A PALEOGENE SEQUENCE IN CENTRAL CAUCASUS: A RESPONSE TO PALEOENVIRONMENTAL CHANGES

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The Paleocene-Eocene basin in the south of the Former USSR occupied a large area that extended E-W over 3000 km. The northern periphery of the basin was characterized by essentially terrigenous and biogenic siliceous sedimentation, and the southern (Crimea-Caucasus) region was dominated by carbonate nanno-foraminiferal sediments, giving way in some stratigraphic intervals to carbonate-terrigenous, terrigenous, and biogenic silica-terrigenous sediments. The Paleogene stratigraphic scheme of the area is based on foraminifera and nannofossil studies (Subbotina 1960; Leonov & Alimarina 1964; Shutskaya 1970; Krasheninnikov & Muzylöv 1975; Muzylöv 1981, etc.).

The proportion of different sediments varied considerably from stage to stage through the development of the basin; this variation is more clearly pronounced in North Caucasus. The lithostratigraphic subdivision remains roughly identical in different parts the area; this is why we choose the classical Paleocene-Eocene reference section on the Kheu River (Kabardino-Balkaria, central North Caucasus) (Fig. 1) to characterize sediment variation in time. Zonal subdivision is made on the basis of the standard nannofossil scale.

1. Maastrichtian. White limestone with thin marl intercalations (exposed thickness, 15 m). Further upsection, an unexposed interval several meters thick.

2. Elburgan Formation (40 m). CP1/CP2 Zone range represents rhythmically alternating greenish gray limestone (10-25 cm) and marl (several cm). The lowermost CP3 Zone is composed of soft marl with more calcareous intercalations; the uppermost CP3 Zone, hard limestone.

3. Nalchik Formation (80 m). Over a sharp boundary (hiatus?), Danian limestone is overlain by bluish and greenish gray calcareous clays with variable carbonate content (maximal in the middle CP4 Zone and near the CP7/CP8 Zone boundary, ~50% $CaCO_3$). Vague layers alternately high and low in calcareous matter, with abundant bioturbation marks (up to 0.5 m in length) are documented. A sapropelite horizon (0.45 m) rich in C_{org} (up to 10%) occurs at the CP8a/CP8b Subzone boundary (see Gavrilov this volume). The uppermost 30 m, (CP8b Subzone) - intercalations of bluish gray bioturbated slightly calcareous clay and massive cherts (several decimeters thick).

4. Cherkessk Formation (55 m), CP9-CP12 Zones. Greenish gray non-laminated marls with vague bioturbation marks. In the middle part, a sequence (15 m) with eight sapropelite interlayers (10-25 cm) occurs. C_{org} content reaches ~2-3.5% (Gavrilov & Muzylöv 1992).

5. Keresta Formation (20 m), CP13 Zone. Alternating massive limestones (up to 1m at the base, 0.1-0.3 m further upsection) and softer marls (0.05-0.15 m).

6. Kuma Formation (40 m), CP14 Zone. Coffee to dark brown calcareous sediments (limestone in the lowermost part, marl in the uppermost part) rich in OM. C_{org} varies from 2% to 9% in the lowermost part, and is less variable in the uppermost part (2.5-4.5%). Fine (millimeter-scale) lamination and numerous fish remnants are recorded, and bioturbation is absent. Twenty bentonite interlayers (several millimeters to 10 cm) occur in the lowermost part.

7. Belaya Glina Formation (100 m), CP15 Zone. Greenish gray vaguely laminated sediments alternately high or low in calcareous matter (generally, marls).

8. Maykop Formation, Oligocene-Early Miocene. A thick clay sequence rich in OM accumulated in an environment that differed drastically from the Paleocene-Eocene environment. The sediments are characterized by the most common clay association: hydromica, smectite, mixed-layer mica/smectite minerals, and chlorite, which vary in proportion through the section. In the sapropelite sequence of the Cherkessk Fm., kaolinite appears. Smectite makes up bentonitic interlayers in the Kuma Fm., and is present in the Keresta Fm. along with clinoptilolite. Throughout the section, OM is low, although initially it was higher, judging by sulfide nodules. Certain horizons, however, are considerably enriched in OM (sapropelites of the Nalchik and Cherkessk Formations, limestones and marls of the Kuma Fm. (Fig. 1). Accordingly, OM-rich sediments are high in P, V, Ni, Co, Cr, Mo, etc. Significant biotic changes (involving a decline of nannofossil and planktonic forams and disappearance of benthic forams) accompanied OM accumulation (Muzylöv et al. 1996).

