexcostata	+	+	
Ne. striatocostata	+	+	+
Spondylus dutempleanus	+	+	+
Sp. subplicatus	+		+
Liopistha aequivalvis	+	+	+

In the Crimea in several localities (near Bakhchisaray: Salachik; Skalistoe; near Belogorsk: Belaja Skala - also called Akkaja - and a few others), the assemblage unit XXIII of ALEKSEEV (1989) contains a very rich bivalve fauna (Table 3) indicating a very shallow, warm environment. As in Maastricht, mainly the taxa with calcitic shells are preserved, and others such as nuculids, lucinids, pholadomyids are only found in steinkern preservation.

The youngest Crimean Cretaceous strata, i.e. member XXIV of ALEKSEEV (1989), best visible at Belbek, with a thickness of up to 5 m, form a short transgressive impulse, resulting in marls with numerous *Neobelemnella kazimiroviensis*, and numerous bivalves (Table 3) /large smooth pectinids, and more planktonic Foraminifera than in the very shallow-water member XXIII (ALEKSEEV & KOPAEVICH, 1997) (Table 3).

MANGYSHLAK

In N. Mangyshlak the relatively deep-water chalk Maastrichtian sections at Kyzylsay and Koskak (see in KOPAEVICH & BENJAMOVSKII, this volume, p. 000) have a terminal Cretaceous chalk unit (2-2.5 m) with an assemblage of more belemnites and diverse planktonic foraminifera; bivalves are relatively rare. As in the Maastrichtian near Maastricht and in the Crimea only pteriomorphs are preserved with shells. Probably because the Mangyshlak chalks are fairly "deep water" deposits they contain a relatively poor bivalve assemblage:

Lower Maastrichtian: pteriids (*Pseudoptera coerulescens*), oysters (*Pycnodonte* sp. , *Hyotissa semiplana*,? *Amphidonte* sp.), pectinids (*Microchlamys "pulchella"*, *Neithea sexcostata*);

Upper and uppermost Maastrichtian: pteriids (*Pseudoptera coerulescens*), a few limids (*Plagiostoma* sp. , *Pseudolimea* sp.), oysters (*Pycnodonte similis*, *Hyotissa semiplana*,? *Amphidonte* sp.) almost no pectinids (a few *Microchlamys* sp. , *Merklinia* sp. and *Neithea sexcostata*), spondylids (*Spondylus dutempleanus*). Also present in the Upper Maastrichtian of Mangyshlak until just under the K/T boundary is the inoceramid *Tenuipteria argentea*.

DANIAN

In the Danian in Mangyshlak, as is also the case in some localities on the Russian platform (ARKHANGUELSKY, 1905), just above the K/T boundary level *Pycnodonte similis* is still found but none of the other bivalve taxa known from the Maastrichtian (see above) seem to cross this boundary.

The Danian, as far as present in the three areas (JAGT, 1996; NAIDIN, 1987; 1997; NAIDIN & KOPAEVICH, 1988) is often separated from the Maastrichtian by a short time hiatus. The Lower (but not lowermost) and "middle" Danian contain a not very diversified, fairly cool water molluscan fauna (GLIBERT, 1973; GLIBERT & VAN DE POEL, 1973; JAGT & JANSSEN, 1988). The climate must have warmed up progressively and the Upper Danian fauna, especially in the Crimea, is definitely a warm

Table 3 — Maastrichtian bivalve faunas from Crimea. Abbreviations: Ak: Akkaya; St: Starocelje; Sk: Skalistoe; others: i.e. Beshkosh, Glubokij Yar, Feodosia; 1: Lower Maastrichtian; 2: Upper Maastrichtian.

