# Events at the Turn of the Eocene and Oligocene in the Central Eurasia Region (Middle Latitudes)

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GEOLOGY

# Events at the Turn of the Eocene and Oligocene in the Central Eurasia Region (Middle Latitudes)

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**Abstract**—The Eocene and Oligocene transition sections (Priabonian–Rupelian) of the Aral–Turgai, West Siberian, Volga–Don, and Crimea–Caucasus regions have been studied in detail [1], and the global biospheric crisis events have been estimated at the turn of the Eocene and Oligocene. In spite of the idea of the gradual regression in the Priabonian with drainage of the inner sea basins, it has been established that shallowing of the sea was preceded by repeated transgression that continued for 1 Ma with warming up and humidification of the climate. The final regressive phase (130–200 ka) was accompanied by frequent eustatic and climatic fluctuations, reconstruction of the isotopic and geochemical background, and also the recurrence at the boundary between layers in certain continuous sections.

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The Phanerozoic biospheric crises have received great attention recently. They were related to the events, environmental changes, and climatic fluctuations that happened in the era of "great glaciations." Some periods were accompanied by transformation of the Earth's magnetic field with pole remagnetization. The biospheric transformations were related to impact events, occurrence of isotopic and geochemical anomalies, and development of anoxic conditions in the bottom waters.

In recent decades, the stratigraphic services of different countries have been focused on study of the Phanerozoic biospheric crises and biotic and abiotic events. They are related to the cause-and-effect relationships, global climatic fluctuations, and eustatic and environmental changes in the critical periods. Most boundaries of the stratons, especially of the high-grade structures, were drawn along the critical lines of the most contrasting biospheric reconstructions. Nonetheless, the crisis situations are occasionally not consistent with their boundaries.

The investigation data on the crisis events at the turn of the Eocene and Oligocene in the Central Eurasia Region are given below to estimate the planetary model of eustatic and climatic fluctuations upon transition from the "warm" to the "cold" biosphere. The paleontological base has helped to clarify the boundary position in the sections and to develop a basis for the correlation of biotic and abiotic events in the layers at the final life stage of the Peritethys and its framing.

The crisis at the turn of the Priabonian and Rupelian centuries of the Eocene and Oligocene has been the subject of numerous investigations. The event sequence in the period of 5–7 Ma is as follows. The replacement of the chemocline stratification of the oceanic water body by thermal stratification, reconstruction of the high-latitude straits, and formation of the circum-Antarctic current were followed by isolation of the Antarctic Continent. The formation of the ice sheet on the periphery of this continent led to the global regression and cooling down with the drainage of internal sea basins. These events resulted in ecosystem transformations, temperature drops in the extratropical areas, and reduction of marine and terrestrial biota earlier adapted to the "warm" biosphere.

This is the general outline of events that happened in the period of 5–7 Ma at the turn of the Eocene and Oligocene. However, it is more important to find out what events happened in the period of 1.0–1.5 Ma on both sides of the Priabonian–Rupelian boundary and to assess, in the first place, the eustatic fluctuations, temperature, and humidity characteristics of the climate, being of the great prognostic value. Let us start from the climatic characteristics. When considering them, researchers are commonly focused on the temperature parameters, neglecting the distribution of precipitation and its role in biota transformation.

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The humidity of the climate has been described with the help of one of the quaternary geology methods rarely used in ancient climate reconstruction. The phases “humidification” and “drainage” were identified based on the relations of xerophyte and hygrophyte palynomorphs in the spectra. The reliable identification of higher plants of the second half of the Eocene in the Central Eurasia Region combined with the isotopy data make it possible to consider this method to be relatively correct. The degree of manifestation and the duration of the humid phases can be also used for correlation purposes.

N.I. Zaporozhets has identified the antiphase distribution of xero- and hygrophyte palynomorphs. Xerophytes are represented by Ephedra, some species of Cedrus and Pinus, Cypressaceae, Fagageae, Leguminosae, Chenopodiaceae, Artemisia, and partly, Compositae. Their considerable participation in the pollen spectra is regarded as a sign of the growing aridity or the more pronounced climate seasonality. On the contrary, the antiphase growth of the spore component and pollen of Taxodiaceae (*Taxodium, Metasequoia*, and *Glyprostrobus*), Amentiflorae, etc., are indicative of climate humidification.

The zonal scales developed by dinocysts and planktonic foraminifers have been used to substantiate the age of the borderline marine layers. Three zones have been identified in the Priabonian part of the scale of planktonic foraminifers: P15, P16, and P17 with different index species for the Tethys region (Armenia) and the Boreal region (the North Caucasus, Ustyurt, and the Aral Sea Region). That is why the species indexation of the zones is not always consistent.