The generally high carbonate content resulting from high calcareous microplankton (mainly nannofossil) productivity changed significantly through time. The $CaCO_3$ curve reflects two stages in the Paleocene-Eocene sedimentation.

1. The Paleocene stage, with a clear trend in the content of carbonate matter: from the limestone-dominated Danian sequence through marls and carbonate-rich clays to upper Thanetian (CP8b Zone) low-carbonate clays and cherts. Accordingly, nannofossils, very abundant in the Danian-lower Thanetian, become rather various but not abundant in the upper Thanetian chert sequence. Paleotemperature estimates are hard to make because we could not obtain reliable statistics for the *Discoaster/Chiasmolithus* ratio; the Thanetian assemblage, however, does not seem to be very warm, as both genera are relatively equal in frequency. Similar changes in carbonate matter from the Danian to Thanetian have been established for coeval sediments in Western Europe. Considering that similar trends of sediment changes characterize basins that are situated great distances apart, these trends might be related to eustatic sea-level changes, rather than regional factors.

The general Paleocene trend of changes in sedimentation is complicated by smaller-scale fluctuations in $CaCO_3$ content. The middle Paleocene sequence (CP4- CP8a, "pre-sapropelite" stage) displays two positive $CaCO_3$ shifts separated by reduced carbonate accumulation in CP6-lowermost CP7 Zones. In the terminal Paleocene (CP8b Subzone), clays with the lowest $CaCO_3$ content in pre-Oligocene sedimentation accumulated, evidently due to (i) reduced calcareous microplankton productivity coincident with siliceous microplankton outburst, and (ii) a relative decrease in carbonate content owing to increased terrigenous input, resulting in a thick sequence accumulated over a short time interval (CP8b Subzone).

2. The terminal Paleocene/Ypresian transition involved a dramatic warm marine transgression (Leonov & Alimarina 1964 et al.) and a drastic increase in biogenic carbonate sedimentation. In the Ypresian, two $CaCO_3$ maxima are recorded, separated by a minimum during sapropelite accumulation. Lower Ypresian (CP9/CP11 Zones) likely corresponds to a climatic optimum, judging from nannofossil assemblages dominated by warm-water species. Species diversity, however, is not very high. The Middle Eocene shows a great increase in nannofossil productivity and species diversity (with a maximum in CP14a Subzone) caused constantly high $CaCO_3$ content (and accompanied by regional aridization, as established by paleofloristic studies), dropping only in the Late Eocene. This section is clearly rhythmic, consisting of strata several centimeters to tens of centimeters thick alternately higher or lower in calcareous matter (Milankovich cyclicity). This rhythmicity is better pronounced in the Maastrichtian, Danian, and Lutetian (CP13 Zone), and becomes vague to visually absent in the anoxic Kuma Fm. (CP14 Zone).

In summary, in the basinal evolution two stages with distinctive depositional, geochemical, and biotic features stand out sharply against the general carbonate-terrigenous sedimentation: (i) upper Thanetian, beginning in a dramatic decrease in $CaCO_3$ just before the sapropelitic bed accumulated (terminal CP8a), sapropelite formed (CP8a/CP8b Subzone boundary), and siliceous-terrigenous sediments accumulated (CP8b Subzone), and (ii) Bartonian (CP14), characterized by OM-rich sediments accumulated in a dysoxic to anoxic environment. The main changes in the depositional environment were evidently related to eustatic sea-level changes, anoxic episodes, climatic variations, and terrigenous input.