	Ak 1	Ak 2	St 1	St 2	Sk 1	Sk 2	oth 1	oth 2
Hypoxytoma danica				+				
Pseudoptera coerulescens								
Tenuipteria argentea				+				
Pycnodonte mirabilis		+		+		+		
P. vesicularis	+	+	+		+		+	+
Hyotissa semiplana		+		+		+		
Amphidonte auricularis		+		+				+
A. decussata	+	+	+	+		+	+	+
A. goldfussiana		+		+				
Ceratostreon pliciferum		+		+				
Gryphaeostrea canaliculata		+		+				+
Agerostrea ungulata		+				+		
Rastellum sp.		+		+		+		+
Acutostrea sp.				+				
"Ostrea" biconvexa				+				
Entolium membranaceum								+
Camptonectes virgatus			+					+
Microchlamys acuteplicata		+		+		+		+
Mi. pulchella						+		
Chlamys denticulata		+		+		+		
Lyriochlamys septemplicata						+		+
Merklinia trigeminata			+		+			+
Neithea sexcostata		+		+		+		+
Spondylus dutempleanus	+		+		+		+	
Limatula decussata	+		+					+
Li. kunradensis								+
Li. semisulcata		+						
Plagiostoma cretaceum			+					
Pl. hoperi				+				
Pl. marrotianum		+		+				+
Pl. sowerbyi	+							
Pseudolimea granulata						+		
? Ps. geinitzi		+	+			+		
Crassatella arcacea				+				
Leptosolen sp.		+						
Panope sp.		+						
Liopistha aequivalvis		+		+		+		

water fauna. A similar change in climate is also illustrated for the microfauna of Mangyshlak by KOPAEVICH & BENIAMOVSKII (this volume).

Conclusions

— In the Maastricht area, Mangyshlak, and the Crimea similar trends in sedimentology [from chalk facies in uppermost Campanian (lower Maastrichtian in the Maastricht area) to shallow limestones, calcareous sandstones and siltic limestones (in Crimea) at the top Maastrichtian] and in community structures in the Maastrichtian (environments vary from deep to extremely shallow water) are seen.

— The Upper (but not uppermost) Maastrichtian bivalve faunas in the stratotypical Maastricht area (Nekum and lower Meerssen Members) and in the Crimea (assem-

blage XXIII of ALEKSEEV, 1989) are highly diversified and typical of a shallow, probably littoral, relatively warm environment with a Tethys influence. Near Maastricht these faunas even contain rudists.

— The uppermost Maastrichtian bivalve faunas in the stratotypical area (''middle'' Meerssen Member up to the Berg en Terblijt Horizon) contain a less diverse fauna with no obvious warm water taxa. The bivalve fauna of faunal assemblage XXIV in the Crimea is also more restricted (mainly oysters and smooth pectinids).

— The Upper Maastrichtian bivalve fauna in the Mangyshlak outcrops is not diverse. It contains no real littoral taxa, and its fauna can be considered as a ''white chalk'' fauna, representing a deeper/colder water fauna. It does not contain all typical Lower Maastrichtian ''Schreibkreide'' taxa, which do occur in the Crimea and in the Vijlen Member of the Gulpen Formation in the Maastrichtian stratotypical area.

— Biostratigraphically, the uppermost Maastrichtian strata of the three regions considered contain the belemnite *Neobelemnella kazimiroviensis* and the inoceramid *Tenuipteria argentea*. However, *N. kazimiroviensis* has a different vertical extension in the three regions - in Mangyshlak it is present throughout the Upper Maastrichtian, whereas in the Maastricht area only the uppermost Maastrichtian ''middle'' Meerssen Member contains rare *N. kazimiroviensis*. Similarly, *Tenuipteria argentea* occurs often in the Nekum and Meerssen members of the Maastricht Fm. and also in Mangyshlak it is present throughout the Upper Maastrichtian. In the Crimea it is extremely rare: I have seen so far only two specimens - one from the Besh Kosh outcrop near Bakhchisaray and one from near Feodosia.

— Environmentally, the Crimean Maastrichtian bivalve faunas of assemblage XXIII (ALEKSEEV, 1989) probably represent the ''warmest'' episode, as can be assumed from the very large and thick-shelled *Rastellum* sp. [*Rastellum pectinatum* (Lamarck) and *R. deshayesi* (Fischer de Waldheim) in literature] and from the large and equally thick-shelled *Pycnodonte radiata* (Fischer de Waldheim) and *P. mirabilis* (Rousseau in Huot).

The Upper Maastrichtian faunas (Nekum and p. p. Meerssen members) in the Maastrichtian type area contain, at approximately the same level as assemblage XXIII in Crimea, small rudists indicating a Tethyan warm water influence, but the oysters (and other pteriomorph taxa) do not reach the shell thickness nor the size of the Crimean specimens. I assume that the sea grass community in which they lived was deeper/colder than the Crimean environment - possibly about 5 - 15 m depth.

