Zitteliana	10	107–114	München, 1. Juli 1983	ISSN 0373 – 9627

Late Cretaceous transgressions and regressions on the Russian Platform

By

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With 3 text figures

ABSTRACT

During the Late Cretaceous a generally smooth eustatic transgression took place on the Russian Platform, in the Crimea and in the Transcaspian region. It was replaced in the middle of the Maastrichtian by a rapid eustatic regression. On different parts of the Platform the general eustatic transgression has been interrupted by relatively shortterm regressions determined either by an epeirogenesis or by a shallowing of the sea as a result of its being filled out by sediments; some regressions were of a eustatic nature. Data are quoted on Late Cretaceous transgressions and regressions in Western Kazakhstan (Eastern Precaspian, Mangyshlak) which supplement material published earlier (NAIDIN et al., 1980a, b).

Temperature conditions of the seas that invaded the Platform and its framework during the Late Cretaceous for the time being can not be reconstructed to give a complete picture. It is obvious that in the middle of the Late Cretaceous, when the sea areas have been largest owing to an expanding transgression, the temperatures of sea water were higher than during the Early Cretaceous. Various palaeontological data as well as data of isotope palaeothermometry indicate the lowest temperatures during the Late Cretaceous in the Early Maastrichtian. Apparently, in the Maastrichtian on the background of an expanding regression a general "deterioration" of the climate began, reaching its maximum at the beginning of the Danian.

Some general statements are made regarding the evolution of the climate at the end of the Mesozoic in connection with a change in the land/sea (ocean) ratio, the fluctuations of CO_2 concentrations in the atmosphere and the development of the terrestrial and marine flora. The dispersal of organisms, their taxonomic diversity during the Late Cretaceous in the general scheme corresponded to E. VOIGT's (1964) suggestion that thermophile marine organisms were most abundant in the Cenomanian and Late Maastrichtian which is not directly associated with climatic fluctuations, but reflects a wide occurrence during these time intervals of shallow portions of the sea floor subjected to a good heating up. In general the variety of planktonic and benthic organisms has been differently affected by transgressions and regressions. One can agree with the concepts of A. G. FISCHER and M. A. ARTHUR (1977) that, owing to the eustatic rise of the ocean level (which resulted in an expansion of the areas of continental seas), the Late Cretaceous represented a polytaxic episode in the evolution of the pelagic biota. With the polytaxic episode of 94–62 million years very exactly coincides the maximum of white chalk accumulation – a formation very characteristic for the European palaeobiogeographic region.

The necessity is recorded to correlate the evolution stages of the marine biota with the stages of the organic world evolution on land. Data available for the land indicate that a rearrangement of the vegetable kingdom and a very drastic turn in the evolution of the most numerous terrestrial animals – insects – took place at the end of the Aptian – during the Albian – or, maybe, even already at the beginning of the Cenomanian (ZHERIKHIN, 1978).

KURZFASSUNG

Während der Oberkreide wurde die Russische Tafel, die Krim und die Transcaspische Region von einer allmählichen eustatischen Transgression erfaßt. Sie wird abgelöst im mittleren Maastricht von einer schnellen eustatischen Regression. In verschiedenen Regionen auf der Tafel wird die allgemeine Transgression durch relativ kurzfristige Regressionen unterbrochen, verursacht durch epirogenetische Vorgänge oder durch Auffüllung mit Sediment; nur einige Regressionen sind eustatischen Ursprungs. Von West-Kasakstan (östliche Präcaspische Region, Mangyshlak) werden zusätzlich zu älteren Daten (NAIDIN et al. 1980 a, b) neue Ergebnisse über die Transgressionen und Regressionen vorgestellt.

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Die Aussagen über die Wassertemperaturen des Meeres auf der Tafel und ihrer Umgebung können zur Zeit noch nicht zu einem vollständigen Bild zusammengefügt werden. Es ist jedoch eindeutig, daß in der Mitte der oberen Kreide, als die weitesten Überflutungen herrschten, die Wassertemperaturen höher lagen als in der Unterkreide. Verschiedene paläontologische Hinweise und Isotopen-Paläotemperatur-Bestimmungen zeigen die niedrigste Temperatur während Oberkreide für das untere Maastricht an. Offensichtlich begann im Maastricht vor dem Hintergrund einer ausgedehnten Regression eine allgemeine Klimaverschlechterung, die ihren Höhepunkt mit dem Beginn des Dan erreichte.

Allgemeine Angaben für Klimaentwicklung am Ende des Mesozoikums im Zusammenhang mit der Meer/Land-Verteilung, der Fluktuation der CO_2-Konzentration in der Atmosphäre und der Entwicklung der terrestrischen sowie marinen Flora werden aufgezeigt. Die Ausbreitung und die Diversität der Organismen während der Oberkreide stimmt in großen Zügen überein mit der Angabe von Voigt (1964), daß thermophile marine Organismen am häufigsten im Cenoman und im oberen Maastricht sind; dies steht nicht direkt im Zusammenhang mit den Klimaschwankungen, aber zeigt an, daß weite Meeresgebiete sich durch die geringe Wassertiefe gut erwärmten. Im allgemeinen wird die Variabilität planktonischer und benthonischer Organismen durch Transgressionen und Regressionen unterschiedlich beeinflußt. In Übereinstimmung mit dem Konzept von A. G. Fischer & M. A. Arthur (1977) (durch eustatischen Meerespiegelanstieg vergrößerte sich die Fläche mit Flachmeeren) stellt die Oberkreide eine Zeit der Polytaxie in der Entwicklung der pelagischen Organismen dar. Mit dieser polytaxischen Episode (von 94 bis 62 Millionen Jahren) fällt die Hauptbildung der Schreibkreide-Sedimente zusammen.

