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Lower Miocene Sediments of Central and Western Ciscaucasia

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Abstract—The composition, structure, and geochemical properties of the thickest, relatively deep-water Lower Miocene sediments developed in western Ciscaucasia are considered. Of particular interest are materials from the Kuban superdeep borehole SG-12000 that recovered the uppermost layers of the Maikop Group at 3148–3961 m in the central Indol–Kuban Trough west of Krasnodar. However, the borehole did not penetrate the whole Lower Miocene section of the Maikop Group. Therefore, characteristics of the Maikop Group are supplemented with new materials from several other boreholes drilled in the eastern Kuban region. Thus, the typical (reference) Lower Miocene section of central and western Ciscaucasia has been sufficiently well described.

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The composition and structure of the upper Lower Miocene section of the Maikop Group in the central segment of the Eastern Paratethys, as well as some aspects of their stratigraphy and correlation, were discussed in (Stolyarov and Ivleva, 2006). The major facies–paleogeographic features of Early Miocene sedimentation basins and relevant manganese and uranium–rare metal ore formation were also considered. It was shown that the Lower Miocene sections are most complete and geologically diverse in central and western Ciscaucasia. Therefore, this area of Ciscaucasia can be considered a reference region with respect to metallogeny and other issues.

New more detailed lithological–geochemical materials on several boreholes drilled in this region, including the unique Kuban superdeep borehole SG-12000 (hereafter, Borehole SG-12000), are available now. Therefore, it seems reasonable to discuss them separately in order to expand substantially the characteristics of Lower Miocene sediments given in (Stolyarov and Ivleva, 2006).

The upper part of the Maikop Group in central and western Ciscaucasia is composed of formations defined by K.A. Prokopov in sections along the Kuban and Zelenchuk rivers (from the bottom to top):

(I) The clayey–siderite Rittsa Formation with siderite and dolomite concretions. It should be noted that the Russian spelling of this formation is still ambiguous (Rittsa or Ritsa). Since the formation stratotype is located at Mt. Ritsa, the formation name ‘Ritsa’ accepted in many works (Zhizhchenko, 1958; Ter-Grigoryants, 1969; Popov *et al.,* 1993; Kochenov and Stolyarov, 1996; and others) should be considered as more correct.

(II) The clayey Ol’ga Formation developed near the eponymous settlement (the sediments include bivalves, gastropods, and arenaceous foraminifers).

(III) The clayey–siderite (Karadzhalga) Formation composed of foliated dark gray clays enclosing siderite concretions with crystalline pyrite, jet, and remains of large and small fishes’ (Prokopov, 1938, pp. 5, 6).

According to Prokopov, the Karadzhalga Formation is underlain by the Zelenchuk sandy formation.

Ter-Grigor’yants (1969) reported that clays of the Karadzhalga Formation in sections (150–170 m thick) exposed along the Kuban River near Cherkessk contain mainly arenaceous foraminifers *Cyclammina kubanica* sp. nov. and others.

The Ol’ga Formation (up to 300 m) is composed of sandy clays. Its stratotype section near the eponymous settlement includes abundant and diverse foraminifers *Neobulimina elongata* Orb., *Bolivina* ex gr. *floridana* Cushm., *Haplophragmoides* spp., and *Cyclammina* spp.

In the Ritsa Formation (200–300 m), paleontological remains are scarce. Its middle part hosts *Saccammina zuramakensis* Bogd., *S. ovalis* (Subb.), pyrite casts of diatoms, spherical bodies, and fish scales.

At the western foothills of the Ciscaucasus, the composition and structure of Lower Miocene sections show significant facies variations scrutinized in (Kalinenko, 1990) and slightly refined in (Stolyarov and Ivleva, 2006).

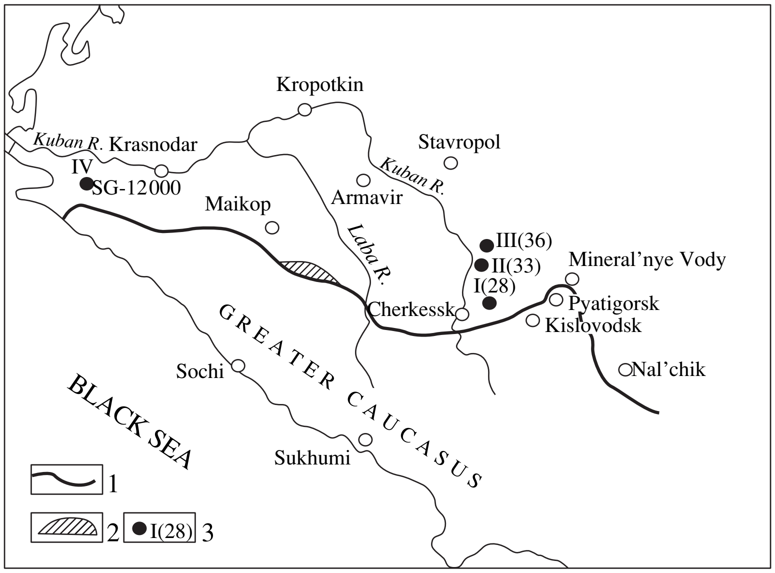


Fig. 1. Schematic location of Lower Miocene sections. (1) Boundary of Lower Miocene sediments; (2) Laba manganese deposit; (3) borehole sections and their numbers.

Additional data on the composition and structure of Lower Miocene sediments obtained from several borehole sections are discussed below (Figs. 1, 2).

SECTIONS OF THE EASTERN KUBAN REGION

The Lower Miocene section on the southern slope of the Eastern Kuban Trough in the Kuban reservoir area includes the Karadzhalga and Ol'ga formations (Fig. 2, Section I).

The Upper Oligocene sandy–clayey Zelenchuk Formation is overlain by the following members of the *Karadzhalga Formation*:

(1) Dark gray striated and thin-bedded clays with dispersed fish remains ("fish facies") and separate jet inclusions (thickness 23 m). Locally, silty material forms thin laminae and films. Member 1 also contains a thin (2 cm) interlayer of smectite tuffite. This member is characterized by the presence of 5–6 interlayers (3–8 cm) of iron sulfides with fish bone detritus and compositionally anomalous sulfide–siderite interlayers with thin (2–3 mm) intercalations of sulfides and carbonate material. The composition of sulfide interlayers is variable: S_{pyr} 8–17%; P_2O_5 0.9–8.01% (mainly, 1.22–2.07%). The U content in phosphate fish remains (0.10–0.15%) is lower than the content in bone deposits (0.2%) of the Upper Oligocene (Stolyarov and Ivleva, 2004).

(2) Gray to dark gray relatively uniform clays with rare fish remains and small nested–lenticular accumulations of silt or its thin (1–2 mm) laminae and films (50 m). Small carbonaceous sulfide aggregates and thin (2–5 cm) siderite intercalations are also present in Member 2.

(3) Dark gray clays enriched in iron sulfides (17 m). The sooty sulfide is mainly dispersed in clayey material and locally forms oolitic aggregates at bedding planes frequently together with fish detritus or fish scale (sometimes up to 1 cm across). The middle part of Member 3 hosts three closely spaced (separated by an interval of 1.5–2.0 m) interlayers of siderite concretions 5–6 cm thick. Like Member 1, these sediments enclose thin (1.5–6.0 cm) sulfide intercalations with bone detritus, sometimes up to 1 cm across (bone breccia). They contain as much as 8.4–12.1% S_{pyr} and 0.9–1.8% P_2O_5. Uranium concentration is higher (up to 0.15–0.19%) as compared with that in Member 1.