In the sections in the southwestern Siberian Region [1], North Caucasus, and Armenia [2], the first humidification phase fell on the middle part of the Late Eocene (the *Turborotalia cocoaensis* P16 zone (by planktonic foraminifers) and *Charlesdowniea clathrata angulosa* (by dinocysts)) at a spore content of 23.5% in the pollen spectra. In the sections of the southern wing of the Omsk Trough [1], contrary to the established conception of the gradual shallowing of the internal sea basins in the Late Eocene, the saline-water West Siberian Sea regained normal salinity in the second half of the Priabonian. It happened not because of the seawater breaking through the land bridge to the basin bowl, but due to the transgression, which had also manifested itself in the Crimea–Caucasus Region. The maximum rise of the West Siberian Sea reached 100–120 m, after which it rapidly regressed with the drainage of the West Siberian Plate.

A few sections were studied to trace the dynamics of the eustatic and climatic fluctuations in the Crimea–Caucasus Region and Aral–Turgai Region right in the borderline interval.

The humidification was replaced by short-term aridization in the terminal Priabonian in Armenia, the *Turborotalia centralis–Globigerina gortanii* (P17) zone [2]. It can be judged by the growth of the Ephedra and Cedrus pollen and predominance of Pinaceae over Taxodiaceae. The sea shallowing is confirmed by the replacement of clay sediments by aleurolite. It was completed at the Priabonian–Rupelian boundary, which is confirmed by the washaway in the basement of the overlapping Oligocene member in the *Globigerina tapuriensis* (P18) zone.

The second short-term humidification phase in the Rupelian is recorded in the section 1.2 m above the basal layer (the same zone P18). The occurrence of this phase is evidenced by a considerable increase in the spore component in the pollen spectra (25.5%). The sea level rise was accompanied by short-term water ingression to the lowlands adjacent to the Peritethys (Ashcheairyk and Chelkar–Nura transgressions). The readily occurring new aridization phase still fell on the *G. tapuriensis* (P18) zone. The Ephedra content reaches over 20% in the eight-meter aleurolite member occurring at a depth of 3.5 m above the Oligocene foot. This aridization phase is also reliably recorded in the Aral–Turgai Region by the abundance of the Shintuzsai flora comprising narrow-leaved xeromorphic oaks and small-leaved acacia trees. The Shintuzsai layers overlap the Upper Eocene Chegan Formation.

Hence, the replacement of the “humid” and “arid” climatic phases and orientation of the eustatic fluctuations in the Late Priabonian and Early Rupelian (figure) led to degradation and transformation of the Eocene subtropical plant communities. The cooling down was accompanied by the reduction of Lauraceae, some Fagageae, Araliaceae, Hamamelidaceae, Nyssaceae, Sumacheae, etc. They were replaced by Coniferae and Amentiflorae forming the main core of the Turgai moderate-warm flora in the Rupelian [3].

The Eocene–Oligocene boundary was marked by depletion of zoned dynocists with the replacement of index species.

The data on the section in drillhole 3006 in the North Aral Region are noteworthy [2]. The Priabonian layer is composed of marl clay (7 m). In the pollen complex, the Coniferae pollen is predominant over Taxodiaceae, and the Sumecheae and Hamamelidaceae pollen is predominant over Amentiflorae. The Ephedra pollen content is 15–20%, while the Cedrus is 8–10%. The maximum aridization and the peak of cooling fall on the Eocene terminal layers (P17) and borderline bioturbated member. The increased cooling affected the composition of the pollen spectrum dominated by the Coniferae (more than 90%). The cold phase is also characteristic of the following Rupelian period with the ongoing aridization and growing content of the Ephedra and Cedrus pollen in the pollen spectra. In the Armenian sections, this phase corresponds to the start of P18.