Es wird darauf hingewiesen, wie notwendig es ist, die Evolutionsschritte der marinen Biota mit der Entwicklung auf dem Land zu vergleichen. Die verfügbaren Daten aus dem terrestrischen Bereich zeigen eine Umgestaltung des Pflanzenreiches und auch einen sehr einschneidenden Wendepunkt in der Entwicklung der artenreichsten Tiergruppe, den Insekten, am Ende des Apt und während des Alb, vielleicht bis zum Beginn des Cenoman an (Zherikhin, 1978).

I.

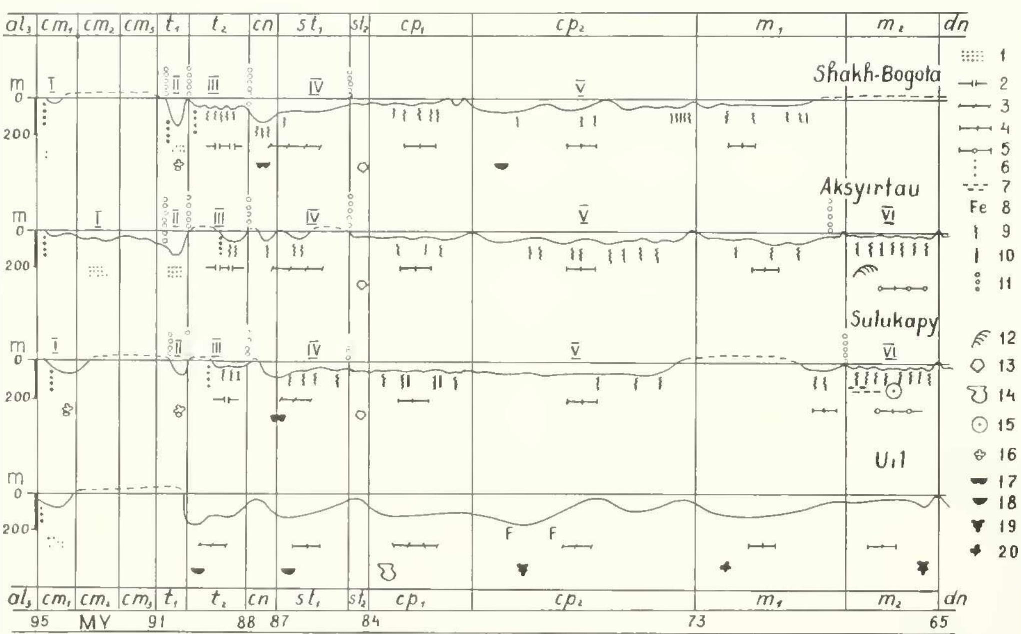

Fig. 1. Diagrams of sea depth fluctuations constructed according to the data of some Upper Cretaceous sequences on Mangyshlak and in the Eastern Precaspian.
I–VI – Upper Cretaceous lithological measures (members) of Mangyshlak.
1 – terrigenous deposits (sands, sandstones, clays, etc.), 2 – marls, coarse chalk (including "spheric" marls and chalk), 3 – predominantly marls, 4 – chalk and chalk – like marls predominant, 5 – organogene-detritic limestones, 6 – phosphorites, 7 – phosphorized coprolites, 8 – higher pyritization, 9 – hardgrounds, 10 – bands of bentonites, 11 – boundaries between the lithological measures of Mangyshlak, 12 – phytoherms, 13 – *Marsupites*, 14 – *Oxytoma tenuicostata*, 15 – large benthic foraminifers of the orbitoid group; planktonic foraminifers: 16 – *Hedbergella*, 17 – *Marginotruncana*, 18 – *Globotruncana*, – 19 – Heterohelicidae, 20 – *Rugoglobigerina*.
al, al_3 – Albian, Late Albian; cm_1, cm_2, cm_3 – Early, Middle, Late Cenomanian; t_1, t_2 – Early, Late Turonian; cn – Coniacian; st_1, st_2 – Early, Late Santonian; cp_1, cp_2 – Early, Late Campanian; m_1, m_2 – Early, Late Maastrichtian; dn – Danian.
Radiometric time scale – according to D. P. Naidin (1982) – with due regard of sedimentometric data for the Turonian and Santonian (G. Ernst, 1978) and for the Maastrichtian of the author's material on carbonate sequences of Western Kazakhstan.

Here transgression and regression diagrams are supplied compiled according to Upper Cretaceous sequences of Western Kazakhstan – the extreme south-east of the Russian Platform (Eastern Precaspian) and Mangyshlak (Figs 1, 2B). Together with our previously published data (NAIDIN et al., 1980a, b) and the material by J. M. HANCOCK (1976, Fig. 1; HANCOCK & KAUFFMAN, 1979, Fig. 4; see Fig. 2A) new information warrants an appraisal of the evolution of palaeogeographic conditions in the entire European palaeobiogeographic region (EPR).

Lithologically the Upper Cretaceous of Western Kazakhstan is distinctly divided into two unequal parts. The lower part consists of essentially terrigenous facies of Cenomanian and Lower Turonian age; their thickness comes locally to 60–75 m. The top part – from Upper Turonian to the Danian inclusively – consists of carbonate deposits 360–420 m thick (not including the Danian stage deposits).

The leading factor that determined the sedimentation and organism dispersal in Late Cretaceous seas of the Platform and Transcaspian has been their belonging during the Late Cretaceous to the EPR. The sublatitudinal trend of the EPR stretch reflects the climatic zonality of the Late Cretaceous in Western Eurasia (NAIDIN, 1973; NAIDIN et al., 1980a, b). The extraordinary similarity of fauna in the west and east of the EPR is striking. Over the enormous expanses of EPR the same belemnites (NAIDIN, 1973), bryozoans (VOIGT, 1967), inocerams (TRÖGER, 1982) and other faunistic groups are present. The biostratigraphic subdivision of Upper Cretaceous deposits used here is justified in previously published articles (NAIDIN & KOPAEVICH, 1977; NAIDIN, 1979b, 1981).