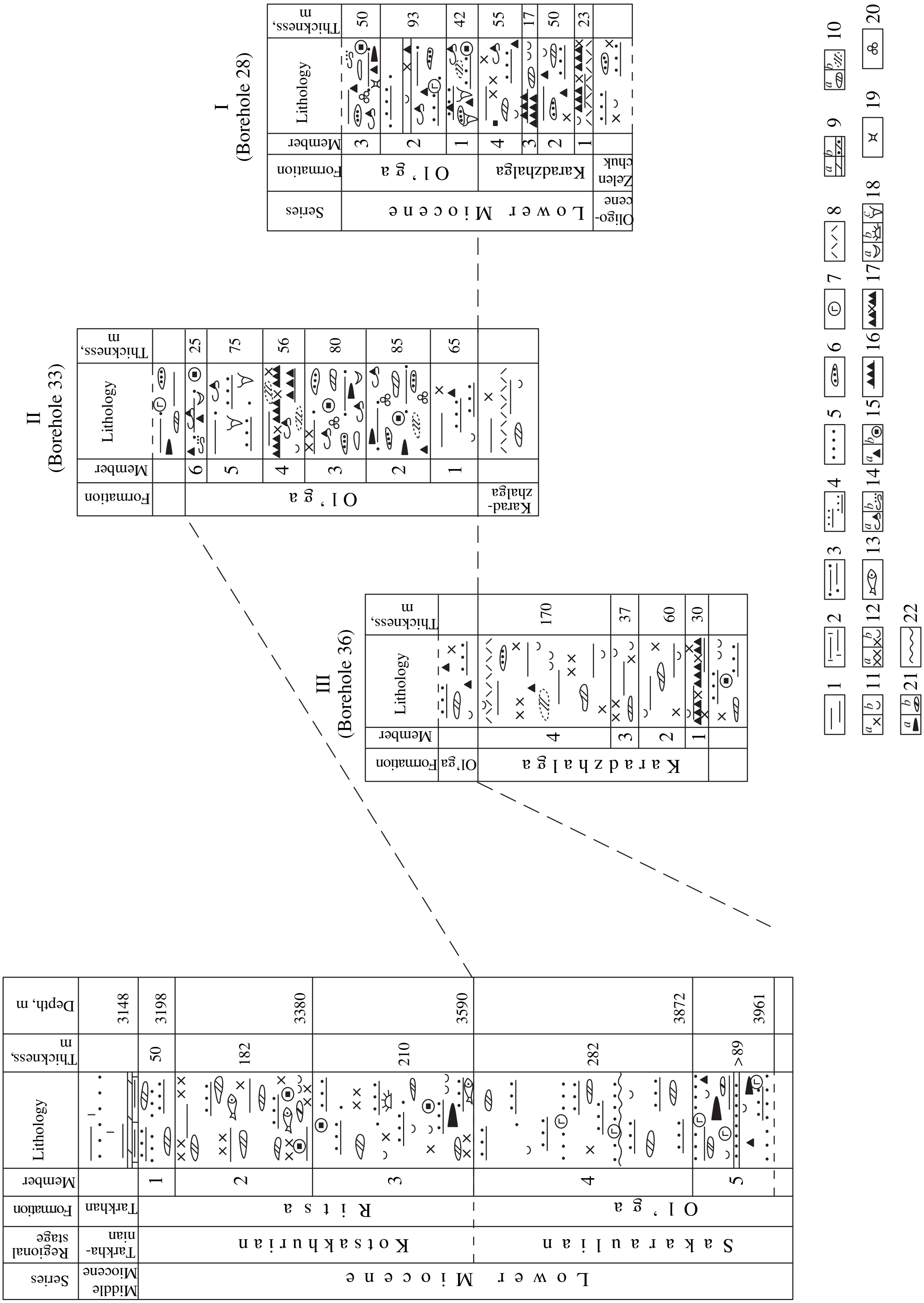
(4) Gray to dark gray clays dominated by uniform massive varieties almost lacking inclusions (55 m). In some places, they show obscure bedding emphasized by scaly organic matter or silty films. Scarce fish remains form small local accumulations. Isolated pyrite aggregates are microcrystalline (developed sometimes after fucoids) or cryptocrystalline (sooty) at bedding planes.

The most characteristic feature is the presence of thin (0.1–1.0 cm) layers of siderite concretions that occupy intervals up to 3–4 m thick. Some concretions, 3–5 cm in diameter, bear signs of dissolution (cavernous structure) with sulfide inclusions covered by a brown film of iron hydroxides.

The total thickness of the Karadzhalga Formation is 145 m.

The overlying **Ol'ga Formation** is characterized by the nearly universal presence of silty admixture in clays, while fish remains occur as sporadic inclusions. The Ol'ga Formation can be divided into the following members (from the bottom to top):

(1) Gray to dark gray clays, obscurely lenticular-bedded, less commonly thin-bedded because of differ-


I (Borehole 28)
Series
Formation
Member
Lithology
Thickness, m
Lower Miocene
Oligo-cene
Ol'ga
Karadzhalga
Zelenchuk
II (Borehole 33)
Karad-zhalga
III (Borehole 36)
IV (Kuban Borehole SG-12000)
Regional stage
Depth, m
Middle Miocene
Tarkha-nian
Kotsakhurian
Sakaraulian
Tarkhan
Ritsa

ent contents of silty material (42 m). The silty material usually contains cryptocrystalline (sooty), fine-crystalline, and globular (buckshot) sulfide aggregates. Sometimes, the sulfides fill up fucoids. It is noteworthy that globular sulfide grains are enveloped by a brown crust of iron hydroxides. Siderite forms numerous thin (up to 1–2 cm) lenticular interlayers closely spaced in narrow (up to 0.5 m) section intervals. Member 1 is remarkable for the presence of peculiar organic remains at bedding planes. Their impressions resemble small (up to 1.0–1.5 cm) undeterminable crustacean organisms. Algalike remains or white inclusions found in some places probably represent decomposed foraminiferal tests.

(2) Gray clays (93 m) with massive or lenticular-laminated structure depending on the distribution pattern of silty material with rare glauconite grains. In some layers, one can see thin lamination and striation defined by scaly organic matter with single fish remains. The sediments host both sooty (at bedding planes) and iron sulfide globules developed after fucoids in massive clays.

(3) Gray massive clays (50 m) with an irregular admixture of silty material as dispersion in clays, various lenticular accumulations, and filling in fucoids. The fucoids are relatively abundant. Sometimes, they are large (up to 2–3 cm) and filled with iron sulfides that locally make up sooty spots (in clays) or globules. Siderite concretions are mostly isolated and from 2–3 cm to 0.1 m thick. Locally, one can see coalified elongated plant remains, foraminiferal tests, and redeposited fish vertebrae.

The total apparent thickness of the Ol'ga Formation is approximately 185 m and the total thickness of the Lower Miocene section is 330 m.

