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EVIDENCE OF UPPER CRETACEOUS WORLD OCEAN EUSTACY IN THE NORTH OF SIBERIA

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Signs of the World Ocean eustacy have been identified in the Upper Cretaceous section of the Ust-Yenisei trough at the Cenomanian—Turonian boundary (analogue of anoxide event OAE-2), in mid-Turonian (regressive phase), in the Turonian roof (transgressive phase), in the Santonian (transgressive and regressive phase), in the Campanian (transgressive phase) and (?) Maastrichtian (regressive phase). Analysis of dynamics of section formation and application of global cyclostratigraphic scale allowed the following unit chronozones of the 3rd order to be distinguished: UZA-2.5 (end-Cenomanian—Lower Turonian); UZA-3.1 (end-Turonian—Early Coniacian), UZA-3.2 (Upper Coniacian), UZA-3.3 (Santonian). The Campanian-Maastrichtian interval represented by one unit cyclite is not identified.

Signs of global events are of interest as ideal chronostratigraphic correlation levels in sedimentary formations and evidence of events of all-planetary nature in the Earth history as well.

In connection with searching for signs of global events in the geologic past, the deposits formed on rigid and stable plates deserve special attention. The results of all-planetary processes, particularly those involved with the World Ocean eustacy, are supposed to be conserved just under plate stable conditions.

Some levels with signs of global events are known from Upper Cretaceous. To discover them we, should make purposeful analysis of section structure, dynamics of biota development and definition of geochemical criteria. Such studies have not been fulfilled on the territory of Siberia up to now, though Upper Cretaceous marine sequences have been known from the Ust-Yenisei trough long since [1].

Upper Cretaceous deposits are distributed throughout West Siberia. However, they are exposed only in some places along the periphery of the West Siberian Plain.

Most complete Upper Cretaceous sequences are exposed within the Ust-Yenisei trough and contain all stages from Cenomanian to Maastrichtian (Fig. 1). A detailed composite section for this region was first composed on the basis of the correlation of five reference sections, each being represented by dozens of outcrops at separate areas. The section descriptions have been published somewhere [2–4].

Reference sections at the rivers Nizhnyaya Agapa (Upper Cenomanian—Lower Turonian), Yangoda (Upper Turonian—Coniacian) and Tanama (Santonian—Campanian—?Maastrichtian) are the most informative and complete. They are related with each other by comparatively small outcrops on the eastern coast of the Yenisei gulf, near the mouth of the Chaika River (Upper Turonian base) and above the village of Vorontsovo, near the Bragina Brook (Upper Coniacian). All the sections were correlated by methods of zonal biostratigraphy and thus a composite section was derived for the Upper Cretaceous Ust-Yenisei trough (Fig. 2).

Apparent total thickness of the Upper Cretaceous deposits in outcrops is 450 m and, according to borehole data, 500 to 900 m [5]. We believe that some gaps in observations do not significantly affect the completeness of the section model proposed below. The only significant deficiency here is the lack of exposures of intermediate beds between Coniacian and Santonian. According to borehole survey, the Lower Santonian is 150 m thick in the section [1].

The Ust-Yenisei Upper Cretaceous section includes all basic units both of geostratigraphic and regional stratigraphic scales (see Fig. 2). All substages and inoceram zones are recognized within the interval from Upper Cenomanian to Upper Santonian. Some of inoceram zones include cosmopolitan zones (*labiatus, lamarcki, cardissoides, patootensis*). The Campanian and ?Maastrichtian stages, where inocerams are absent, are not subdivided. The Maastrichtian stage in the Tanama River section is traditionally recognized by records of *Baculites anceps leopoliensis* N o w . * and *Tancredia americana* M e e k , while the underlying clays lacking in

* Preliminary identification of the baculited fragments sampled from ?Maastrichtian led A. L. Beizel to the conclusion that they could