Obvious proofs of an alternation of transgressions and regressions are supplied by coastal portions of the former sea, on which there has been a predominant accumulation of terrigenous sediments. Transgressions and regressions can then be appraised by the areas involved in them. The author made an attempt to describe the transgressions and regressions by studying sequences distant from the coastline of the Late Cretaceous sea in the areas with a predominant carbonate sedimentation. In such areas it is, apparently, possible to judge about transgressions and regressions on the basis predominantly of a reconstruction of the depth of palaeobasins. This conclusion agrees with the concepts of many geologists a criterion of transgressions and regressions can be depths fluctuations: a deepening corresponds to transgressions, while a shallowing – to regressions. The relation, however, between these two pairs of concepts: deepening/shallowing and transgression/regression is much more complicated (NAIDIN et al., 1980a). The difficulty is, first of all, in establishing the relation between the phases of deepening and shallowing and the phases of an expansion and shrinking of the palaeoaquatoria. In any case, for shallow-water seas in the first approximation it is a fact that their deepening corresponds a transgression and a shallowing – a regression.

Late Cretaceous seas of Western Kazakhstan have been shallow basins. In Eastern Precaspian just as in other parts of the Russian Platform the depths did not exceed 50–200 m (NAIDIN et al., 1980a: 31). On Mangyshlak the depths of Late Cretaceous seas during the accumulation of carbonate sediments (measures 3–7; see Fig. 1) were even smaller. During some time intervals, when these sediments have been accumulating, phytal conditions existed. For instance, in the Upper Maastrichtian of the Aksyirtau sequence occur forms greatly reminding Turonian-Santonian bioherms of Northern France and the Maastrichtian-Danian of Denmark, which W. J. KENNEDY and P. JUIGNET (1974) associate with the vital activity of plants. The shallowness of Late Cretaceous basins on Mangyshlak is indicated by the presence of numerous hardgrounds surfaces formed under the effect of strong bottom currents in shallow waters.

II.

The Late Cretaceous time in the evolution of palaeogeographic conditions on the face of the Earth is connected with the expansion of the general smooth eustatic transgression, which began in the Albian and became replaced in the middle of the Maastrichtian by a rapid regression also of a eustatic nature (NAIDIN et al., 1980a, b; SLITER, 1977; VAIL et al., 1977). On the general background of eustasy events of a smaller scale were taking place. Part of them has apparently also been determined by eustatic fluctuations of the world ocean level (regressions at the Coniacian-Santonian boundary, the pre-Campanian regression). Another part (the greatest by the number of manifestations) has been determined by an epeirogenesis (Fig. 2B).

Into this scheme nicely fits the evolution of palaeogeography in Eastern Precaspian and Mangyshlak.

Among the large regional features in the evolution of palaeogeographic environments of the Late Cretaceous in the Precaspian mention should be made of the absence of Upper Cenomanian and Lower Turonian depostits, on one hand, the existence of rather deep-sea conditions in the Late Turonian, on the other (Figs 1, 2B). And yet in many regions of the world (within the USSR – in the south-west of the Russian Platform, in the Crimea and Central Asia) in the Late Cenomanian and Early Turonian there has been a definite deepening of the sea. Among other places, this phenomenon can be boldly traced on the transgression and regression diagrams for Central Asia (NAIDIN et al., 1980a, Figs 4, 5). J. M. HANCOCK on the basis of data for Western Europe and E. G. KAUFFMAN on a material obtained for North America (HANCOCK, 1976; HANCOCK & KAUFFMAN, 1979) refer one of the major Late Cretaceous transgressions to the Early Turonian and associate with the Late Turonian a substantial Late Cretaceous regression. According to R. A. REYMENT (1980) in Western and Northern Africa an extensive transgression began in the Late Cenomanian and reached its maximum in the Early Turonian when the Transsaharan basins became joined up in these regions of Africa. Very important are data on the southern periphery of the Baltic shield (Southern Sweden), according to which a transgression took place in the very Late Cenomanian (the *Actinocamax plenus* time) (BERGSTRÖM et al., 1973).