Approximately 20–25 km west of the discussed borehole section, the Karadzhalga Formation is exposed in walls of the Kuban River valley near Cherkessk. This section makes it possible to specify some lithological features considered in (Stolyarov and Ivleva, 2006). Here, one can see that layers with siderite concretions extend over tens of meters. Sometimes, they are closely spaced (up to 1.5–2.0 m) and stacked in an echelon manner. Concretions (2–5 cm thick) are flat and elongated along bedding (up to 0.2–0.3 m). Isolated concretions are less common.

The chemical composition of concretions from the lower part of the Karadzhalga Formation exposed along the Kuban River is as follows (%): Na_2O 0.24, MgO 8.25, Al_2O_3 6.95, SiO_2 16.96, P_2O_5 0.58, K_2O 0.51, CaO 2.96, CO_2 15.07, TiO_2 0.27, MnO 0.25 (Mn 0.19), Fe_2O_3 33.90, and FeO 29.57. The carbonate composition is as follows (%): $FeCO_3$ 61, $MgCO_3$ 30, $CaCO_3$ 7, and $MnCO_3$ 0.4.

Thus, siderites are represented by the magnesian varieties (sideroplesites) typical of the Karadzhalga Formation and its stratigraphic analogues in western areas of the Caucasian homocline (Kalinenko, 1990).

Fish remains are scattered irregularly (in some interlayers, they form the typical "fish facies') and represented by bone detritus and scales that are sometimes large (up to 1.0–1.5 cm). Such clayey layers often contain wood remains (jet) that form locally thin (1–2 cm) lenticular structures.

The lithological–geochemical features of Maikop sediments of the Kuban River section are discussed in more detail in (Nedumov, 1993, 1998).

The Lower Miocene sediments demonstrate notable variations in the Southern Stavropol Swell and at its eastern subsidence (Figs. 1, 2, sections II, III).

The **Karadzhalga Formation** (Section III) is substantially thicker (297 m) and includes the following member.

(1) As in the North Caucasus homocline, the lower member (30 m) consists of dark gray clays of the typical fish facies, with the predominance of scales among fish remains. The member also includes sulfide interlayers with fish bone detritus (up to 0.1 m) characterized by the high U content in phosphate matter.

It should be noted that Member 1 extends as a typical fish-facies band (10–15 m thick) to the west along the South Stavropol Swell. It includes thin (up to 0.1–0.3 m) sulfide interlayers traceable over many kilometers as the Urakovo–Bogoslovsk, Nevinnomysk, Sengilei, Kaz'mino, and other uranium and rare metal occurrences (Kochenov and Stolyarov, 1996).

The sulfide interlayers (S_{pyr} 14–21%) contain an insignificant amount of bone detritus (P_2O_5 1.3–2.2%, average 1.75%). However, its phosphate matter is characterized by a high U content (0.36%) and relatively low REE concentrations (0.5%) (Stolyarov *et al.*, 1991). Bone remains are usually differently oriented, frequently large (up to 3–4 mm), and accompanied by rare angular grains of quartz, feldspars, and glauconite.

(2) Gray clays (60 m) with obscure striation or thin bedding emphasized by scaly organic matter. The clays contain abundant fish remains and rare relatively thick (0.15–0.25 m) siderite concretions.

Fig. 2. Composition and structure of the examined Lower Miocene sections in the central and western Ciscaucasus region. (1) Clay; (2) calcareous clay; (3) silty clay; (4) clay with thin silty intercalations and films; (5) interlayers of fine-grained sandstones; (6) silty lentils in clay; (7) glauconite aggregates; (8) tuffite interlayers; (9) carbonate interlayers: (*a*) marl, (*b*) sandy marl; (10) siderite concretions: (*a*) distinct, (*b*) obscure; (11) dispersed fish remains: (*a*) bones, (*b*) scales; (12) accumulations of fish remains: (*a*) bones, (*b*) bones and scales; (13) remains of fish skeletons; (14) fucoids filled with (*a*) dispersed pyrite and (*b*) silt; (15) pyrite aggregates: (*a*) finely dispersed, (*b*) microcrystalline; (16) iron sulfide interlayers; (17) iron sulfide interlayers with subordinate bone detritus; (18–20) organic remains: (18) mollusks (*a*), sea urchin (*b*), and crustaceans (*c*); (19) fish vertebra; (20) foraminifers; (21) admixture of organic matter: (*a*) humic, (*b*) jets; (22) unconformable boundaries.

(3) Dark gray striated and lenticular-bedded clays (37 m) with abundant scattered fish remains (bone detritus and scales) that form accumulations at bedding planes. This is a typical fish facies correlated with Member 3 of the homocline (Fig. 2, Section I) with sulfide interlayers that are missing in the considered section. Like in underlying sediments, some siderite concretions are relatively thick (0.15–0.20 m). The sediments include a brown earthy phosphate concretion 0.5 m across.

(4) Relatively uniform, gray to dark gray clays usually with vague striation or obscure bedding (170 m). Separate intervals of the section are distinguishable only owing to the variable quantity of dispersed fish remains, which disappear in some layers or make up accumulations of large bone detritus and fish scale (up to 1.0–1.5 cm thick) at bedding planes. Siderite concretions are isolated and up to 5–10 cm thick. The upper part of the Karadzhalga Formation hosts a thin (5 cm) interlayer of massive clayey tuffite with bluish tint.

According to the XRD data, clays (fraction <0.001 mm) of the Karadzhalga Formation are composed of smectite with an admixture of chlorite, hydromica, and kaolinite.

In the southern part of the Stavropol Uplift, the Karadzhalga Formation is composed of deep-water clays without silty material. However, they are characterized by a local development of interlayers of iron sulfide aggregates in the lower part of the section (Member 1). Iron sulfides also occur as isolated microglobules within clays of the fish facies.

Clays of the Karadzhalga Formation are overlain with a relatively distinct boundary by sediments of the **Ol'ga Formation** that is characterized by a more variable lithology and greater thickness (386 m) (Fig. 2, Section II). The Ol'ga section includes the following members (from the bottom to top):

(1) Gray to dark gray clays without siderite concretions (65 m). Some layers of its lower part (30 m) contain lenticular accumulations and films of silt (locally, scaly organic matter). Thin bedding of rocks is related to alternation of light and dark clay varieties.

(2) Gray and less common dark gray clays (85 m) with a massive or lenticular structure depending on the quantity of silty material. Some lentils contain numerous glauconite grains. Member 2 contains various sulfide aggregates ranging from sooty spots to globules. In massive clay varieties, sulfides frequently fill up fucoids. The sediments include numerous (up to 17) siderite concretions varying from thin (2–5 cm) isolated indistinct varieties to well-developed aggregates up to 0.1–0.15 m thick. Locally, one can see small coaly inclusions and accumulations of foraminiferal tests. Fish remains are missing.

(3) Gray to dark gray massive lumpy clays (80 m) with a variable silt content. Sometimes, nest-shaped accumulations are found. Abundant fucoids are filled with pyrite that locally makes up nodular or globular inclusions with an occasional coating of iron hydroxides. Siderite concretions (5–15 cm thick) are rather numerous and usually beaded.

Organic remains are represented by single impressions of echinoids, fragments of molluscan shells, large (1–2 mm) foraminiferal tests, and rare coaly detritus.