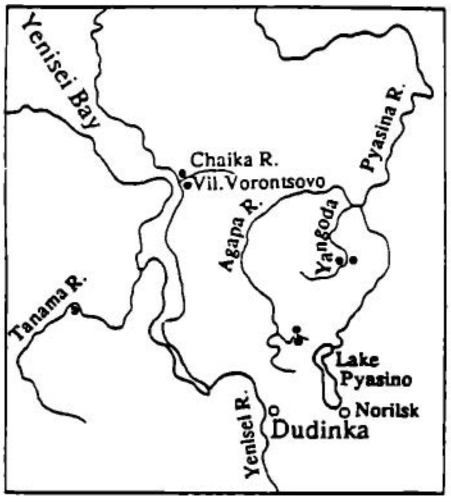

Fig. 1. Location of Upper Cretaceous reference sections of the Ust-Yenisei depression.

age-suggestive macrofossils, are referred to Campanian according to their position in the section between fossiliferous Santonian and Maastrichtian [3].

The Upper Cretaceous section is made up of alternating continental and marine rocks, the latter being predominant. Lithologically it is represented by terrigenous sandy silt-argillaceous rocks or by their weakly cemented varieties. Calcareous and phosphate concretions, intercalations of sandstones and siltstones constitute an insignificant portion of the section. Sandy silts predominating in the section are characterized by their enrichment with silicate ferruginous minerals of glauconite group, which is more typical of Upper Turonian, Coniacian, and Santonian deposits. Clay members are of special interest to us. Clay thin intercalations and lenses occur throughout the section, but more thick (from 8 to 20 m) and persistent members, corresponding to the maximum transgressions, occur at the base of Lower Turonian, at the Turonian – Coniacian boundary, in the roof of Upper Coniacian zone of *russiensis* and Campanian.

Transgressive-regressive curve in Fig. 2 was chiefly plotted on the basis of facies analysis data. Along with sedimentologic features, continental facies are recognized by the lack of remains of marine macro- and microfauna and microphytoplankton. They contain spores and pollen only. Lagoonal-marine (or lagoonal-continental) deposits are defined to be transient from continental to typical marine and occupy an intermediate position in facies series. As a rule, they contain representative assemblages of marine microphytoplankton, though lacking in remains of marine macrofauna. Shallow-water marine rocks are characterized by essentially sandy composition, abundance of fauna remains and trace fossils, phosphate concretions and other peculiar indications. Deep-water marine environments are recognized through comparatively thick clay members lacking in remains of benthic groups or being characterized by their taxonomic poorness (the shells of one or two species of typical marine benthic mollusks are present).

At the base of the Upper Cretaceous section there is the unit of continental alluvial-deltaic sands, the Dolgan Suite of the Upper Cenomanian age (the Uvat horizon), which is exposed at the Nizhnyaya Agapa R.. The rocks contain many carbonaceous interbeds and wood fragments, amber grains with remains of the Upper Cenomanian insects inside [6]. Upward the section the continental deposits are rapidly replaced by typical marine deposits, yielding rich invertebrate and dinoflagellate assemblages, whose Cenomanian age is defined by numerous records of *Inoceramus pictus* S o w. [2].

The transgression reaches its maximum by the early Turonian. Evidence of this is a member of black clays about 20 m thick, where replacement of inoceram zonal species occurs. Bivalve, gastropod and dinoflagellate assemblages are renewed at stage boundaries due to facies replacement and, partly, to invasion of new species. Then rapid regression takes place, which is recognized in the section by a sandy and silty member, lacking in macrofossils and containing dinoflagellates only.

This transgressive-regressive cycle comprising end-Cenomanian and Early Turonian stages, corresponds to

not be referred to this species, and in this connection doubts arise whether it is correct to recognize the Maastrichtian stage in the Tanama R. section.