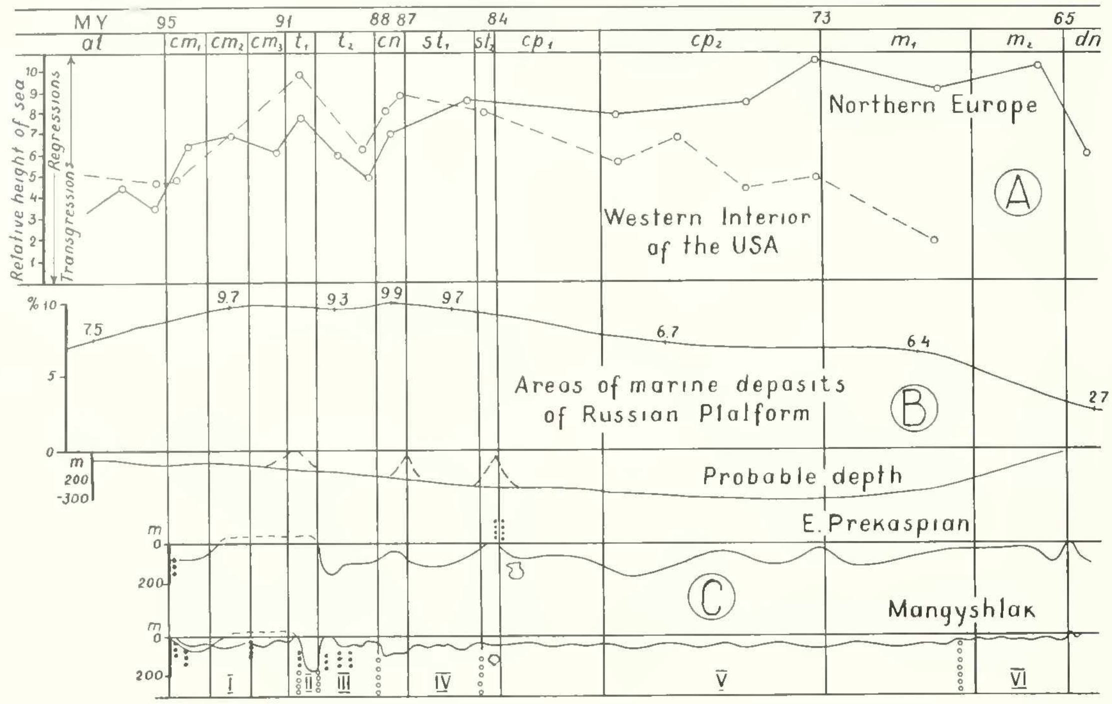

Fig. 2. A) Fluctuations of the ocean level during the Late Cretaceous. According to J. M. HANCOCK (1976, Fig. 1) and J. M. HANCOCK and E. G. KAUFFMAN (1979, Fig. 4). – B) Relations between the area occupied presently by the deposits of Upper Cretaceous stages on the Russian Platform (in % of the total Platform area) and the assumed depths of Late Cretaceous basins according to D. P. NAIDIN et al. (1980a, Fig. 6). – C) Generalized curves of depth fluctuations in Late Cretaceous seas of Eastern Precaspian and Mangyshlak.

There exist, however, quite opposite appraisals of the evolution of transgressions and regressions at the Cenomanian-Turonian boundary. So G. ERNST and F. SCHMID (1979) state that a interregional (überregional, i. e. most extensive) regression took place in the terminal Cenomanian (the "Plenus Regression"); in South-Western and South-Eastern Africa an extremely large break is present in the sequences at the Upper Cenomanian-Lower Turonian boundary (FÖRSTER, 1975; SIESSER, 1978), i. e. in the same way as in Eastern Precaspian and in many other parts of the Russian Platform.

In this way marked differences become outlined in the interpretation of the transgression-regression evolution during the Late Cenomanian-Turonian. These differences way, possibly, be connected with the differences in a stratigraphic reference of transgressions and regressions. So, for instance, S. W. PETTERS (1980) thinks that in Western Africa the transgression maximum took place not in the Early Turonian, as suggested by R. A. REYMENT, but in the Late Turonian-Coniacian. But it might be that there are also deeper reasons for it.

Just as on the remaining part of the Platform, there is a most pronounced transgressive occurrence in the Precaspian of "Pteria beds" of the Campanian base – an Early Campanian transgression.

A very interesting feature in the evolution of the palaeogeography of the Eastern Precaspian is a certain sea deepening at the very end of the Maastrichtian (Fig. 1 – diagram for Uil; Fig. 2B). This deepening that took place on the background of a general eustatic Late Maastrichtian regression can be detected by the plankton/benthos ratio (P/B). The deepening, apparently, corresponds a brief regional transgression, as result of which the Upper Maastrichtian deposits on the Mugodzhary and on the eastern flanks of the Urals rest directly on Palaeozoic deposits and even on Precambrian rocks (NAIDIN et al., 1980a).

The transgressive occurence of constantly younger deposits of the Upper Cretaceous (including the Maastrichtian) in moving from the west eastwards in the Preurals has been recorded by P. L. BEZRUKOV (1938). In the Volga region the Lower Maastrichtian in some localities rests on the Albian. Cases of a transgressive occurrence of the Maastrichtian are known in Bulgaria and Italy. However, we regard all these occurrences only as complications of a general regression at the end of the Late Cretaceous.

On Mangyshlak the evolution of the general transgression in the Cenomanian has been complicated by local movements; and yet, just as in the Precaspian and in other substantial areas of the Russian Platform, beginning with the middle of the Cenomanian and throughout nearly the entire Late Cenomanian there has been a predominance in this region of regression conditions.

A very important feature in the evolution of palaeogeography on Mangyshlak during the Late Cretaceous was the existence in the early Turonian of sufficiently stable marine conditions. Despite a predominance of a terrigenous sedimentation (measure II), the depths of the Early Turonian basin of Mangyshlak (estimated by the P/B ratio) have been greater than during the subsequent ages, when carbonate sediments have been accumulating. In this way by the tendency of transgressions and regressions evolution Mangyshlak during the Early Turonian approached conditions fixed for the south-west of the Platform, the Crimea, Middle Asia and many regions beyond the boundaries of the USSR (Fig. 1).

Beginning with the Late Turonian and to the beginning of the Late Santonian, owing to a general rise of the world ocean level a carbonate regime of sedimentation gets established in the area (members III and IV). The peculiarity of the regime consisted in an extensive occurrence of Calcisphaerulidae ("spheric" chalk). Drastic fluctuations in the completeness of the sequences and in the thickness of separate stratigraphic levels of the members III and IV indicate an unstable tectonic regime of the region.

The picture substantially changes beginning with the Late Santonian, in other words, since the beginning of the accumulation of measure V, in the composition of which there is a pronounced predominance of chalk. We associate the change in the nature of sedimentation, firstly, with the continued global rise of the sea level and, secondly, with a stabilization of the tectonic regime of the region. A combined effect of these two factors resulted in a general equalization of local physico-geographical environments, which led to an accumulation of thick measure V. The sea depths somewhat changed throughout the accumulation time of the measures. At certain moments, when thin bentonite bands have been formed, the depths could have been substantial, which is demonstrated by a sharp reduction in the number and, sometimes, even a complete absence of foraminiferal tests (H. Ernst, 1978). But on the whole, by the end of the accumulation of chalk measures, the sea depths become very small, which, among other things, is indicated by an increase in the number of hardgrounds surfaces. We see no contradiction between the assumed by us genereal eustatic rise of the ocean level and the shallowing of the Campanian sea on Mangyshlak: the shallowing is connected with a filling out of the Mangyshlak sea by sediments. The possibility of such a process has been discussed previously (Naidin et al., 1980a: 40; Naidin et al., 1980b: 386, Fig. 10).

In this way, we refer the beginning of the transgression during which measures V have been accumulated, to the Late Santonian. This coincides with the data of G. Ernst and F. Schmid (1979), who distinguish in the GFR a "*Marsupites* transgression" (beds with *Marsupites* occur transgressively on Lower Turonian deposits).