As stated above, the Mangyshlak Upper Maastrichtian was even deeper and definitely colder, without littoral taxa.

— The bivalve faunas from the three areas concerned bring complementary data for the evolution and extinction of such bivalve groups as the rudists (only around Maastricht), inoceramids (*Tenuipteria* only in Maastricht and Mangyshlak in sufficient numbers), exogyrine oysters and the Neitheinae. They also illustrate that e.g. the Pycnodonteine oysters survived the K/T boundary without the slightest problem. This can be explained by their adaptation to deeper seawater.

Acknowledgements

Many colleagues and friends over the years helped in this bivalve research. For the present paper I would especially like to thank A. S. Alekseev, A. A. Atabekian, V. N. Beniamovskii, J. M. Hancock, J. W. M. Jagt, L. F. Kopaevich, D. P. Naidin, A. M. Nikishin, E. Steurbaut. I am also very grateful to the MGU students at Polygon (1996, 1997, 1998) who collected a surprising number of unexpected and interesting taxa.

At the KBIN I thank for various help in the course of this research D. Anne, R. Cremers, H. De Potter and W. Miseur.

References

ALEKSEEV, A. S., 1989. Cretaceous System. *In:* MAZAROVICH, O. A. & MILEEV, V. S., Geologic structure of the Kacha uplift of Mountain Crimea. Mesozoic Stratigraphy. pp. 123-157. Moscow University, Moscow (in Russian).

ALEKSEEV, A. S. & KOPAEVICH, L. F., 1997. Foraminiferal biostratigraphy of the uppermost Campanian-Maastrichtian in SW Crimea (Bakhchisaray and Chakhmakhly sections). *Bulletin Institut royal des Sciences naturelles de Belgique. Série Sciences de la Terre* **67:** 103-120.

ARKHANGUELSKY, A. D., 1905. Sur quelques Ostrea du Paléocène et du Crétacé supérieur de la Russie. *Annuaire géologique et minéralogique de la Russie*, **VII, 7:** 1 - 27.

BLESS, M., 1989. Event-induced changes in Late Cretaceous to Early Paleocene ostracode assemblages of the SE Netherlands and NE Belgium. *Annales de la Société géologique de Belgique*, **112**: 19 - 30.

DHONDT, A. V., 1971. Systematic revision of *Entolium, Propeamussium* (Amusiidae) and *Syncyclonema* (Pectinidae, Bivalvia, Mollusca) of the European boreal Cretaceous. *Bulletin Institut royal des Sciences naturelles de Belgique* **47**, 32: 95 pp.

DHONDT, A. V., 1972a. Systematic revision of the Chlamydinae (Pectinidae, Bivalvia, Mollusca) of the European Cretaceous. Part 1: *Camptonectes*. *Bulletin Institut royal des Sciences naturelles de Belgique - Sciences de la Terre,* **48**, 3: 60 pp.

DHONDT, A. V., 1972b. Systematic revision of the Chlamydinae (Pectinidae, Bivalvia, Mollusca) of the European Cretaceous. Part 2: *Lyropecten*. *Bulletin Institut royal des Sciences naturelles de Belgique - Sciences de la Terre,* **48**, 7: 80 pp.

DHONDT, A. V., 1973a. Systematic revision of the subfamily Neitheinae (Pectinidae, Bivalvia, Mollusca) of the European Cretaceous. *Mémoires Institut royal des Sciences naturelles de Belgique*, **176:** 101 pp.

DHONDT, A. V., 1973b. Systematic revision of the Chlamydinae (Pectinidae, Bivalvia, Mollusca) of the European Cretaceous. Part 3: *Chlamys* and *Mimachlamys*. *Bulletin Institut royal des*

Sciences naturelles de Belgique - Sciences de la Terre, **49,** 1: 134 pp.

DHONDT, A. V., 1976. Systematic revision of the Chlamydinae (Pectinidae, Bivalvia, Mollusca) of the European Cretaceous. Part 4: *Merklinia. Bulletin Institut royal des Sciences naturelles de Belgique - Sciences de la Terre,* **51,** 7: 38 pp.

DHONDT, A. V., 1989. Late Cretaceous *Limea* (*Pseudolimea*) species of Europe. *Bulletin Institut royal des Sciences naturelles de Belgique - Sciences de la Terre,* **59**: 105-125.