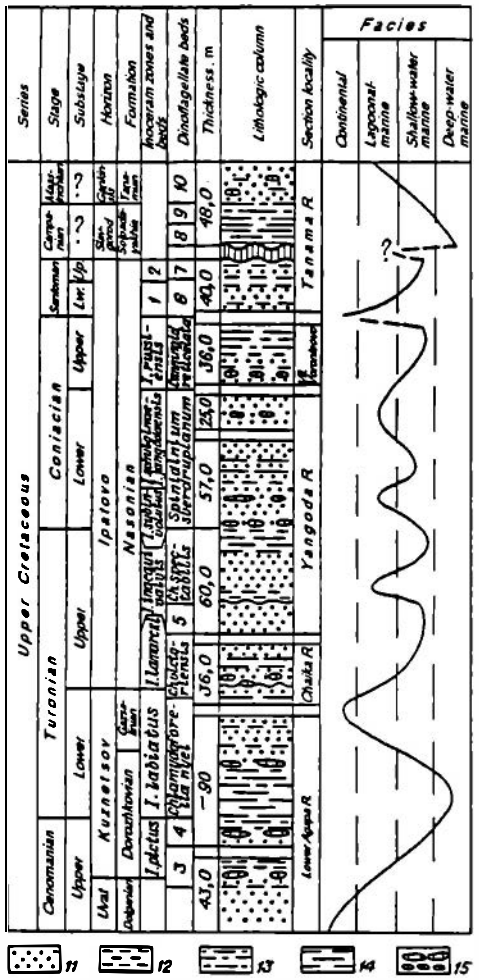

Fig. 2. Composite stratigraphic section for Upper Cretaceous of the Ust-Yenisei depression and transgressive-regressive curve. ***1 — Sphenoceramus cardissoides , 2 — Sphenoceramus patootensis, 3 — Geiselodinium sp. A., 4 — Euridinium saxoniense, 5 — Cyclonephelium vannophorum, 6 — Chatangiella obtusa, 7 — Alterbidinium daveyi, 8 — Isabelidinum spp., 9 — Chatangiella niiga, 10 — Operculodinium centocarpum,*** **11 – sands, 12 – silts, 13 – argillaceous silts, 14 – clays, 15 – horizons with concretions.**

the Kuznetsov transgression in West Siberia. Dynamics and chronology of this transgression are of great importance for understanding the range and structure of the Kuznetsov horizon, which appears to be the basic marker in the Upper Cretaceous section of West Siberia and the most important datum level for correlation with contiguous regions.

In our opinion the entire territory of West Siberia, including the Ust-Yenisei trough, underwent single marine transgression. It arose in Late Cenomanian in the north and reached its maximum at the beginning of Early Turonian and covered the whole of West Siberian plate, i.e., the distance over 2000 km from north to south. Because of relief roughness Upper Cenomanian basal deposits are lens-like and have mixed lithologic composition.

Accumulation of black clays and bituminous shales of the Kuznetsov horizon is consistent with global anoxic event OAE-2. Simultaneously cosmopolitan species *I. labiatus* is substituted for *I. pictus*. It is inoceram cosmopolitan species that are assumed to undergo anoxic influence first of all [7]. Thus, one can trace the causal relationship between maximum transgression, development of anoxic conditions and replacement of inoceram cosmopolitan species. The combination of such events suggests the Cenomanian-Turonian boundary to be one of the most reliable isochronous stratigraphic datums on a global scale.

The end-Cenomanian – Lower Turonian interval, as evaluated in units of global *sequence chronostratigraphy*, totally corresponds to the 3rd order *sequence chronozone* UZA-2.5 [8].

In the mid-Turonian a deep regressive phase took place, whose signs are actually found throughout the periphery of the West Siberian basin and outside [9, 10, 11]. In the north-eastern part it falls on a sandy unit of the Kuznetsov horizon known as "the Gazsalinian member."* It is overlain by the Upper Turonian clays and, along with the Cenomanian sands of the Uvat horizon, appears to be the collector of gas fields of the Urengoi group. As a result of the Gazsalin regression the sea most probably left the limits of the Ust-Yenisei trough, and prograding continental facies existed here.

The beginning of a new, Late Turonian (Ipatovo), transgression is recorded in the Chaika R. section, in the central part of the depression. Here continental rocks are gradually replaced by the marine ones, which contain very rich assemblage of Upper Turonian inocerams (the *Inoceramus lamarcki* zone). Upper Turonian offshore sediments at the Chaika R. differ from that of Upper Cenomanian in lithology (abundance of authigenous glauconite, presence of large-size pebble material, and so on) and in mollusk composition as well (the Upper Turonian assemblage is on the whole less diverse, though inoceram assemblage shows considerable diversity).