(4) Clays (56 m) without silty material. Member 4 is characterized by the presence of scaly organic matter in some layers and isolated fish remains (poorly manifested fish facies). Locally, such clays contain thin (up to 1 cm) sulfide intercalations with fish remains or aggregates of iron sulfides at bedding planes. Phosphate matter of fish bones is characterized by the high content of U (up to 0.3%) and Y (up to 0.7%). Massive clay varieties enclose numerous fucoids filled with sulfides. One can also observe thin (up to 5 cm) interlayers with siderite.

(5) Silty clays (75 m). In the lower part of the unit (50 m), they are mostly thin-bedded with silty laminae (up to 1 cm thick) and impressions of various crustacean organisms (up to 1 cm in size) that form accumulations along some bedding planes. Similar impressions were previously noted in sections of the North Caucasus homocline in the lower part of the Ol'ga Formation (Fig. 2, Section I, Member 1). Sulfides usually fill up fucoids in massive clays.

(6) Massive silty clays with bluish tint (25 m). They contain abundant sulfides in the form of spots within clays and nodular structures up to 2 cm across. The sulfides also fill up the abundant fucoids. The sediments enclose poorly preserved molluscan shells usually covered by cryptocrystalline sulfides. Siderite concretions are absent.

The XRD data indicate that, like in the Karadzhalga Formations, clays of the Ol'ga Formation (fraction <0.001 mm) are mainly composed of hydromicas and a smaller amount of smectite. Chlorite and kaolinite are subordinate.

The overlying sequence, arbitrarily attributed to the **Ritsa Formation,** is only represented by the lowermost layers (a few tens of meters thick) preserved after erosion. They are composed of ash-gray Òlays with a variable admixture of silty material, which forms locally patches and lenticular interlayers up to 1 cm thick. Some interlayers contain accumulations of mica, glauconite, black fine coaly material, and rare thin (up to 5 cm) siderite concretions.

It should be noted that the uppermost part of the Maikop Group was eroded in many areas of the central Ciscaucasus region. Therefore, its upper boundary is frequently unconformable (Stolyarov and Ivleva, 2006). In this respect, the section of Borehole SG-12000 drilled in the Indol–Kuban Trough 50 km west of Krasnodar is unique (Figs. 1, 2, Section IV). As was mentioned, the borehole penetrated only the uppermost part of the Maikop Group, because the drilling was stopped.

The stratigraphic position of the upper boundary in this section is determined by the conformable contact with the overlying Tarkhanian sediments of the Middle Miocene. This section, probably, characterizes the thickest part of the upper Maikop sequence that was deposited in an open sea basin in the central part of the Indol–Kuban Trough.

SECTION OF THE KUBAN SUPERDEEP BOREHOLE SG-12000

Over 200 core samples obtained from the Kuban geological–prospecting expedition of superdeep drilling (Krasnodarneftegaz Enterprise) were used to study the section of Maikop sediments and lower Tarkhanian strata (150 m). Field description of cores carried out down to a depth of 3600 m made it possible to obtain a more complete idea of the composition and structure of these sediments.

In total, 140 samples, including 24 samples of Tarkhanian sediments, were taken from the depth interval of 3000–3961 m for different analyses, and 136 thin sections were used for petrographic studies.

We performed the semiquantitative spectral analysis of rocks (140 determinations), complete chemical analysis of rocks (27), X-ray spectral analysis of uranium (140), determination of C_{org} (19), X-ray structural analysis (diffractometry) of clays (14), and mineralogical analysis of sandstones (12).

Because of the incomplete recovery of the Maikop section and certain ambiguity of its stratigraphy and correlation, which is discussed below, it seems reasonable to consider the given section beginning from the Tarkhanian interval, i.e., from the base to top.

Tarkhanian sediments (3000–3148 m). In contrast to Maikop sediments, the Tarkhanian layers are characterized by an admixture of carbonate (calcareous) material ($CaCO_3$ up to 12–25%) in all rock varieties that largely consist of clays (usually, silty) with the subordinate siltstone, sandstone, and rare marl interlayers.

Clays are gray to dark gray, sometimes with brownish tint. Their structure is generally oriented owing to the layerwise distribution of clayey aggregates that usually contain small (fractions of millimeter) pyrite globules. The clays also contain small gelified inclusions of brown organic matter elongated along bedding planes and abundant foraminiferal tests.

According to Kholodov and Nedumov (2001a, 2001b), the clayey material mainly consist of hydromica (70%) with subordinate chlorite and kaolinite.

Table 1 presents the chemical composition of clays from a depth of 3022 m. Data on the semiquantitative spectral analysis show high contents of the following elements relative to clarke concentrations (Cc): Mo 6.5; Sc 2; Mn, V, Zn, Mg, Cr, and Sr 1.2–1.5.

The silty admixture (1–2%) is usually dispersed in clays. Less commonly, it forms small lentils and thin (up to 1 mm) intercalations. The silt is largely composed of quartz with an admixture of feldspar, plagioclase, glauconite, tourmaline, zircon, leucoxene, and muscovite flakes. The silty layers have a clayey–carbonate (calcitic) basal-interstitial cement with pyrite segregations.

Light gray fine-grained sandstones with oblique to wavy-sinuous structures and clayey–carbonate cement constitute interlayers a few meters thick. The clastic material of sandstones is primarily composed of quartz with the subordinate feldspar, plagioclase, and glauconite grains. One can also see rare fragments of carbonate and siliceous rocks; tourmaline, ilmenite, leucoxene, zircon, and garnet grains; muscovite and biotite flakes; and small fragments of fish remains. Grains are usually angular, subangular, and, less commonly, rounded (quartz). The sandstones have a clayey–carbonate (hydromicaceous–calcitic) cement with rare siderite. The cement contains foraminiferal tests and small pyrite globules, which fill test chambers and envelope quartz and glauconite grains.

According to the semiquantitative spectral analysis data, the following elements in sandstones are characterized by high contents relative to Cc values: Cr 2, Sr 1.6, and Ba 1.5.

The lower part of the section (depth 3146.5–3147 m) encloses a interlayer of brown compact clayey marls with uneven fracture and the following composition (%): CaO 23.16, Al_2O_3 8.42, SiO_2 29.58, MgO 3.18, Fe_2O_3 6.86, FeO 4.55, Na_2O 0.65, K_2O 0.93, TiO_2 0.30, MnO 0.41 (Mn 0.32), and S_{tot} 0.70.

The marls are underlain by dark gray calcareous silty clays (0.6 m) with thin (0.5 cm) intercalations of fine-grained calcareous sandstone. The clays are underlain by a thicker (0.22 m) interlayer of compositionally similar compact sandstone. The boundary (basal) layer of Tarkhanian sediments (0.3 m) is composed of dark gray calcareous–silty bedded clays that conformably overlie carbonate-free clays (probably, the roof of the Maikop section).

Maikop sediments. The recovered section (depth 3148–3961 m) can be divided into five lithostratigraphic units (sequences) up to 180–280 m thick.

Sequence 1 (interval 3148–3198 m). The Tarkhanian–Maikop boundary layers (50 m) are composed of dark gray (locally, black), virtually carbonate-free ($CaCO_3$ 0–3%) clays. Their upper part (25 m) encloses abundant thin (0.2–9 cm) intercalations of black silt with local admixture of carbonate material in cement ($CaCO_3$ up to 4–7% and $CaMg(CO_3)_2$ up to 10%). The share of silty material decreases downsection both in the clays (1–2%) with oriented structure and in separate layers.