DHONDT, A. V. & JAGT, J. W. M., 1987. Bivalvia uit de Kalksteen van Vijlen in Hallembaye (België). *Grondboor en Hamer*, **41**: 78-90.

DHONDT, A. V. & JAGT, J. W. M., 1988. Upper Cretaceous *Liopistha* species in North Western Europe. *Bulletin Institut royal des Sciences naturelles de Belgique - Sciences de la Terre,* **58**: 187-197.

DHONDT, A. V., NAIDIN, D. P., LEVINA, A. P. & SIMON, E., 1996. Maastrichtian faunas from the Turgay Strait (northern Kazakhstan). *Mitteilungen aus dem Geologisch-Paläontologischen Institut der Universität Hamburg*, **77**: 49-65.

DOBROV, S. A. & PAVLOVA, M. M., 1959. ''Inoceramidae'' *in* MOSKVIN, M. M., (Editor). Atlas of the Upper Cretaceous fauna of the Northern Caucasus and Crimea. Trudy VNIIGAZ, Moscow. pp. 130-165 (in Russian).

FAUJAS-DE-SAINT-FOND, B. 1799? 1802. Histoire naturelle de la Montagne de Saint-Pierre de Maëstricht. Paris, 263 pp.

FELDER, W. M. & BOSCH, H. W., in press. Afzettingen uit het Boven-Krijt en Danien in Zuid-Limburg en omgeving. Geologie van Nederland (Rijks Geologische Dienst).

FISCHER de WALDHEIM, G., 1835. Lettre à Monsieur le Baron de Férussac sur quelques genres de coquilles du Muséum Démidoff et en particulier sur quelques fossiles de la Crimée. *Bulletin Société impériale des Naturalistes de Moscou*, **8:** 101-119

GLIBERT, M., 1973. Revision des Gastropoda du Danien et du Montien de la Belgique. I. Les Gastropoda du Calcaire de Mons. *Mémoires Institut royal Sciences naturelles de Belgique,* **173:** 116 pp.

GLIBERT, M. & VAN DE POEL, L., 1973. Les Bivalvia du Danien et du Montien de la Belgique. *Mémoires Institut royal Sciences naturelles de Belgique,* **175**: 89 pp.

GOLDFUSS, A., 1833-1841. Petrefacta Germaniae. Arnz & Co, Düsseldorf. 312 pp.

GORBACH, L. P., 1972. Stratigrafiya i fauna molliuskov rannego Paleotsena Kryma. Izdatelstvo ''Nedra'', Moskva. 115 pp. (in Russian).

JAGT, J. W. M., 1995. The Maastrichtian of the Type Area (Southern Limburg, The Netherlands): recent developments. Field excursion A1. Second International Symposium on Cretaceous Stage Boundaries Brussels 8 - 16 September 1995, 15 pp.

JAGT, J. W. M., 1996. Late Maastrichtian and Early Palaeocene index macrofossils in the Maastrichtian type area (SE Netherlands, NE Belgium). *Geologie en Mijnbouw* **75**, 2-3: 153-162.

JAGT, J. W. M., 1999. An overview of Late Cretaceous and Early Palaeogene echinoderm faunas from Liège-Limburg (Belgium-The Netherlands). *Bulletin Institut royal des Sciences naturelles. Sciences de la Terre,* **69 - Supplement A:** 103-118.

JAGT, J. W. M., DONOVAN, S. K., DECKERS, M. J. M., DORTANGS, R. W., KUYPERS, M. M. M. & VELTKAMP, C. J., 1998. The Late Maastrichtian bourgueticrinid crinoid *Dunnicrinus aequalis* (d'Orbigny, 1841) from The Netherlands and Belgium. *Bulletin Institut royal des Sciences naturelles. Sciences de la Terre,* **68:** 129-154.

JAGT, J. W. M., FELDER, W. M., DORTANGS, R. W. & SEVERIJNS, J., 1996. Cretaceous-Tertiary boundary in the Maastrichtian type area (SE Netherlands, NE Belgium); a historical account. *Geologie en Mijnbouw* **75,** 2-3: 107-118.