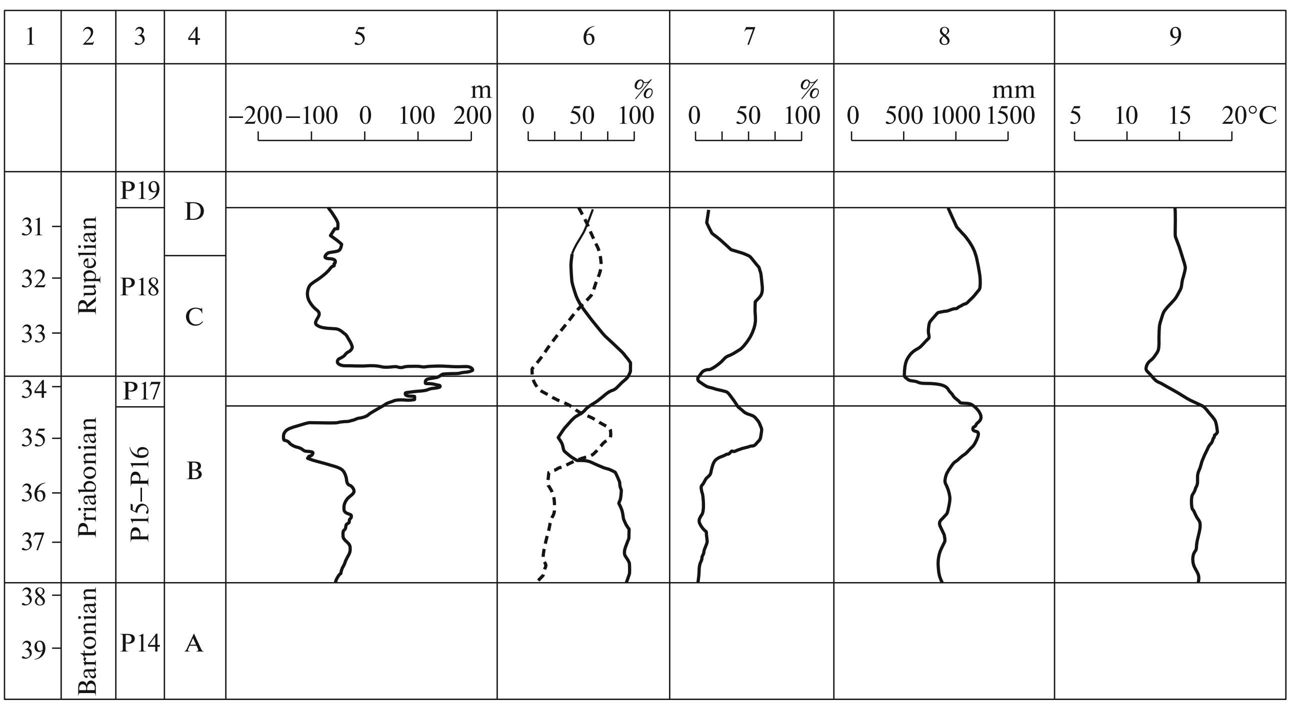
We have estimated the velocity of the sea rise in the Central Eurasia Region in the Late Priabonian over its

Contents of chemical elements in the section of the Eocene/Oligocene boundary layers (Beloglinskii/Maikop sequences), Kheu River valley, Kabardino–Balkaria (Central Caucasus Region)

| Sample No. | $C_{org}$ | $CaCO_3$ | Fe | P | S | Ti | Ni | V | Cr | Cu | Co | Zn | As | Mo | Ga | Ge | Sn | Pb | Hg |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 300 (Blg) | <0.1 | 47.1 | 2.67 | 0.01 | 0.5 | 0.26 | 48 | 120 | 95 | 38 | 12 | 55 | 5 | <0.8 | 7 | 1 | 3.5 | 13 | 0.1 |
| 301 (Blg) | <0.1 | 39.49 | 2.39 | 0.03 | 0.57 | 0.35 | 55 | 165 | 120 | 38 | 12 | 65 | 10 | 0.8 | 9 | 1 | 4 | 15 | 0.07 |
| 302 (Mcp) | 0.51 | 38.04 | 3.06 | 0.02 | 0.86 | 0.29 | 70 | 200 | 115 | 50 | 20 | 60 | 20 | 3.4 | 11 | 1 | 4.3 | 14 | 0.08 |
| 303 (Mcp) | 0.66 | 34.5 | 3.52 | 0.02 | 1.29 | 0.34 | 70 | 220 | 125 | 55 | 18 | 78 | 50 | 7 | 10 | 1 | 4.3 | 15 | 0.08 |
| 304 (Mcp) | 0.82 | 32.91 | 3.74 | 0.04 | 1.26 | 0.33 | 85 | 210 | 140 | 60 | 20 | 85 | 36 | 21.5 | 11 | 1.4 | 5.5 | 15 | 0.08 |
| 305 (Mcp) | 1.04 | 19.18 | 4.02 | 0.04 | 1.79 | 0.41 | 70 | 240 | 125 | 55 | 16 | 90 | 32 | 29 | 16 | 1.4 | 5.5 | 18 | 0.07 |
| 307 (Mcp) | 1.36 | 25.53 | 3.54 | 0.04 | 1.37 | 0.36 | 75 | 240 | 140 | 50 | 16 | 90 | 30 | 26 | 14 | 2 | 5 | 18 | 0.04 |