In contrast to Tarkhanian sediments, the Maikop section contains thin (2–8 cm) siderite concretions confined to particular layers and rare coalified plant remains. The chemical composition of clays is given in Table 1. According to semiquantitative spectral analysis data, high contents (relative to Cc values) are only

Table 1. Chemical composition of Maikop and Tarkhanian clayey rocks from the section of the Kuban superdeep borehole SG-12000, %

Age	Stratigraphic units (sequences)	Sampling depth, m	Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	K_2O	CaO	TiO_2	MnO	Fe_2O_3	FeO	L.O.I.	Total	S_{tot}	CO_2	C_{org}
Middle Miocene (Tarkhanian)		3022.00	1.43	2.64	26.27	53.67	0.15	2.98	4.11	0.77	0.10	7.03	3.21	10.35	99.50	0.89	4.27	1.17
Lower Miocene (Late Maikop)	Sequence 1	3148.90	1.06	2.08	19.14	51.90	0.06	2.53	0.35	0.68	0.10	8.31	1.96	13.28	99.50	3.48	0.70	–
		3198.00	0.96	1.98	14.39	56.73	0.12	2.26	0.32	0.56	0.06	8.42	1.60	13.69	99.50	4.12	0.35	3.69
	Sequence 2	3362.10	0.97	2.34	18.78	56.64	0.16	2.97	0.52	0.76	0.04	7.45	3.09	8.67	99.50	1.78	0.31	
	Sequence 3	3414.15	0.94	2.63	19.46	51.61	0.11	2.75	0.39	0.78	0.04	8.23	2.07	12.56	99.50	2.25	2.10	1.20
		3459.50	0.91	3.32	14.92	51‘.47	0.21	2.63	0.77	0.64	0.20	12.70	9.61	11.78	99.50	1.33	7.08	–
		3465.60	0.02	2.22	16.20	60.02	0.15	2.75	0.65	0.73	0.07	7.30	2.45	9.40	99.50	1.86	2.00	–
		3541.20	0.96	2.06	17.20	53.29	0.09	2.37	0.27	0.76	0.05	7.67	1.80	14.77	99.50	2.71	1.68	5.00
	Sequence 4	3597.60	1.08	2.26	17.75	57.79	0.09	2.73	0.50	0.87	0.08	7.64	3.04	8.74	99.50	2.27	1.39	–
		3604.30	1.07	2.32	20.41	55.39	0.06	2.41	0.53	0.95	0.07	7.97	2.05	8.37	99.50	0.93	0.26	–
		3629.70	1.16	1.60	13.19	68.46	0.10	1.83	0.73	0.53	0.04	6.15	1.59	5.65	99.50	0.21	0.53	–
		3648.50	1.10	2.01	17.39	60.48	0.12	2.64	0.55	0.82	0.05	7.07	2.34	7.27	99.50	1.90	0.57	–
		3686.00	1.12	2.99	17.38	57.87	0.14	2.52	0.65	0.82	0.05	8.27	3.61	7.69	99.50	1.52	0.67	0.77
		3759.20	1.08	2.65	14.42	59.07	0.22	2.19	1.08	0.69	0.08	10.06	6.27	8.00	99.50	1.46	3.08	–
		3856.20	1.12	2.20	20.47	56.26	0.08	2.77	0.48	0.98	0.05	7.18	2.26	7.91	99.50	1.65	0.56	0.56
	Sequence 5	3883.50	1.23	2.16	16.73	59.97	0.11	2.44	0.52	0.89	0.06	8.67	4.19	6.72	99.50	0.96	1.37	0.54
		3909.30	1.00	2.25	20.63	54.36	0.10	3.50	0.37	0.97	0.06	7.63	2.34	8.64	99.50	2.53	0.66	0.62
		3937.40	0.92	2.42	20.80	53.50	0.09	2.92	0.54	0.94	0.06	7.89	2.86	9.43	99.50	2.21	0.95	1.23

Table 2. Chemical composition of carbonate concretions from Maikop sediments in Borehole SG-12000, %

Stratigraphic units (sequences)	Depth, m	Fe_2O_3	FeO	MgO	CO_2	MnO	Mn	CaO	SiO_2	Al_2O_3	P_2O_5	Na_2O	K_2O
Sequence 1	3150	26.53	25.02	5.98	21.33	0.61	0.47	2.43	35.23	5.44	0.35	0.46	1.13
	3168	43.30	40.09	4.26	25.42	1.06	0.84	3.19	11.98	6.01	1.33	0.34	0.29
Sequence 2	3288	30.71	27.71	4.12	19.04	1.01	0.78	1.84	26.89	10.28	0.89	0.52	1.07
	3380	33.68	32.66	9.67	27.76	0.26	0.20	3.76	14.56	6.24	1.05	0.33	0.72
Sequence 3	3534	30.36	26.11	5.06	20.91	0.40	0.31	2.27	27.29	9.20	0.61	0.58	1.14
Sequence 4	3713	37.85	35.72	7.31	–	0.32	0.25	2.39	16.21	6.58	0.90	0.35	0.61
	3825	25.58	23.58	4.37	–	0.53	0.41	3.48	32.50	10.01	2.02	1.08	1.10
Average for the section		32.57	30.41	5.82	22.89	0.60	0.47	2.77	23.52	7.68	1.02	0.52	0.87

typical of Sc, Mo, V, Cu, Zn, Ti, and Co (Cc = 2, 11.5, 1.5, 1.2, 1.25, 1.2, and 1.2, respectively).

The silty material in clays and interlayers is represented by quartz with subordinate feldspars, plagioclase, zircon, mica flakes, and glauconite grains. Like in clays, the clayey cement in siltstones contains small pyrite globules.

Rare interlayers (up to 3 cm) of the fine-grained sandstone are primarily composed of quartz with the subordinate admixture of feldspars, plagioclase, and flakes of biotite, muscovite and chlorite. The heavy fraction includes mostly angular to subangular tourmaline, leucoxene, barite, zircon, garnet grains, and small pyritized fish bones. The sandstones have an interstitial carbonate–clayey (locally, siliceous) cement of the contact-type with small pyrite and marcasite globules. The contents of chemical elements in sandstones are at the clarke level, except for Cr (Cc = 4).

Tables 2 and 3 present data on the chemical composition of siderites from the uppermost part of the section (depth 3150 m). Downward the section (depth 3168 m), the siderites are characterized by higher Fe and Mn contents.

According to the semiquantitative spectral analysis data, contents of the following elements are higher than clarke values: Sc 1.6, P 3.4, Zn 1.25, Y 1.3, Yb 1.3, Mn 15.

Sequence 2 (interval 3198–3380 m). The 182-m-thick sequence is distinguished by the following features: clays of this sequence contain fish remains largely as accumulations of small bone detritus and fish scale at bedding planes; the presence of small (a few centimeters) intact fish skeletons; the abundance of siderite concretions; the development of silty films and thin (up to 1–2 cm) laminae of fine-grained (locally, wavy-bedded) sandstones, which occur mainly in the lower part of the section; and the presence of coalified plant remains. The depth of 3260 m is marked by a thin (3 cm) interlayer of brownish compact limestone ($CaCO_3$ 74%, $CaMg(CO_3)_2$ 19%).