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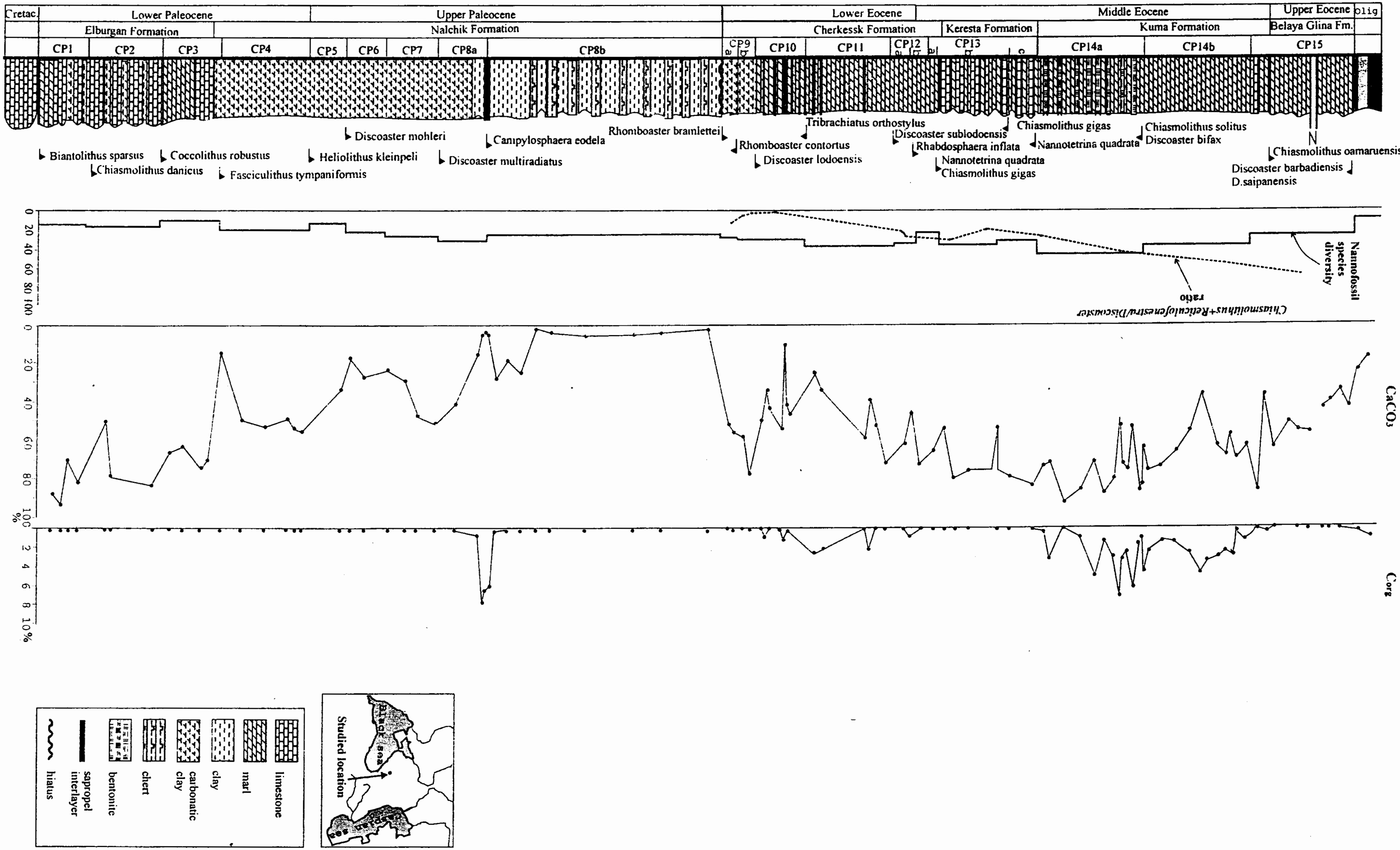

Cretac.
Lower Paleocene
Upper Paleocene
Lower Eocene
Middle Eocene
Upper Eocene
olig
Elburgan Formation
Nalchik Formation
Cherkessk Formation
Keresta Formation
Kuma Formation
Belaya Glina Fm.
CP1
CP2
CP3
CP4
CP5
CP6
CP7
CP8a
CP8b
CP9
CP10
CP11
CP12
CP13
CP14a
CP14b
CP15
Biantolithus sparsus
Chiasmolithus danicus
Coccolithus robustus
Fasciculithus tympaniformis
Discoaster mohleri
Heliolithus kleinpeli
Campylosphaera eodela
Discoaster multiradiatus
Rhomboaster bramlettei
Rhomboaster contortus
Discoaster lodoensis
Tribrachiatus orthostylus
Discoaster sublodoensis
Rhabdosphaera inflata
Nannotetrina quadrata
Chiasmolithus gigas
Chiasmolithus gigas
Nannotetrina quadrata
Chiasmolithus solitus
Discoaster bifax
Chiasmolithus oamaruensis
Discoaster barbadiensis
D.saipanensis
Nannofossil species diversity
Chiasmolithus+Reticulofenestra/Discoaster ratio
CaCO3
Corg
0 20 40 60 80 100
0 20 40 60 80 100 %
0 2 4 6 8 10%
limestone
marl
clay
carbonatic clay
chert
bentonite
sapropel interlayer
hiatus
Black sea
Studied location

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