The Ipatovo transgression proceeds in the Yangoda R. section (see Fig. 2). Maximum transgression is recorded at the Turonian-Coniacian boundary, and a new regressive phase occurs in the mid-Coniacian. The Turonian-Coniacian cycle is not so distinctly expressed as the Cenomanian-Turonian one. Sea level variation was not great and alternation of sandy and clayey members are indicative of it. The Yangoda R. reference section comprises several (up to 7–8) basal "phosphorite horizons", which are characterized by coarse-grained sands, erosion surfaces, deep green color due to glauconite enrichment, numerous phosphorite concretions and also abundance of fossils and trace fossils. "More marine" sediments and lower sedimentation rates are typical of these horizons.

In the Turonian roof the member of dark-gray silty clays about 7 m thick contains numerous sulfide concretions and lacks macrofossils. An interbed of black dense silty clay without concretions occurs in its middle part. Irregular renovation and enrichment of palinologic assemblages take place at this level. The interbed is a condensed horizon corresponding to the peak in transgression.

To follow the event scale, this peak coincides with the Lower Coniacian boundary. Hence, this boundary disagrees with that of biostratons of the Yangoda R. section: we place the lower boundary for the Coniacian stage 8 m above the level of maximum transgression, in the bottom of the sandy bed where the Coniacian inocerams have been found. This bed was deposited in the middle of regressive phase (see Fig. 2).

In the mid-Coniacian the marine Ust-Yenisei basin underwent subsequent reduction in area. Regressive facies of the mid-Coniacian are exposed at the Yangoda River, though they are overlain everywhere by overthrust sheets [12].

End-Turonian and Early Coniacian transgressive-regressive periods are apparently consistent with a greater part of the 3rd-order unit chronostratigraphic cycle UZA-3.1 [8], though in the absence of microfossils-based zonal scales it is difficult to say how appropriate both boundaries are.

Late Coniacian transgression is distinctly expressed in the section near the village of Vorontsovo [13]. Based on inocerams and dinocysts, this section is compared with Upper Coniacian in the northernmost outcrop at the Yangoda R. Range of Upper Coniacian is restricted apparently by the central part of the Ust-Yenisei basin.

For lack of Upper Coniacian lower and upper boundaries it is difficult to judge about full correspondence of this stratigraphic interval to unit chronostratigraphic cycle UZA-3.2 [8], though this supposition does not contradict transgressive-regressive trend in the development of the portion of section in the Ust-Yenisei depression (see Fig. 2).

The Santonian section at the Tanama R. starts in regressive semi-continental facies, i.e., uniform blue-gray silts lacking not only macro- and microfauna but also dinocysts. Above lies a transgressive sandy-silty marine unit, which conforms to the uppermost beds of *I. cardissoides* zone and *I. patootensis* zone. Santonian is characterized by abundance of diverse fauna indicating normal-marine regime in the basin.

In the absence of the Santonian lower boundary in exposure and with its upper boundary being eroded the rest portion of the section may conform to UZA-3.3 unit chronocycle quite well [8].

The Santonian deposits are overlain with deep washout by the Campanian opoka-like clays. This boundary contrasts not only in lithology but also in all paleontological features. Inocerams disappear from benthic assemblages completely, and the composition of microphytoplankton changes drastically. By analogy with adjacent areas one can assume that the Ust-Yenisei depression has a comparatively short regressive phase in its development at the Santonian-Campanian boundary or in early Campanian. In the Tanama R. area regression resulted

* In our opinion it should be classiffied as suite.