The clays are dark-gray to black in the upper part of the section (~80 m) and dark gray with brownish tint in the lower part. They are composed of hydromicas (50%) with the subordinate kaolinite and chlorite (20%). The smectite content is anomalously high (up to 30%) for the section (Kholodov and Nedumov, 2001a, 2001b). The clays are enriched in scaly organic (animal) matter (C_{org} up to 3.7%) and dispersed iron sulfides (S_{pyr} up to 4.1%) that are typical of the fish facies.

We have noted the following mineral inclusions and fish remains at different levels of the section: accumulation of bone detritus (1 mm in size) with large fins at the roof of the sequence (depth 3198 m); small fish skeleton lacking the head (3274.5 m); intact fish skeleton (3337 m); accumulation of scales and small fish bones (3342 m); cubic pyrite crystal (3342.4 m); accumulation of large (up to 1–2 cm) fish bones (3362 m); jet fragment (3363 m); plant remains (3364 m); accumulation of fish remains (3365 m); fish vertebrae (3366 and 3377 m); branchial fish bones (3379 m); and accumulation of large (1–2 cm) fish bones at the contact with siderite concretion (3380 m).

Some large fish bones from a depth of 3362 m are enriched in Sc (0.007%, Cc = 7), Sr (0.1%, Cc = 2), Ce (0.1%), and Y (>0.05%). Intervals of clays with fish

Table 3. Composition of carbonates in concretions from Maikop sediments in Borehole SG-12000, %

Stratigraphic units (sequences)	Depth, m	$FeCO_3$	$MgCO_3$	$CaCO_3$	$MnCO_3$
Sequence 1	3150	63.00	28.00	7.00	2.00
	3168	76.00	14.00	8.00	2.00
Sequence 2	3288	72.00	19.00	6.00	3.00
	3380	60.00	32.00	8.00	1.00
Sequence 3	3534	70.00	22.00	7.00	1.50
Sequence 4	3713	68.00	25.00	5.00	1.00
	3825	66.00	20.00	12.00	1.50
Average for the section		68.00	22.86	7.57	1.71

bone accumulations are also characterized by the high U content (0.0005–0.00082%, Cc = 1.5–2.5).

Average contents of the majority of chemical elements in clays are at the clarke level. Contents higher than Cc values are only noted for Mo, Sc, V, Cu, and Zn (Cc = 18.5, 2.2, 1.5, 1.3, and 1.4, respectively).

The silty admixture in clays is largely represented by quartz, feldspars, muscovite and biotite flakes, glauconite, and single grains of zircon and silica. The fine-grained sandy material also includes garnet and tourmaline grains, small fragments of fish bones, and clayey rolls. The sandy–silty material is composed of angular to subangular grains.

As was noted, clays of this sequence contain abundant siderite concretions of rudimentary and other shapes. Tables 2 and 3 show that the concretions are composed of magnesian siderites (sideroplesites) characterized by high contents of the following elements: Mn, Mo, Sc, P, Pb, Zn, Y, Yb (Cc = 7.3, 7.0, 3.0, 2.8, 1.6, 1.25, 1.5, 1.5, respectively).

Sequence 3 (interval 3380–3590 m). Like in Sequence 2, sediments of the 210-m-thick Sequence 3 contain abundant fish remains. The sequence is characterized by high contents of silty and sandy material in the form of dissemination, separate layers (up to 10–12 cm), and lenses of cross-bedded and other varieties of siltstones and sandstones. Siderite concretions are more differentiated in the section and locally grouped into four to six closely spaced interlayers 3–13 cm thick.

The enrichment of dark gray to black clays in the sandy–silty material and fish remains, as well as some other lithological features noted below, indicate peculiar sedimentation settings during the accumulation of Sequence 3.

Clays in this sequence are characterized by the following lithological features and characteristic inclusions: pyrite lens (depth 3385 m); small fish bones in silty laminae (3409 m); 5-cm-thick marly clay layer (3417 m); accumulations of fish remains (3420 and 3425 m); large (up to 1–2 cm) fish bones (3427 m); branchial fish bones (3429 m); accumulation of fish scale and bone detritus in the siltstone interlayer (3440 m); large (3 cm) coprolite (3442 m); accumulation of fish scale (3470 m, 3482 m); siderite concretion with dissolution cavities and iron hydroxide rim (3507 m); 1-cm-thick coprolite (3513 m); clays of the fish facies with dissemination of fish bone detritus and scale (replaced by chalcedony in some places) and fish fin (3526–3535 m); large pyrite and chalcopyrite crystals (3541 m); siderite concretion with dissolution caverns (3565 m); large (a few centimeters) coaly inclusions (3571.5 m); fish scale replaced by chalcedony (3576 m); accumulation of black coaly organic matter (3580 m); 5-cm-long fish skeleton (3582 m); and clays of the fish facies with scattered fish detritus and accumulation of scaly organic matter (3586–3588 m).

Like in the underlying sequences 4 and 5, oriented clays in sequence 3 are largely composed of hydromicas (50–60%), kaolinite, and chlorite (Kholodov and Nedumov, 2001a, 2001b).

The sandy–silty material is composed of quartz with the subordinate glauconite, feldspars, biotite, tourmaline, and ilmenite. Grains of these minerals are usually angular. The cement of silty sandstones is composed of clayey, locally carbonate–clayey (calcite–siderite), and contact-type siliceous materials.

Sediments from intervals with accumulations of fish remains are characterized by the high contents of phosphorus (P_2O_5 up to 0.2%), organic matter (C_{org} up to 5%), and U (average 0.001%, Cc = 3). The U content recalculated to phosphate matter of fish remains is 0.158%, which is slightly lower than the average U content (0.2%) in fish remains from deposits in Upper Oligocene sediments (Stolyarov *et al.,* 1991).

According to semiquantitative spectral measurements in 15 samples, clayey rocks are characterized by high contents of the following elements (%): Sc 0.0018, Mo 0.0018, V 0.014, Cu 0.056, Zn 0.015, and Ti 0.65 (Cc = 1.8, 9.0, 1.3, 1.1, 1.2, and 1.2, respectively).

Sandstone samples with cement enriched in iron sulfides (5 analyses) are characterized by high contents of the following elements (%): Mo 0.0027, Cr 0.021, Sc 0.0015, Zr 0.026, and Ca 3.0 (Cc = 13.2, 1.0, 1.5, 1.3, and 1.2, respectively).

Tables 2 and 3 show that concretion from the depth of 3534 m is composed of ferruginous and magnesian siderite (sideroplesite).

Coprolite from the depth of 3442 m demonstrates high contents of phosphorus (>1%), Sc (0.01%, Cc = 10), Y (>0.3%), Yb (0.015%), and La (0.1%).

Sequence 4 (interval 3590–3872 m) is the thickest unit (282 m) and differs from the overlying sequence by the nearly complete absence of fish remains (rare scales and bones) and the notably lower content of sandy–silty material, organic matter (C_{org} 0.66%), and iron sulfides.

The sequence is composed of relatively uniform gray to dark gray (rarely, black) clays with an admixture of silty material developed as dispersion in the section and coating at bedding planes, which are responsible for the thin lenticular lamination of rocks. The sequence includes rare interlayers (<0.1 m) of fine-grained sandstone, the base of which is sometimes marked by wavy structure with clayey lentils (1–2 cm) near the contact.