JAGT, J. W. M. & JANSSEN, A. W., 1988. The Danian in the Maastrichtian type area (SE Netherlands, NE Belgium): past, present and future research. *Mededelingen Werkgroep Tertiair Kwartair Geologie*, **25**: 213-223.

KOPAEVICH, L. F. & BENIAMOVSKII, V. N., 1999. Foraminiferal distribution across the Maastrichtian/Danian boundary of Mangyshlak Peninsula (West Kazakhstan). *Bulletin Institut royal des Sciences de la Terre*, **69, Supplement A:** 129-145.

LIEBAU, A., 1978. Paläobathymetrische und paläoklimatische Veränderungen im Mikrofaunenbild der Maastrichtter Tuffkreide. *Neues Jahrbuch für Geologie und Paläontologie, Abhandlungen*, **157**: 233-237.

MAKARENKO, D. E., 1961. Moliyuski paleotsenovikh vidkladiv Krimu. Akakemii Nauk Ukrainsjkoi RSR, Kiiv. 111 pp. (in Ukrainian).

MALCHUS, N., 1990. Revision der Kreide-Austern (Bivalvia: Pteriomorphia) Ägyptens (Biostratigraphie, Systematik). *Berliner Geowissenschaftliche Abhandlungen* **A 125**: 231 pp.

NAIDIN, D. P., 1973. On the relationship between small units in biostratigraphy and those in palaeobiogeography. *Byulletin moskovskogo Obshchestva Ispitatiley Prirody, otdel geologicheskij,* **48:** 50 - 63 (in Russian).

NAIDIN, D. P., 1986. Cretaceous/Tertiary boundary in Mangyshlak and proposed events on the limit of the Maastrichtian and Danian. *Izvestia vuzov. Geologia i razvedka*, **9:** 3-13 (in Russian).

NAIDIN, D. P., 1987. The Cretaceous-Tertiary boundary in Mangyshlak, USSR. *Geological Magazine*, **124**: 13-19.

NAIDIN, D. P., 1997. On the two types of Cretaceous/Paleogene boundary. *Doklady Akademii Nauk,* **352**: 369-373 (in Russian).

NAIDIN, D. P., BENJAMOVSKY, V. N., & KOPAEVICH, L. F., 1984. Methods of transgression and regression study (exemplified by Late Cretaceous Basins of West Kazakhstan). 164 pp. Moscow University Press (in Russian).

NAIDIN, D. P., BEN'YAMOVSKY, V. N. & KOPAEVICH, L. F., 1996. Palaeocene reference sections of Mangyshlak. *Stratigraphy and geological Correlation*, **4,** 3: 254 - 268.

NAIDIN, D. P. & KOPAEVICH, L. F., 1988. Intraformational breaks in the Upper Cretaceous of Mangyshlak. 140 pp. Moscow University Press (in Russian).

NAIDIN, D. P., KOPAEVICH, L. F., MOSKVIN, M. M., SHIMANSKAYA, N. V., KALINICHENKO, G. P. & ANDREEV, Yu. N., 1990a. Macropalaeontological data on the Maastrichtian/Danian boundary from continuous sections in Mangyshlak. *Izvestia Akademii Nauk SSSR, Serija Geologija*, **11:** 3 - 15 (in Russian).

NAIDIN, D. P., KOPAEVICH, L. F., MOSKVIN, M. M., SHIMANSKAYA, N. V., KALINICHENKO, G. P. & ANDREEV, Yu. N., 1990b. Micropalaeontological data on the Maastrichtian/Danian boundary from continuous sections in Mangyshlak. *Izvestia Akademii Nauk SSSR, Serija Geologija*, **12:** 68-82 (in Russian).

NIKISHIN, A. M., ALEKSEEV, A. S., KOPAEVICH, L. F., YANIN, B. T., BARABOSCHKIN, E. J. & V. V. YUTSIS, 1993. Crimea Field Guide Book. Cretaceous-Eocene sedimentation in the Shelf Alma Basin of the Cimmerian mobile belt (Crimea): eustatic

and tectonic influences. Sequence stratigraphy workshop. Book 4. Crimea Field Guide Book. University of Amsterdam and Moscow State University. Department of Historical Geology and Centre for Marine Geology and Geophysics. 74 pp.