An amazingly extenisve – cosmopolitan – range of Marsupites from Australia to North America associated with a very-very brief time interval is a doubtless proof of a global nature of the phenomenon: this has been a moment of a most pronounced thalassocraty.

All the transgressions mentioned have been eustatic. However, we think, just as T. Matsumoto (1977), that there should not always be a complete synchroneity of regressions and transgressions and particularly of their maxima in different areas. Worth attention is the explanation by N. A. Mörner (1976) of "anomalous" transgressions embracing one region, but of untraceable in other regions by the effect of a geoidal eustasy.

In the same way as in other regions of the world the Maastrichtian (organogene-detritic measure VI) of Mangyshlak has been a time of regression.

III.

The presence of numerous discontinuities of a varying scale is one of the characteristic features of Upper Cretaceous sequences on Mangyshlak and in Eastern Precaspian.

An analysis of the size of gaps is of great importance in constructing diagrams for transgressions and regressions. An appraisal of the scale of gaps has been done for Upper Cretaceous strata of Eastern Precaspian. Methods suggested by A. A. Saveljev (1971) have been used; they permit to appraise and show clearly the stratigraphic scale of the hiatus. By the scale of the stratigraphic hiatus four categories of gaps have been distinguished (Fig. 3).

The stratigraphically large pre-Upper Turonin break traceable on the Platform, which determined a peculiar evolution of palaeogeographic environments at the Cenomanian-Turonian boundary, over substantial portions of the Platform, reflected the effect of a regional factor. At the same time a stratigraphically minor interval between the Maastrichtian and Danian can be traced all over the world and is associated with the effect of a global mechanism (Naidin et al., 1980a, b; Naidin, 1976).

It is amazing that the events at this boundary were proceeding on the background of a generally one cycle of carbonate sedimentogenesis. E. Voigt (1981) with full justification stated that coccolite-bryozoan limestones in the Danian of Europe in a natural way complete the carbonate cyclothem of the Late Cretaceous.

IV.

Before speaking about the climatic conditions of the EPR during the Late Cretaceous, a few general remarks should be made on the palaeoclimatic reconstructions.

The main factors determining a climate are: 1) the intensity of solar radiation; 2) the concentration of carbon dioxide (CO_2) in the atmosphere; 3) the land/sea (ocean) ratio. Fluctuations of these three factors in the geological past are the main cause of global changes in the climate. Other factors also affect the climate. But no matter how enormous they might be imagined (possible migrations of continents, displacements of the poles, etc.), they are only of a secondary, regional significance.

The effect of the first fundamental factor, i. e. the effect of the sun leads to the origin on the surface of the globe of clima-

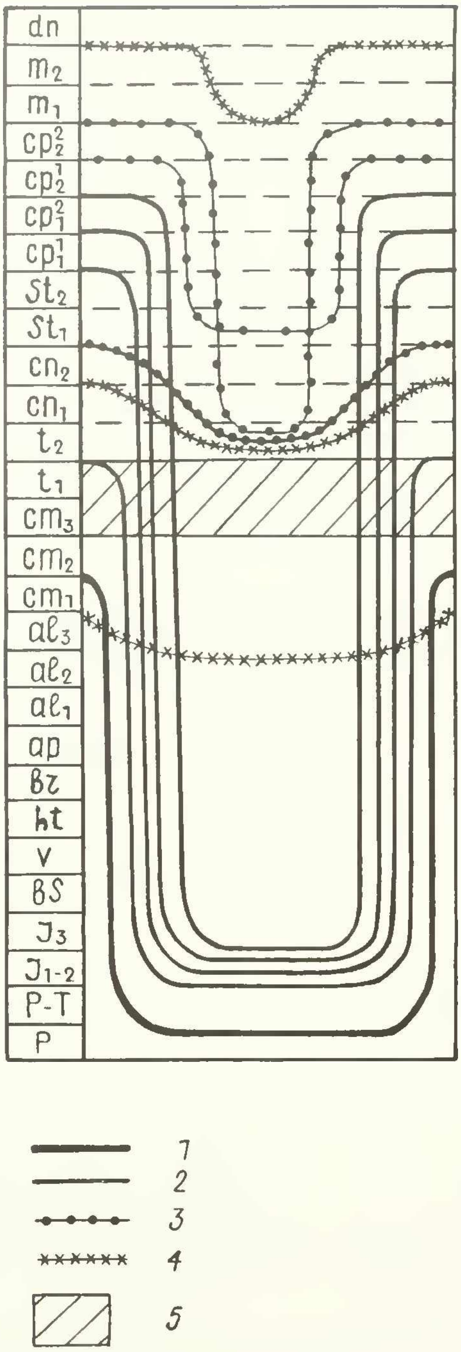

Fig. 3. Types of gaps by the scale of stratigraphic hiatus in Upper Cretaceous deposits of Eastern Precaspian.
The interval embraces the deposits of: 1 – systems, 2 – parts of systems, 3 – stages, 4 – substages, 5 – deposits are absent.
P – Permian; P-T – Permo-Triassic; J_1, J_2 – Lower and Middle Jurassic; J_3 – Upper Jurassic; *Lower Cretaceous:* bs – Berriasian, v – Valanginian; h – Hauterivian; br – Barremian; ap – Aptian; al_1, al_2, al_3 – Lower, Middle and Upper Albian; *Upper Cretaceous* – see caption of Fig. 1.

tic belts. Climatic zonality is the most important manifestation of a solar climate. Reconstructions of geological changes in the climate are limited first of all by the establishment of the climatic zonality of the past. It should be noted that in mobilistic palaeoclimatic constructions it is not the climatic zonality of the globe that is reconstructed, but mainly the belonging of a certain continent to this particular climatic zone.