Based on the semiquantitative spectral analysis data, clays of Sequence 4 are distinguished from other sequences by higher contents of the following elements (%): V 0.030, Zn 0.015, Ti 0.65, and Mg 1.78 (Cc = 2.3, 1.8, 1.4, and 1.3, respectively). However, they are depleted in Sc (0.0017) and Mo (0.0013) (Cc = 1.7 and 6.5, respectively).

Sandstones are composed of quartz with an insignificant admixture of glauconite, muscovite flakes, feldspars, and apatite. The clayey–carbonate (calcite, siderite) cement of the interstitial and basal types includes globular pyrite and marcasite.

Siderite concretions occur throughout the entire sequence. They are less abundant (although compositionally similar) than in the overlying sediments (Tables 2, 3).

Semiquantitative spectral measurements in 10 concretions from different parts of the section revealed high average contents of Sc, P, Mn, V, Zn, and Mg (Cc = 1.5, 1.3, 4.2, 1.4, 1.6, and 1.9, respectively).

Sequence 5 (interval 3872–3961 m). Analysis of 25 samples from the 89-m-thick recovered part of this sequence revealed the highest contents of sand. The apparent presence of thick (meter-scale) layers with cross-wavy and lenticular-bedded structures indicates high-energy sedimentation settings. The absence of siderite concretions is noteworthy.

The sequence includes black sandy clays with black fish scale and plant remains (at 3886 m), dark gray clays with inclusions of jet and plant remains (3905 m), sandy clays with scarce fish scales (3909 m), and clays with black remains of plant (?) material (3937 m).

The clays are largely composed of hydromicas with the subordinate kaolinite and chlorite (Kholodov and Nedumov, 2001a, 2001b). They contain silty material, small pyrite globules, and rare scaly organic matter mainly confined to black varieties (C_{org} up to 1.23%). Such clays are characterized by the high U content (Cc = 2.15).

In terms of the composition and concentrations of chemical elements (Table 1), the clays are similar to those in the overlying sequences with the contents of many elements (Sc, Mo, V, Zn, Ti, Mg, Co, and Y) exceeding clarke values (Cc = 1.6, 3.0, 3.0, 2.0, 1.3, 1.4, 1.1, 1.3, respectively).

The sandstones are mostly composed of fine- and medium-grained sand. Downward the section, they are depleted in glauconite and enriched in tourmaline, zircon, apatite, garnet, and biotite. Brookite and rutile grains are sporadic. Detrital grains are subangular (less commonly, angular).

The clayey (locally, siliceous) cement in the sandstones varies from the interstitial to basal and regeneration type. Interlayers with siderite cement are encountered at depths of 3872.5 and 3917.0 m are marked by interlayers. The content of most chemical elements in the sandstones is at the clarke level or lower. Only Ni, Mo, Zn, and Fe are characterized by higher concentrations (Cc = 2.8, 4.0, 1.5, and 1.2, respectively).

Data on the examined part of the Maikop section penetrated by Borehole SG-12000 suggest the following inferences.

Despite generally uniform composition of the recovered relatively thick part of the clayey sequence (813 m), it can be subdivided into several lithostratigraphic units that are characterized by the specific composition and structure of rocks. One can see discrepancies in the distribution of sandy–silty material, siderite concretions, and, particularly, fish remains. This has been first shown for the studied part of the Maikop section.

We have identified a thick (392 m) complex with the fish facies (sequences 2 and 3). The lower part (Sequence 3) is also characterized by the high content of sandy–silty material, which is atypical of sediments of the fish facies. An exception is provided by the Upper Oligocene Zelenchuk Formation that accommodates the large Cherkessk bone–sulfide deposit (Stolyarov and Ivleva, 2004).

Lithological–geochemical features of the examined sediments are characteristic of the Maikop Group as a whole. Clays are largely composed of hydromicas. Terrigenous mineralogical associations are virtually identical to those in the general Maikop section of the Ciscaucasian province (Grossgeim, 1961; Stolyarov and Ivleva, 2004).

The composition of siderite concretions in the recovered section of Maikop sediments is relatively sustained. Variations in the content of major components are as follows (%): $FeCO_3$ 63–76, $MgCO_3$ 14–28, $CaCO_3$ 5–12, and $MnCO_3$ 1.0–2.0.

Siderite concretions are enriched in Mn (0.2–0.8%). Its high content (0.32%) is also established in an interlayer of clayey marl (0.65 m) in the lowermost part of the overlying (Tarkhanian) sediments. As was mentioned, Lower Miocene (Ol'ga) sediments of western Ciscaucasia are characterized by the high Mn content and they enclose the Laba manganese deposit (Kalinenko, 1990).

High contents of Sc (average 0.0020–0.0025%, Cc = 2–2.5) in clays are among the characteristic geochemical features recently established in Maikop sediments (Stolyarov *et al.,* 1991). Its concentrations in upper Maikop clays of the examined section is slightly lower (0.0016–0.0018%, Cc = 1.6–1.8).

The main metallogenic feature of Maikop sediments is the universal intense accumulation of rare elements in fish remains. Let us recall that average contents of U and Sc in phosphate matter of Oligocene sediments are as high as 0.2 and 0.003%, respectively (Stolyarov *et al.,* 1991; Stolyarov and Ivleva, 2004).

Accumulations of fish remains in the examined section are generally characterized by lower U contents in bone phosphate (U 0.158%), while Sc concentrations (0.006–0.007%) are virtually as high as its maximum values established in bone detritus deposits (0.008%). Moreover, the Sc content in coprolite from a depth of 3442 m is 0.01% (Cc = 10), which is the highest value among established ones in Maikop sediments.

Concluding the lithological–geochemical characteristic of the Borehole SG-12000 section, we should note that Maikop sediments penetrated in the depth interval of 3148–3961 m experienced catagenetic alterations and tectonic deformations. Clays in this interval are always compact and hard (argillite-type). Sandstones are strongly cemented. Siderite concretions are frequently characterized by conchoidal fracture and dissolution caverns. The sediments demonstrate usually horizontal bedding (dip angle 1–2°), but the dip angle increases to 5–10° in the lower part of the section. The entire section is characterized by the development of slickensides that crosscut the bedding at an angle of 20–40°. In some places, they are covered by chalcedony films.

The problem of catagenetic hydromicatization in Ciscaucasia, including the Kuban superdeep borehole area, is considered in (Kholodov and Nedumov, 2001a, 2001b). They have shown that beginning from the depth of approximately 3 km, smectite in clayey sediments is subjected to hydromicatization, which represents a significant geological phenomenon accompanied by the formation of carbonate dissemination and authigenic iron minerals, interaction of interstitial solutions with the dispersed organic matter, and other processes.

STRATIGRAPHIC ASPECTS

Stratigraphic correlation of sediments drilled by Borehole SG-12000 is one of the most important issues. Their paleontological study was carried out in the Geological Section of the Scientific–Technical Center of the Kubangazprom Enterprise (Krasnodar) by T.A. Malakhova and T.N. Pinchuk (foraminifers) and in the Geological Institute of the Russian Academy of Sciences by M.A. Akhmet'ev and N.I. Zaporozhets (spores and pollen). Results placed at our disposal suggest the following inferences.