ORBIGNY, A. d', 1850. Prodrôme de Paléontologie stratigraphique universelle des animaux mollusques et rayonnés. II. Bivalvia cretacica: 72-84, 117-120, 135-139, 151-171, 194-198, 233-257.

ROUSSEAU, L. *in* HUOT, J.J.N. *in* DEMIDOFF, A. 1842. Description des principaux corps organiques fossiles. *in:* Voyage dans la Russie méridionale et la Crimée. Tome II.

SCHLOTHEIM, E. T. von, 1813. Beiträge zur Naturgeschichte der Versteinerungen in geognostischer Hinsicht. *Leonhard's Taschenbuch für Mineralogie*, **7:** 112-113.

SCHLOTHEIM, E. T. von, 1820 -1823. Die Petrefactenkunde und Nachträge zur Petrefactenkunde. pp. III-LXII, 1-437, Gotha.

SOBETSKI, V. A., 1977. Dvustvorchatie Mollyuski pozdnemelovikh platformennikh morej. *Trudy paleontologicheskogo instituta Akademii nauk SSSR* **159**: 256 pp. (in Russian).

SOBETSKI, V. A., NEKHRIKOVA, N. I., BALAN, T. M., PLAMADYALA, G. S., MASLENNIKOVA, L. N., SAVCHINSKAYA, O. V., KUZMICHEVA, E. I., BENIAMOVSKII, V. N., VOLCHEGURSKIJ, L. F., 1982. Atlas bespozvonochnikh pozdnemelovikh morej Prikaspijskoj vladini. *Trudy paleontologicheskogo instituta Akademii nauk SSSR*, **187**: 254 pp. (in Russian).

UHLENBROEK, G. D., 1912. Het Krijt van Zuid-Limburg. Toelichting bij eene geologische kaart van het Krijt-gebied van Zuid-Limburg. *Jaarverslag van de Rijksopsporing van Delfstoffen over 1911*: 48-57.

VILLAIN, J.-M., 1977. Le Maastrichtien dans sa région type (Limbourg, Pays-Bas). Étude stratigraphique et micropaléontologique. *Palaeontographica* **A 157**: 1-87.

VOGEL, F., 1895. Beiträge zur Kenntniss der holländischen Kreide. 66 pp. Brill, Leiden & Friedländer, Berlin.

WALLER, T. R., 1978. Morphology, morphoclines and a new classification of the Pteriomorphia (Mollusca: Bivalvia). *Philosophical Transactions of the royal Society of London*, **B 284**: 345-365.

ZIEGLER, P. A., 1990. Geological Atlas of Western and Central Europe. Second Ed. Shell Internationale Petroleum Maatschappij B. V., 239 pp., 56 enclosures, The Hague.

Annie V. DHONDT
Paleontologie,
Koninklijk Belgisch Instituut
voor Natuurwetenschappen
Vautierstraat 29,
B - 1000 Brussels, Belgium
[dhondt@d5100.kbinirsnb.be]

Typescript submitted: 15.2.1999
Revised typescript received: 20.4.1999

Explanation of Plate

Some Maastrichtian bivalves from the Crimea

Fig. 1 — ? *Hypoxytoma danica* (Ravn): left valve, Upper Maastrichtian, Starocelje, S. side of the valley, near Bakhchisaray; Museum of MGU at Polygon, Crimea; no n°; x 4.