We have certain information on the changes at the end of the Mesozoic in the second and third factors. Let us begin with the third: the ratio of land and sea expanses. The tremendous eustatic Late Cretaceous transgression, which lead to an expansion of epicontinental basins, undoubtedly resulted also in a general global warming up as compared with the Early Cretaceous. In the middle of the Late Cretaceous, according to lithological data and the data of isotope palaeothermometry (Teiss & Naidin, 1973) beyond the Polar Circle on the 70–75° of N. Lat. surface temperatures of the water were 15–17° C. A global regression at the end of the Cretaceous, as result of which the area of the land increased and the aquatoria shrank, must have lead to a drop in temperature.

To establish the effect of the second factor is much more complicated. The original source of carbon dioxide in the atmosphere is the volcanic activity. It seems that researchers agree on this point. It seems that after the papers by S. Arrenius and other authors at the end of last century the greenhouse effect on the degree of heating of the atmosphere is not denied by anybody.

M. I. Budyko has compiled (1980, Fig. 2–1; 1981, Fig. 3) for the Phanerozoic diagrams of changes of volcanic activity and CO_2 concentration in the atmosphere. It follows from these diagrams that first of all there has been a certain intensification of volcanic activity during the Cretaceous and its obvious slackening down at the end of the period, which lasted with minor variations throughout the Cenozoic; secondly, an increase in CO_2 concentration in the Late Cretaceous and a marked decrease in this concentration (again with fluctiations) during the Cenozoic. In this way these data, generelly speaking, confirm the conclusion derived from the land/sea (ocean) ratio effect. The real pattern has been however much more complicated, because in the system atmosphere – land-sea (ocean), the state of which actually determines the what we call the c l i m a t e, the CO_2 content is controlled by a number of factors. The most important of them, undoubtedly, is the photosynthetizing activity of the plants.

An expansion of angiosperms began at the end of the Early Cretaceous epoch on land and at the same time (or maybe somewhat later – in the Cenomanian) a phytoplankton "burst" began in the oceans. Obviously a sharp increase in the number and mass of CO_2 consumers must have meant its high concentrations. It is true that an opposite opinion is also put forth. M. I. Golenkin and Yu. V. Teslenko (see Vakhrameev, 1978: 10) associate the replacement of a predominance of gymnosperms by angiosperms at the end of the Early Cretaceous with a decrease of the CO_2 amount in the atmosphere.

Directly related to the problem of transgressions and regressions is the establishment of the role of phytoplankton and the terrestrial flora in regulating the CO_2 content. When more CO_2 had been consumed (and, consequently entered the deposits): during the periods of regression (which means mainly by a terrestrial flora) or during transgressions (and, consequently, predominantly by a marine flora)?

For the time being there is no satisfactory answer to this question. D. M. McLean (1978 a) assumes that a leading role in combining the atmospheric carbon dioxide belongs to the terrestrial flora. That is why in his opinion to the epochs of regression corresponds a decrease in the CO_2 content in the atmosphere, whereas the epochs of transgressions are characterized by higher CO_2 concentrations, which differs from the accepted views on the leading role of phytoplanton in the consumption of CO_2 from the atmosphere. In this case, if we remember the greenhouse effect, at an expansion of terrestrial areas a refrigeration should take place whill a warming up occurs during transgressions.

The papers by D. M. McLean (1978a, b) contain quite an extensive bibliography on this problem. Here we are going to present briefly our variant for the evolution of the CO_2 content and the effect of this process on the evolution of the climate at the end of the Mesozoic.

The supply of the volcanic carbon dioxide in geosynclines during the Cretaceous has, apparently, been substantial. Even in the white chalk sequences – a most characteristic formation of the EPR and, as it would seem, a very distant one from volcanic manifestations – bands of bentonite are quite usual as well as various forms of "camouflaged volcanic material" (Muravjev, 1976).

An increase in the amount of CO_2 lead, on one hand, to a rapid development at the end of the Early Cretaceous – the beginning of Late Cretaceous of its consumers – terrestrial and marine plants, and, on the other hand, to a general warming up throughout the greater part of the Late Cretaceous, which happened on the background of a progressing transgression. The absorption of CO_2 by plants and a decrease in the supply of a volcanic carbon dioxide resulted in a cooling of the atmosphere and of the surface waters in sea basins, this, in its turn, increasing the solubility of CO_2 in the water and, correspondingly, a rise of the CCD level. All this together with a developing regression meant a "deterioration" of the climate, that began, apparently, during the Early Maastrichtian and reached its maximum at the beginning of the Danian.

The development of the vegetable cover of the Earth depending upon the land/sea (ocean) ratio and upon the CO_2 content – is a self-regulating process, operating according to the biospheric homeostate principle (Barinov, 1972). In a more general form the ratio land/sea (ocean), atmosphere and terrestrial vegetation obey mechanisms of autocorrelation (Funnel, 1981).

And now about the climatic conditions in EPR during the Late Cretaceous. The sea basins of EPR belonged to the southern part of a wide warm climatic belt. In the middle of the Late Cretaceous, when the aquatoria have been at their largest, the temperatures of sea water were higher than during the Early Cretaceous. According to micropalaeontological (Bettenstaedt, 1962; Wicher, 1953), macropalaeontological (Jeletzky, 1951) data, as well as by the dispersal of Coccolithophoridae (Reinhardt, 1973) and the data of isotope palaeothermometry (Teiss & Naidin, 1973) a slight drop in temperature took place in the Early Maastrichtian. This fits the above quoted scheme of the colder spells at the end of the Cretaceous period. However, undoubtedly, the process has been much more complicated – the refrigeration has not been uniform, which is indicated by somewhat higher temperatures (as compared with the Early Maastrichtian) recorded according to the Late Maastrichtian fauna. It is possible that the Late Maastrichtian warming up is associated with the peculiarities of the Late Maastrichtian palaeogeography mentioned higher up. Relatively sharp transient temperature fluctuations may have occured at the Maastrichtian-Danian boundary (Naidin, 1976a: 201).

V.