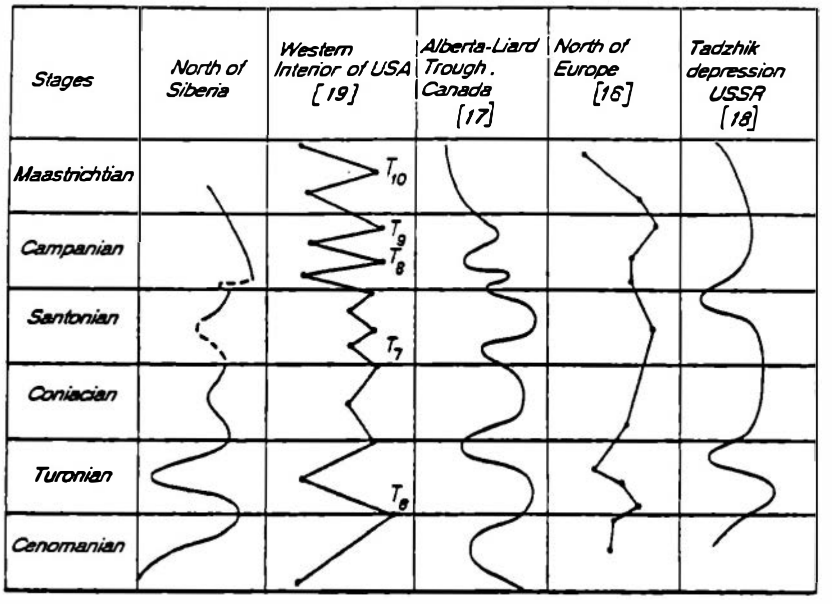

Fig. 3. Comparative graphs of sea level variation in Late Cretaceous in some regions of the Earth's northern hemisphere.

in underwater washout of the Upper Santonian sediments and, partly, of Lower Campanian, though the Early Campanian *Baculites obtusus* M e e k is known from northern Siberia [14]. Omission of part of Campanian in the sections of northern West Siberia was before indicated by foraminifers [15].

The Campanian-Maastrichtian sequence at the Tanama R. is a vividly expressed single regressive unit. However, this regression is not correlated with the global curve which suggests seven continuous eustatic cycles for Campanian and Maastrichtian [8]. Lack of signs of many eustatic events may be indicative of comparatively short time interval for this section formation, which may correspond to some part of Campanian. To solve this problem additional investigations are required with application of parallel zonal scale (based on dinocysts, foraminifers, Radiolaria).

Analysis of the transgressive-regressive curve plotted for the Upper Cretaceous section of the Ust-Yenisei depression (marginal structure of the rigid Siberian craton) is quite necessary to judge about the eustatic nature of some of its peaks.

Figure 3 shows the graphs of sea level variation in the north of Siberia and some other remote regions of the northern hemisphere. The curves for the western interior of the USA and north-western Europe are the most close [16]. Less distinct correlation is obtained for the Canadian basins, though the sea-level curve for the Alberta-Liard foredeep is also quite similar, at least in its lower and upper parts, to that of northern Siberia [17]. This similarity could be explained by that this was the trough along which the Arctic basin was connected through a strait with the North-American seas of the western interior. But this explanation is not always admissible. Thus general outline of transgressive-regressive curve for one of Tethys Late Cretaceous basins (the Tadzhik depression) is also similar to that of coeval North Siberia [18], though there was no direct connection between these basins.

The graphs plotted for various regions of the globe show clearly a good correlation between transgressions and regressions for the Cenomanian—Turonian and Campanian—Maastrichtian time intervals. The Early Turonian transgression with subsequent rapid regression in the mid-Turonian deserves special attention. This cycle is recorded in many regions of the globe [10]. The end-Maastrichtian regression has almost global occurrence. The greatest discrepancies in the nature of the events under discussion are observed in the middle part of Upper Cretaceous.

The fact that a number of Late Cretaceous transgressive-regressive events coincide in time in extremely remote regions with different geohistoric situations should be a consequence of common causes. Among those the world-wide causes of eustatic nature (e.g., spreading of the Atlantic Ocean floor) are most often pointed out. However, the nature of fluctuations is heatedly discussed because transgression-regression peaks in a series of sections fall on different time, which may be effect of a local tectonic movement. Another cause is an imperfect correlation of the sections.

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