# THE LATE PALEOCENE ANOXIC EVENT IN THE SEAS OF EASTERN PERI-TETHYS

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The most impressive event in the latest Paleocene seas of Eastern Peri-Tethys was formation of sapropelite unit (SU), enriched in organic matter (OM). Despite small thickness (0.3-2.5 m), it is spread over vast territory of South Russia and the Central Asia (more than 2500 kilometers) (Fig. 1) and shows structural feature similarity all over the area even being accumulated under different facial conditions. The stratigraphic position of the SU corresponds to CP8a/CP8b Subzone boundary and foraminifer Zone *Acarina acarinata*, layers with *Globorotalia aequa* (Muzylöv et al. 1989, 1994).

The SU is distinguished by dark color and typical thin foliation of rocks after weathering; its lower boundary is always sharp, whereas the upper one is more gradual. Several sections clearly demonstrate transgressive onlap with erosion surface at the base of SU. Toward the coastal-facies zone, the sapropelite unit is OM-depleted; locally, it is replaced by layers with abundant fish detritus, and in places, it is replaced by phosphorite-bearing deposits (Central Asia) or spatially associates with them. SU clay minerals associations usually are of approximate composition of host deposits, but it varies in different parts of the basin.

OM content in the SU is highly variable at different areas (Fig. 1). $C_{org}$ content is more than 20% in Amu Darya region (Suzak oil shale zone); in the Lower Volga, it does not exceed 1%. In the Caucasus and Aral Sea regions $C_{org}$ content is usually negatively correlated with $CaCO_3$ in sections, where the SU is organic-rich; in other places their correlation is more complicated. Fe, P, S are concentrated in SU sediments; by contrast, Mn is slightly depleted. Minor elements registered in sapropelite unit rocks can be divided into two groups: 1) elements, which are generally concentrated to variable extent in SU: V, Cu, Mo, Ni, Ag, Au, Se, Co, Zn, Cr, Sn, Ga, Ge, Br, Re, Te, Tl, Bi, Sb, Cd and possibly Ba (some elements show increased content throughout the area, other in isolated regions only); 2) elements characterized by very low fluctuations and even minor depletion at the transition host rocks/SU: Ti, Zr, Nb, Rb, Sr, Sc, Cs, Hf, and probably REE. Geochemical features of Thanetian sapropelite unit are very close to that of Black Sea and Mediterranean sapropels.

OM in the SU is enriched in light carbon isotope (-30.3 ‰ to -30.8‰) relative to the host rocks (-27 ‰ to -28‰) (Kheu section); carbonates of the SU are also enriched in this isotope ($\delta^{13}C$ up to -1.8‰) against host deposits (+0.5 ‰ to -0.2‰). Consequently, the section is characterized by parallel trend of isotope values of both organic and carbonate carbons. Geochemical and petrographic investigations indicate essentially marine origin of OM and it acquired a mixed structure in areas with terrestrial supply of material. The main marine source of OM was organic-walled phytoplankton with a perceptible content of dinoflagellates, green algae, cyanobacteria, etc. Their decomposition during diagenesis produced abundant colloalginite material within sapropel sediments.

The model of SU formation should consider following circumstances: 1) sapropel sediments were accumulated in a vast, relatively shallow-water, basin during rapid transgression reflected the eustatic rise of sea level at terminal Thanetian, 2) transgression was preceded by regression, which is traced in some sections on the basis of respective hiatuses and erosional sapropelite onlap, 3) the highest concentration of OM is registered in Central Asia, where SU associates with phosphorite-bearing rocks, 4) OM is mostly composed of organic-walled phyto- and bacteriaplankton, but locally the fraction of land-derived OM increases, 5) different basin parts are distinguished by facies; nevertheless, the transgression was accompanied everywhere by the formation of sapropel sediments.

