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## **EARLY EOCENE CLIMATIC OPTIMUM IN THE SECTION ALONG THE KHEU R. (NORTHERN CAUCASUS). CHANGES IN NANNOFOSSIL COMPLEXES AS A REFLECTION OF CRITICAL GEOLOGICAL EVENTS**

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The Early Eocene Climatic Optimum covers a period of ~54.3–49.0 Ma with maximum temperatures in the range of ~52.5–50.3 Ma.

Against the background of a general gradual increase in temperature, brief recurring hyperthermal episodes were identified (Westerhold et al., 2017, 2020):

- insignificant in amplitude and non-indexed episode (~54.3 Ma) – coinciding in time with the occurrence of *Tribachiathus orthostylus*;
- H1/ETM2 (~54.1 Ma and H2 (53.9 Ma) – close to the level of occurrence of *Sphenolithus radians* (54.2 Ma);
- episodes I1 (53.7 Ma) and I2 (53.5 Ma) – corresponding to the time of occurrence of rare *Discoaster lodoensis* (53.7 Ma);
- K/ETM3 (52.8 Ma), coinciding with the beginning of the usual presence in the *D. lodoensis* complexes (52.9 Ma).

Subsequent temperature spikes were less pronounced. The disappearance of *Tribachiathus orthostylus* correlated with a temperature minimum between episodes R and S.

The lithological structure of the studied section and changes in the nannofossil complexes perfectly reflect the “chaotic behavior of the Solar System” (Westerhold et al., 2017, 2020) during the Early Eocene Climatic Optimum. A good correlation of changes in the composition of nannofossils with temperature maxima and minima was revealed, which was expressed in an increase or decrease in its species diversity, the predominance of warm-water or cold-water species (figure).

In the section of the Ypresian stage along the Kheu R., in the interval corresponding to EECO, seven ecological types of nannofossil complexes (NFCs) associated with crisis levels are distinguished:

1. Relatively cold-water NFC of poor species composition of the CNE2 zone, preceding the beginning of the EECO;
2. Warmer-water NFC from the level of the first occurrence of *T. orthostylus* at the base of the member of carbonate clays in the top of the Abaza Formation - the beginning of the EECO. As the temperature increased, many Paleocene–Early Ypresian species, including *T. contortus*, gradually died out, which makes it possible to compare this member with the lower half of the CNE3 Zone (Agnini et al., 2014);
3. Significantly warmer-water NFC, in which single small, ugly *D. lodoensis* appear, as well as numerous large sphenolites, *Chiphragmalithus spp.*, *Toweius gammation*, etc., according to the level of occurrence of which this part of the section is correlated with the upper half of the CNE3 zone.
4. Moderately warm-water complex, in which larger but uglier *D. lodoensis* are constantly present, and the proportion of warm-water species is increasing. It correlates with the lower half of the CNE4 zone.
5. The warmest NFC, where the well-formed *D. lodoensis* is most developed. The maximum development of a number of warm-water taxa, including *Helicospaera seminulum*, *H.*

*lophota*, *Scyphosphaera* spp., is timed to the same time. This level corresponds to the temperature maximum. Clay interlayers enriched with organic matter (sapropelite interlayers) mark short-term temperature maxima with a sharp rise in sea level. In the near-bottom part, conditions arise with insignificant hydrogen sulfide contamination (judging by the presence of pyritized coccoliths), but there was no complete anoxia, which is confirmed by the presence of bioturbation. NFC correlates with the upper half of the CNE4 zone.

6. Moderately warm-water NFC, the beginning of the formation of which is determined by the level of a sharp decrease in the content of *T. orthostylus* (single specimens at the base, up to complete disappearance above). Up the section, there is an alternation of complexes with malformed and normal specimens of *D. lodoensis*. This level correlates with the CNE5 zone.

7. The next NFC, initially warm-water, with normally developed *D. lodoensis*, rapidly depletes up the section; *D. lodoensis* becomes ugly, and almost completely disappears towards the top of the Ypresian Stage due to gradual cooling and regression. The index species of the next zone, *D. sublodoensis*, is present quite rarely, but constantly. The location level of this NFC correlates with the CNE6 zone.

The boundary of the Ypresian and Lutetian stages was determined by the occurrence of *Blackites inflatus*, *Blackites piriformis*, *Nannotetrina cristata* (Agnini, 2014; Geologic Time Scale, 2020).