The dispersal of organisms, their taxonomic diversity during the Late Cretaceous in a general scheme corresponds the suggestion by E. Voigt (1964) that: thermophile organisms have been most abundant in the Cenomanian and Late Maastrichtian; during these time inervals the taxonomic variety has been, correspondingly, the greatest. Such a conclusion hardly reflects a direct effect of the temperature factor. Simply in the Cenomanian and Late Maastrichtian there have been extensive shallow-water portions of the seas subjected to a good heating.

The variety of planktonic and benthic organisms is affected differently by transgressions and regressions. It is, probably, possible to agree the concepts of A. G. Fischer and M. A. Arthur (1977) that the Late Cretaceous owing to an eustatic rise of the ocean level (which reasulted in an expansion of the aquatoria of epicontinental seas, including the sea of the Platform), represented a polytaxic episode in the biota evolution of the pelagic zone.

Polytaxic 32 – million – year intervals were separated from each other by shorter oligotaxic episodes. The Late Cretaceous polytaxic episode began in the Turonian (94 million years ago) and ended at the end of the Maastrichtian (62 million years), which nearly ideally coincides with accumulation maximum of an extremely peculiar formation of epicontinental seas of the EPR – white chalk, the accumulation of which reflects a maximum in the abundance of the phytoplankton.

In the light of the problem on the establishment of the role of terrestrial and marine plants in the CO_2 balance of the atmosphere refered to in section IV of this paper, it is most important to correlate events that took place in the oceans with those that occurred on land. Material available for the land shows that a rearrangement of the vegetable kingdom and a very drastic change in the evolution of insects took place at the end of the Aptian – in the Albian – maybe during the beginning of the Cenomanina (Zherikhin, 1978). A determining role in the organic world does not belong to the largest but most numerous organisms that have the greatest biomass (Rodendorf & Zherikhin, 1974: 87). In the ocean such organisms were planktonic forms, while on the land – invertebrates, first of all insects. It seems that times of biota rearrangements (in the oceans oligotaxic episodes according to Fischer and Arthur) of the and and sea in general have been more lengthy. By such stages of major biogeocenosis changes was limited on the whole the Late Cretaceous (nearly exactly corresponding the polytaxic episode 94–62 million years of Fischer and Arthur): the Albian (maybe the end of the Aptian) – nearly the entire Cenomanian to its beginning and the end of the Maastrichtian – the beginning of the Danian – after it.

REFERENCES

BARINOV, G. V. (1972): Biosfernye ritmy i problema sokhranenija kislorodnogo ravnovesija. – Zhurnal obshchej biologii, 33 (6): 771–778.

BEZRUKOV, P. L. (1938): Mezozojskie otlozhenija na Ufimskom plato. – Izvestija Akademii Nauk SSSR, serija geol., **5–6**: 699–708.

BERGSTROM, J., CHRISTENSEN, W. K., JOHANSSON, C. & NORLING, E. (1973): An extension of Upper Cretaceous rocks to the Swedish west coast at Särdal. – Bull. geol. Soc. Denmark, **22** (2): 83–154.

BETTENSTAEDT, F. (1962): Evolutionsvorgänge bei fossilen Foraminiferen. – Mitt. Geol. Staatsinst. Hamburg, **31**: 385–460.

BUDYKO, M. I. (1980): Klimat v proshlom i budushchem. Gidrometeoizdat: 350 s.

— — (1981): Izmenenija okruzhajushchej sredy i formirovanie posledovatel'nykh faun. – Paleont. Zhurnal, **1**: 3–11.

ERNST, G. (1978): Forschungsfortschritte in der Oberkreide von NW-Deutschland. – Internat. Symposium Deutsche Kreide (Münster), Kurzfassungen der Vorträge: 72–73.

— — & SCHMID, F. (1979): Die Oberkreide des Raumes Braunschweig-Hannover unter besonderer Berücksichtigung des Cenoman und Turon. – Excursionsführer „Kreide Niedersachsen", Berlin-Braunschweig: 1–75.

ERNST, H. (1978): Zu Bathymetrie und Sedimentstrukturen der Schreibkreide von Lägerdorf/Holstein (Coniac-Santon). Eine quantitative Analyse der Foraminiferen-Faunen. – Mitt. Geol.-Paläont. Inst. Univ. Hamburg, **48**: 53–78.

FISCHER, A. G. & ARTHUR, M. A. (1977): Secular variation in the pelagic realm. – Soc. Econom. Paleontol. and Miner. Spec. Publ., **25**: 19–50.

FÖRSTER, R. (1975): The geological history of the sedimentary basin of Southern Mozambique, and some aspects of the origin of the Mozambique channel. – Palaeogeography, Palaeoclimatology, Palaeoecology, **17** (4): 267–287.

FUNNELL, B. M. (1981): Mechanisms of autocorrelation. – J. geol. Soc. London, 138 (2): 177–181.

HANCOCK, J. M. (1976): The petrology of the Chalk. – Proc. Geol. Assoc. London, 86 (4): 499–535.

— — & KAUFFMAN, E. G. (1979): The great transgressions of the Late Cretaceous. – Journal Geol. Soc. London, 136 (2): 175–186.

JELETZKY, J. A. (1951): Die Stratigraphie und Belemnitenfauna des Obercampan und Maastricht Westfalens, Nordwestdeutschlands und Dänemark sowie einige allgemeine Gliederungs-Probleme der jüngeren borealen Oberkreide Eurasiens. – Beihefte zum Geol. Jb., **1**: 1–142.

KENNEDY, W. J. & JUIGNET, P. (1974): Carbonate banks and slump beds in the Upper Cretaceous (Upper Turonian-Santonian) of Haute Normandie, France. – Sedimentology, **21**: 1–42.

MATSUMOTO, T. (1977): On the so-called Cretaceous transgressions. – Spec. Pap. Palaeontol. Soc. Japan, **21**: 75–84.