The model of organic-rich sediment accumulation can be based on the mechanism of biophile element supply into basin from coastal land during rapid eustatic transgression (Gavrilov 1994; Gavrilov & Kopaevich 1996, Gavrilov et al. 1997). In exception the direct transgressive affection, SU formation was determined by landscapes built up during preceding regressive stage, as well as the type of sediments that were mainly accumulated along basin periphery and in interior rises during the "pre-sapropel time" (Fig. 2). As a result of regression, wide areas, generally represented flattened by marine erosion and sedimentation lowlands, were developed along the periphery of relatively shallow inland sea and around archipelagoes. A noticeable peneplanation occurred during Late Cretaceous and Paleogene; consequently, even minor sea-level fluctuations resulted in drastic displacements of coast line. The area, which was released from sea, was covered by loose non-lithified and usually reduced sediments (with authigenic sulfide and phosphate minerals) transformed from marine sediments. Subaerial weathering processes, being more active than that in the case of lithified rocks, reworked the sediments, and in the most degree the pyrite bearing deposits. In addition, favorable conditions for development of lacustrine/bogs landscapes on the lowland surfaces occurred. In the acidic bog's waters sedimentary material has been also reworked, some biophilic elements, first of all phosphorus, firm and dissolved isotopically light OM concentrated here. Thus, during regressive stage "geochemically active landscapes" were developed. Later, transgressive sea interacted with these landscapes and OM, P, other biophilic elements input into the sea promoted intensive growth of bioproduction, and first of all of organic-walled phytoplankton. Deposition of OM masses enriched sediments with $C_{org}$. Diagenetic $H_2S$ diffusion from sediments into the bottom waters opressed benthic fauna. The highest degree of OM enrichment takes place in Central Asia, where SU is in association with phosphatic sediments. Regional differences in geomorphological and geochemical features of nearshore landscapes testified to variations in biophilic element input intensity into the sea and patchy SU distribution. Duration of sapropel sediment accumulation has been probably about 5 ka (similarly to Black and Mediterranean Sea sapropels). When transgression and connected input of biophilic elements was over, phytoplankton bioproduction has been sharply reduced, and as a result accumulation of OM was finished, too. $H_2S$ in sea waters was oxidized, and normal environments developed.

In Thanetian, south-eastern part of studied basin showed arid climate that is why short-lived evaporate water bodies occurred in emerged areas during regression. Lately, in course of transgression they supplied saline water into open basin possibly caused density stratification initiation. Evidently, it was one of causes of most enriched in OM sediment accumulation within this part of basin ($C_{org}$ = 15-25%).

In this connection, it is notable that arid climate existed in West Africa sea shore in Thanetian as evidenced from palygorskite and sepiolite occurrence in sediments (Slansky 1962, etc.). In regression stage, evaporate water bodies can developed in shelf and adjacent areas. During transgression, they discharged heavy saline water into ocean could negatively affect benthic biota and cause isotopic $\delta^{18}O$ and $\delta^{13}C$ shift appearance.

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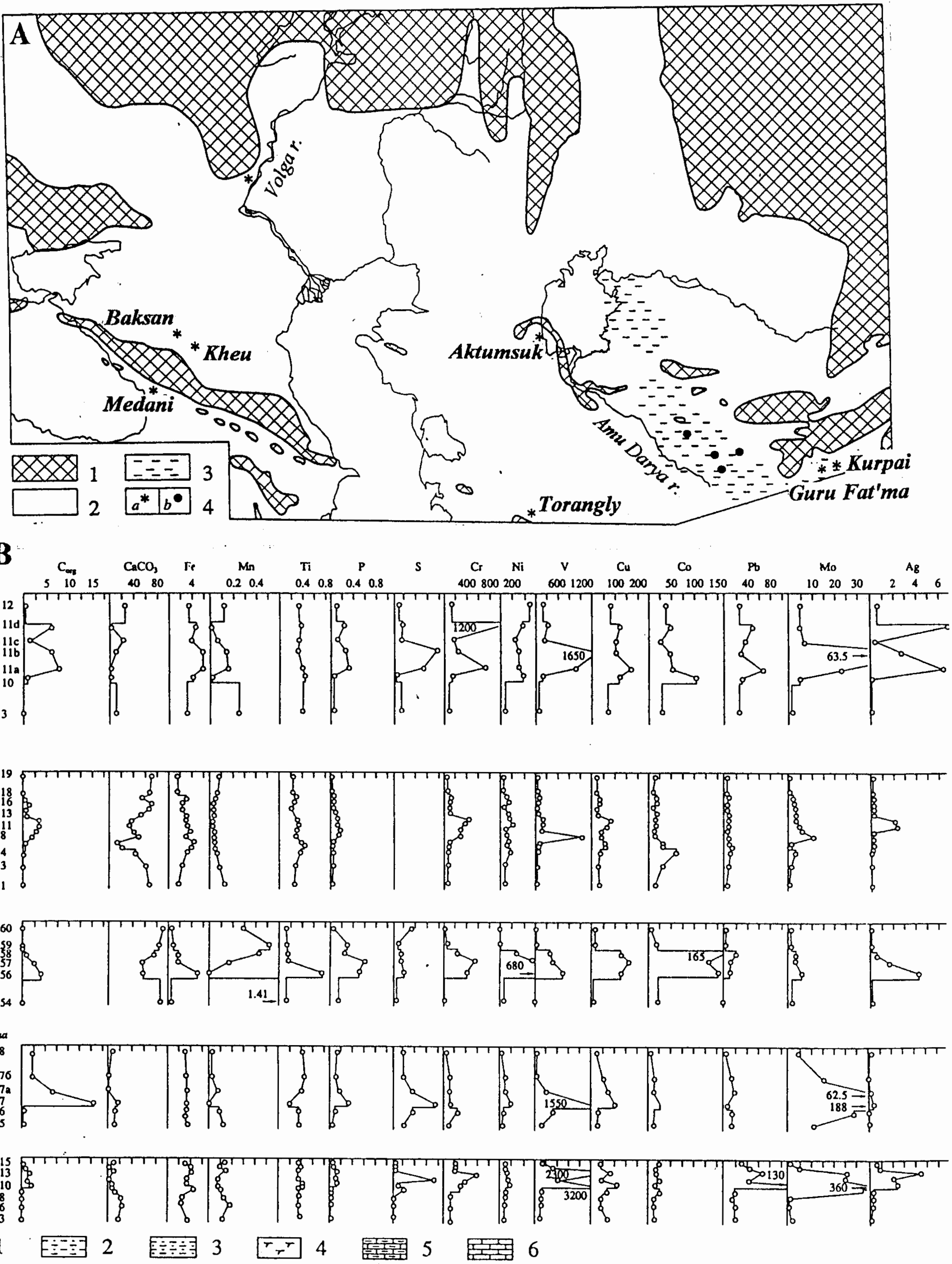
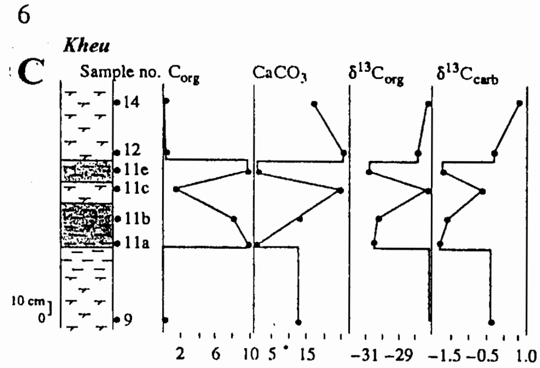