$C_{org}$, $CaCO_3$, Fe, P, S, and Ti contents, %; other elements, ppm; (Blg) roof sediments of the Beloglinskii Formation, (Mcp) basement sediments of the Maikop sequence.

total duration of 3.9 Ma. This interval was characterized by the successive replacement of three zoned complexes of planktonic foraminifers. The life duration of the last zone (P17) was calculated based on the ratio of the thickness values of each of the three zones studied in the sections, assuming that the sedimentation velocity remained almost unchanged in the monofacies clay–marl–aleurolite sequence. The total thickness of the sediments varies from 40 to 150 m in P15 and P16 and from 4 to 9 m in P17. Hence, the sedimentation thickness ratios in P15 + P16 and P17 vary from 14 : 1 to (9–10) : 1, and, thus, the life duration of P17 does not exceed 200–400 ka. In two sections of Armenia and the Aral Region, the activation of elevations, cooling down, and initiation of aridization are characteristic of the middle interval of P17. This fact is confirmed by the predominance of Coniferae and xerophyte pollen. Judging by these sections, the dura-




The eustatic and climatic curves in the transitional interval from the Eocene to the Oligocene in the middle latitudes of the Central Eurasia Region. (1) Age (Ma); (2) Paleogene stage scale; (3) zonal scale of planktonic foraminifers: *Globigerina turcmenica* (P14) and *Globigerina tropicalis* and large foraminifers (P15 + P16), *Turborotalia centralis–Globigerina gortanii* (P17), *Globigerina tapuriensis* (P18), *Globigerina sellii* (P19); (4) zonal scale organic-walled phytoplankton (zones): (A) *Rhombodinium perforatum*, (B) *Charlesdowniea clathrata angulosa*, (C) *Phthanoperidinium amoenum* + *Wetzeliella symmetrica*, (D) *Wetzeliella gochtii*; (5) eustatic fluctuation curve; (6) "marine factor" variations curve (constructed by the percent ratio of organic-walled phytoplankton and higher plant palynomorphs); (7) percent content of xerophyte pollen in the pollen spectra; (8) average annual precipitations curve; (9) average annual temperature curve.

tion of active elevations upon approaching the borderline did not exceed 130–200 ka (the cold phase of the terminal Priabonian) (figure).

Similar values of the duration of P17 (less than 0.5 Ma) have been indicated for the Massigniano section near Ancona (North Italy), the stratotype of the Eocene–Oligocene boundary [4].

The frequent nature of the eustatic fluctuations is also confirmed by the recurrence identified in the continuous sections in the Kuban and Kheu rivers near Cherkessk and in Kabardino–Balkaria, without changing the magnetic field polarity right on the border of layers. The recurrence in the 1–2 m interval is observed as a double alternation of light-colored marls of the Beloglinskii Formation and Maikop dark-colored clays lithologically replacing each other without interruption features, with characteristic, peculiar to them alone, "microplanktonic saturation" (dynocists, planktonic foraminifers, and nanoplankton). The recurrence is caused by the short-term eustatic fluctuations with a variable amplitude, with a return of the sea level to the initial state before the predominance of any trend in its longer changing.

The turn of the Eocene and Oligocene in the middle latitudes of the Central Eurasia Region was characterized by the drainage of the West Siberian Sea and Turgai Strait with the transformation of the Peritethys into the Paratethys [5] with a latitudinal spatial orientation of the sea basin. The formation of new migration paths was accompanied by the elimination of certain groups of land mammals (Titanoteria, Panodonts, some varieties of Rodentia, etc.). Recent findings have been made in the Upper Eocene roof layers of the Zaisan Depression, Turgai Region, and Mongolia. The paleofloral and isotopic data obtained in the Aral Region, Turgai, and North Caucasus sections are indicative of a decrease in the seawater temperature by at least 4°C in the photic layer and by 5–7°C near the land surface at the turn of the Priabonian and Rupelian.

The considerable area of the currently existing sea basin was subject to a rough change in sedimentation conditions and in the lithological and geochemical characteristics of the deposited sediments (table): the normally aerated basin (Beloglinskii Formation) was replaced by a water reservoir with signs of anoxic environments in the prebottom waters (Maikop sequence). This statement is confirmed by the considerable increase in the Mo concentrations (by more than 20 times) in the Maikop sediments and the enrichment in other elements (Ni, V, Cr, Cu, Co, Zn, and As) sensitive to these changes. The contents of organic substances ($C_{org}$), Fe, and S increased simultaneously in the rocks. The climatic and paleoecological changes at this period in the seas likely caused the fall in the calcareous plankton bioproductivity and the following regular depletion of $CaCO_3$ in the sediments.

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