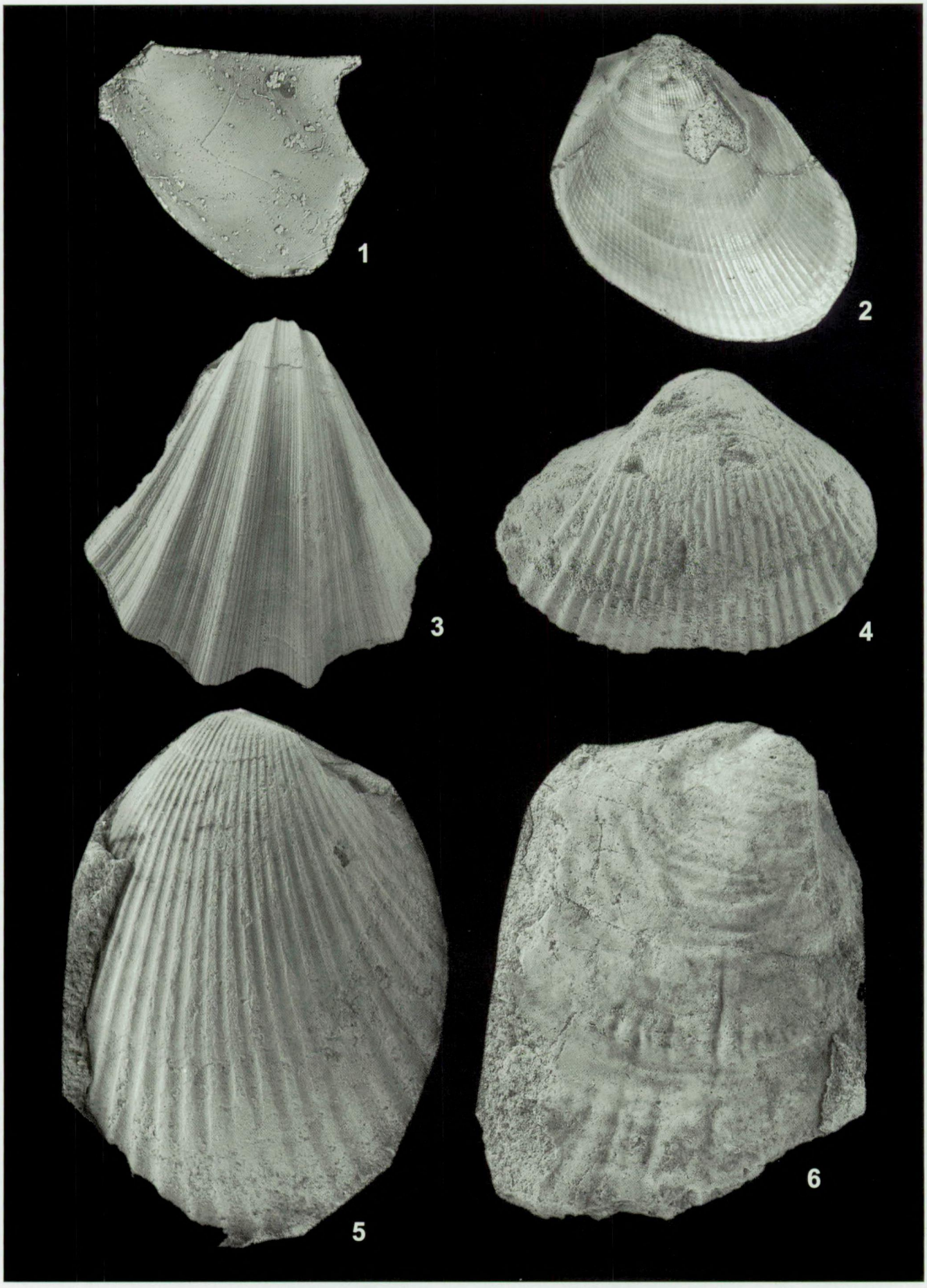
Fig. 2 — *Pseudolimea geinitzi* (von Hagenow): left valve, Upper Maastrichtian, Skalistoe, Bakhchisaray region; Museum of MGU at Polygon, Crimea; n° m 143, x 4. .

Fig. 3 — *Neithea striatocostata* (Münster *in* Goldfuss): convex valve, Upper Maastrichtian, quarry at 455.7 lower than southern side, at 150 m from the road Stavok, Bakhchisaray region; Museum of MGU at Polygon, Crimea; n° m 183, x 2.5.

Fig. 4 — *Liopistha aequivalvis* (Goldfuss): right valve, Upper Maastrichtian, near Glubokii Yar, Bakhchisaray region; Museum of MGU at Polygon, Crimea; n° m 180, x 2.

Fig. 5 — *Pseudolimea* cf. *granulata* (Nilsson): right valve, steinkern, Upper Maastrichtian, ''assemblage XXIII'' of ALEKSEEV (1989), Skalistoe, Bakhchisaray region; Museum of MGU at Polygon, Crimea; no number, x 4.5.

Fig. 6 — *Tenuipteria* cf. *argentea* (Conrad): right valve, Upper Maastrichtian, near Feodosia, E. Crimea, Museum of MGU at Polygon, Crimea; n° m 15/2, x 3.


1
2
3
4
5
6