Fig. 1. **A**. Late Paleocene paleogeographic scheme and location of the sapropel unite section studied. (1) Land; (2) sea; (3) oil shale zone; (*4a*) location of sections studied; (*4b*) position of boreholes, from which the sapropel core was collected. **B**. Distribution of chemical elements in SU sections. $C_{org}$, $CaCO_3$, P, Ti, Fe, Mn, and S are given in %; other elements, in ppm. (1) shales; (2) silt clays; (3) siltstones; (4) marl clays; (5) marls; (6) limestones. **C**. Distribution of $C_{org}$ and $CaCO_3$ (%) and $\delta^{13}C$ (‰) in OM and carbonates from the Kheu River sapropelite unite section.



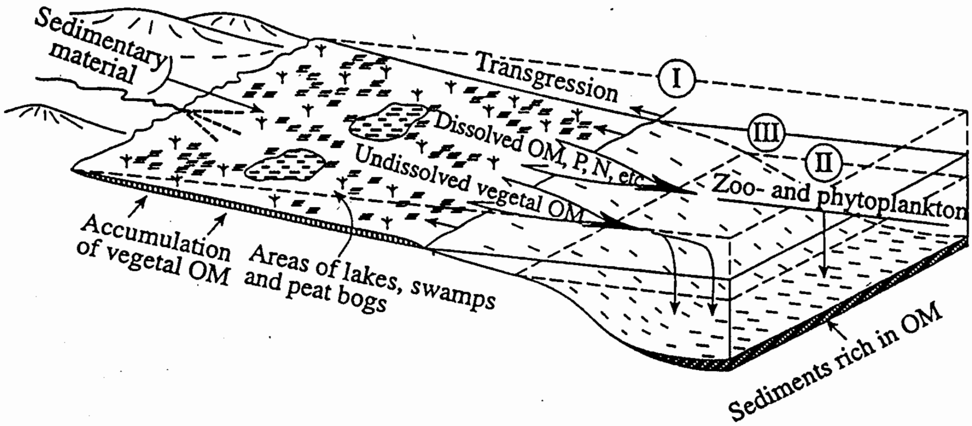



Fig. 2. Schematic model of interaction between the transgressing sea and coastal lacustrine-swamp landscapes (after Gavrilov, 1994). I–III. Position of sea level: I, before regression, II, during maximal regression, III, during developing transgression.

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