MCLEAN, D. M. (1978a): Land floras: the major Late Phanerozoic atmospheric Carbon dioxide/Oxygen control. – Science, 200 (4345): 1060–1062.

— — (1978b): A terminal Mesozoic "Greenhouse": lessons from the past. – Science, 201 (4354): 401–406.

MÖRNER, N.-A. (1976): Eustasy and geoid changes. – J. Geol., 84 (2): 123–151.

MURAVJEV, V. I. (1976): Porody – indikatory global'nykh izmenenij ekologicheskikh obstanovok. – Doklady Akademii Nauk SSSR, 229 (4): 943–946.

NAIDIN, D. P. (1973): O sootnoshenii biostratigraficheskikh i paleobiogeograficheskikh podrazdelenij nizshego ranga. – Bjull. Moskovsk. ob-va ispytatelej prirody, otd. geol., **48** (6): 50–63.

— — (1976): Granitsa mela i paleogena. – V knige: „Granitsy geologicheskikh sistem". Nauka: 225–257.

— — (1979a): The Cretaceous/Tertiary boundary in the USSR. – In: CHRISTENSEN, W. K. & BIRKELUND, T. (eds.): "Cretaceous-Tertiary boundary events. II. Proceedings", Copenhagen: 188–201.

— — (1979b): Vergleichende Stratigraphie der Oberen Kreide der Russischen Tafel und West-Europas. – In: Aspekte der Kreide Europas, IUGS Ser. A, **6**: 497–510.

— — (1981): The Russian Platform and the Crimea. – In: REYMENT, R. A. & BENGTSON, P. (eds.): "Aspects of Mid-Cretaceous regional geology", London, Acad. Press: 29–68.

— — (1982): Geokhronologija melovogo perioda. – Bjull. Moskovsk. ob-va ispytatelej prirody, otd. geol., **57** (1): 57–72.

— — & KOPAEVICH, L. F. (1977): O zonal'nom delenii verkhnego mela Evropejskoj paleobiogeograficheskoj oblasti. – Bjull. Moskovsk. ob-va ispytatelej prirody, otd. geol., **52** (5): 92–112.

— — SAZONOVA, I. G., POJARKOVA, Z. N., DZHALILOV, M. R., PAPULOV, G. N., BEN'JAMOVSKIJ, V. N. & KOPAEVICH, L. F. (1980a): Melovye transgressii i regressii Vostochno-Evropejskoj platformy, Kryma i Srednej Azii. – Bjull. Moskovsk. ob-va ispytatelej prirody, otd. geol., **55** (5): 27–42.

— — SAZONOVA, I. G., POJARKOVA, Z. N., DZHALILOV, M. R., PAPULOV, G. N., SENKOVSKIJ, YU. N., BEN'JAMOVSKIJ, V. N. & KOPAEVICH, L. F. (1980b): Cretaceous transgressions and regressions on the Russian Platform, in Crimea and Central Asia. – Cretaceous Research, **1** (4): 375–387.

PETTERS, S. W. (1980): Biostratigraphy of Upper Cretaceus foraminifera of the Benue Trough, Nigeria. – J. Foram. Research, 10 (3): 191–204.

REINHARDT, P. (1973): Über die Ökologie der kretazischen Coccolithen. – V sbornike: „Mikrofossilii drevnejshikh otlozhenij", Nauka: 47–50.

REYMENT, R. A. (1980): Biogeography of the Saharan Cretaceous and Paleocene epicontinental transgressions. – Cretaceous Research, **1** (4): 299–327.

RODENDORF, B. B. & ZHERIKHIN, V. V. (1974): Paleontologija i okhrana prirody. – Priroda, **5**: 82–91.

SAVELJEV, A. A. (1971): O stratigraficheskikh nesoglaisjakh v tolshche nizhnemelovykh otlozhenij Mangyshlaka. – Bjull. Moskovsk. ob-va ispytatelej prirody, otd. geol., **46** (2): 68–73.

SIESSER, W. G. (1978): Leg 40 results in relation to continental shelf and onshore geology. – Init. Rep. Deep Sea Drilling Project, 40: 965–979.

SLITER, W. V. (1977): Cretaceous foraminifera from the south-western Atlantic Ocean. – Init. Rep. Deep Sea Drilling Project, 36: 519–545.

TEISS, R. V. & NAIDIN, D. P. (1973): Paleotermometrija i izotopnyj sostav kisloroda organogennykh karbonatov. – Nauka: 255 s.

TRÖGER, K.-A. (1982): Remarks concerning inoceramid zonation of Cenomanian to Middle Turonian sequences between West Europe and West Asia. – Cretaceous Research (in press).

VAIL, P. R., MITCHUM, R. M. & THOMPSON, S. (1977): Seismic stratigraphy and global changes of sea level, part 4: Global cycles of relative changes of sea level. – In: C. E. PAYTON (ed.): „Seismic stratigraphy – applications to hydrocarbon exploration": 83–97.

VAKHRAMEEV, V. A. (1978): Klimaty severnogo polusharija v melovom periode i dannye paleobotaniki. – Paleont. Zhurnal, **2**: 3–17.

VOIGT, E. (1964): Zur Temperatur-Kurve der oberen Kreide in Europa. – Geol. Rundschau, **54**: 270–317.

— — (1967): Oberkreide-Bryozoen aus den asiatischen Gebieten der USSR. – Mitt. Geol. Staatsinst. Hamburg, **36**: 5–95.

— — (1981): Critical remarks on the discussion concerning the Cretaceous – Tertiary boundary. – Newsletter Stratigr., 10 (2): 92–114.

WICHER, C. A. (1953): Mikropaläontologische Beobachtungen in der höheren borealen Oberkreide, besonders im Maastricht. – Geol. Jb., **68**: 1–25.

ZHERIKHIN, V. V. (1978): Razvitie i smena melovykh i kajnozojskikh faunisticheskikh kompleksov (trakhejnye i khelitserovye). – Trudy Paleont. in-ta Akademii Nauk SSSR, **165**: 1–198.