As was mentioned above, the base of the Middle Miocene Tarkhanian regional stage is located at s depth of 3148 m. Tarkhanian sediments yielded the characteristic foraminiferal species *Bolivina tarchanensis* Subb. et Ch., *Globigerina tarchanensis* Subb. et Ch., and others. It should be emphasized that Malakhova and Pinchuk assume the location of the Tarkhanian base at a depth of approximately 3200 m, where *Globigerina* ex gr. *tarchanensis* Subb. et Ch. occurs together with redeposited (?) Maikopian forms. At the same time, they indicate that this problem needs an additional study because of a rather complicated pattern of foraminifer distribution in Maikop sediments (see below). Therefore, we place the Tarkhanian base in this communication at a depth of 3148 m, which is also consistent with the standard logging data.

The uppermost layers of the Lower Miocene section constitute the *Kotsakhurian regional stage*, the stratigraphic analogue of which is represented by the *Ritsa Formation* with the characteristic *Saccammina* foraminiferal assemblage in central Ciscaucasia. In the section under consideration, the upper part of the Maikop Group (sequences 1–3) down to a depth of 3590 m is characterized by finds of the following foraminiferal species: *Saccammina zuramacensis* Bogd., *S. ovalis* Subb., *S. suzini* Bogd., *Hyperammina djanaica* Bogd., *H. caucasica* Bogd., and others.

It is important that this stratigraphic interval also contains abundant foraminiferal species that are characteristic of the underlying Ol'ga Formation of central Ciscaucasia (Sakaraulian regional stage). Malakhova and Pinchuk consider them redeposited species.

Sediments from a depth of 3161 m, i.e., 13 m below the Tarkhanian base, yielded *Haplophragmoides* aff. *kjurendagensis* Moros., *H.* sp., *Ammodiscus* sp. and other foraminiferal species. *Saccammina* spp. are accompanied downsection by redeposited *Haplophragmoides* aff. *rotundidorsatus gratus* Ter-Grig. (3178, 3213, 3223, 3243, 3365, and 3590 m), *H.* ex gr. *kjurendagensis* Moros. (3253, 3470, and 3590 m), *Neobulimina* aff. *elongata* Orb. (3264 m), *N.* sp. (3590 m), and others.

Based on the microfauna data, sequences 4 and 5 (3590–3961 m) should be attributed to the *Sakaraulian regional stage* (Ol'ga Formation). This part of the section lacks *Saccammina* representatives, but it contains *Hyperammina djanaica* Bogd., *H. caucasica* Bogd., *H.* sp., *Haplophragmoides* ex gr. *kjurendagensis* Moros., *H.* ex gr. *rotundidorsatus* Hantk., *H.* sp., *Ammodiscus tenuiculus* Subb., *A.* sp., *Trochammina* aff. *floridana* Subb., *T.* sp., and others.

Based on the palynological study of the section, M.A. Akhmet'ev and N.I. Zaporozhets showed that the recovered part of the Maikop section in Borehole SG-12000 should be dated back to the Early Miocene and correlated with the Ritsa and Ol'ga formations of central Ciscaucasia; the borehole did not reach the Karadzhalga level; and the boundary with the Tarkhanian regional stage is located at a depth of 3148 m.

The lower Tarkhanian sediments were studied in the depth interval of 3090–3148 m. Their affiliation to the Lower–Middle Miocene boundary layers is evident from the notable quantity of frutescent, herbaceous, and arboreal (pine and oak) pollen characteristic of the uppermost Burdigalian–basal Helvetian of West Europe and Carpathian of Central Europe, which is traditionally correlated with the Tarkhanian regional stage of the Eastern Paratethys.

The Maikop part of the section contains a common palynological assemblage with a variable proportion of the major components. Therefore, we can define the following four successive palynological subcomplexes (from the top to bottom):

Subcomplex A characterizes the upper 90-m-thick interval of the section (down to a depth of 3238 m). This subcomplex is marked by the relatively high content of thermophile components (particularly, *Quercus*) and *Engelhardtia*, indicating the onset of notable warming that also persisted in the Tarkhanian.

Subcomplex B (3270–3460 m) differs from the previous one in the higher share of gymnosperm pollen and the leading role of Taxodiaceae. In the angiosperm spectrum, Fagaceae, Betulaceae, Juglandaceae, and Ulmaceae pollen are present in approximately equal proportions.

Subcomplex C (3489–3883 m) is characterized by the predominance of coniferous pollen (up to 70%) in the angiosperm spectrum. Simultaneously, the content of Fagaceae and Juglandaceae pollen increases and single *Cedrus* pollen grains appear in sediments. This subcomplex characterizes a new phase of the slightly dry and warmer climate similar to that in the Tarkhanian.

The lowermost *Subcomplex D* is distinguished from all previous subcomplexes by approximately equal proportions of angiosperms and gymnosperms and the notable prevalence of Fagaceae pollen (>50%) in the gymnosperm spectrum.

The organic-walled phytoplankton accounts for no more than 2% of the total palynomorph quantity. However, Akhmet'ev and Zaporozhets have noted that the phytoplankton includes a high content (up to 70–80%) of *Deflandrea spinulosa* Alb., which was previously reported only from Oligocene sediments in southern areas of the former Soviet Union and Romania.

According to Akhmet'ev and Zaporozhets, although the examined sediments are referred to the Early Miocene based on the presence of *Deflandrea spinulosa* in the basal part of the section, one cannot ignore the issue of origin of this species. It is conceivable that either its range also includes the previously unknown Lower Miocene interval or the Ol'ga Formation can at least partly be attributed to the Oligocene. This issue also requires further study because of the ambiguous stratigraphic position of the underlying Karadzhalga sequence (regional stage), which is referred by some researchers to the Lower Miocene (Popov *et al.,* 1993; and others).

Thus, according to palynological data, the main part of the Lower Miocene section (sequences 1–4, >700 m thick) can be correlated with the Ritsa Formation of Ciscaucasia, while only Sequence 5 with an apparent thickness of ~90 m correlates with the Ol'ga Formation.

At the same time, the vertical distribution of foraminifers and lithology of the examined section allow the entire Sequence 4 (~280 m) to be attributed to the Ol'ga Formation, Thus, the Ol'ga Formation can be 370 m thick. In this scenario, the stratigraphic range of the Ritsa Formation should include only sequences 1–3 with a total thickness of 442 m.

It should also be noted that the established palynological subcomplexes do not correspond in range with the volume of defined lithological units except for the lowermost Subcomplex D, which only characterizes Sequence 5.

CONCLUSIONS

The materials discussed in the present communication supplement substantially available data on Lower Miocene sediments developed in western areas of Ciscaucasia, although the Mn potential of these sediments is studied in sufficient detail (Kalinenko, 1990). Of particular interest is the section drilled by Borehole SG-12000. It is the only representative section for the uppermost part of the relatively well-studied Maikop Group. Unfortunately, this borehole recovered the Lower Miocene section only partly. Therefore, we had to use materials on other sections from adjacent areas of the eastern Kuban region. Thus, we could scrutinize the structure, lithology, and geochemical features of the Lower Miocene section that characterizes the thickest sequences of open (relatively deep) zones of marine basin in the southern part of central and western Ciscaucasia.

We have first examined the major features of the development and metallogenic potential of the fish facies. They are localized at two (Karadzhalga and Ritsa) stratigraphic levels and are virtually absent in the intervenient Ol'ga Formation, which is characterized by high Mn contents and the presence of ore-grade Mn concentrations in the marginal deltaic facies (Laba deposit).

The fish facies are most complete in the Karadzhalga Formation of the eastern Kuban region. They control the distribution of extended (kilometer-scale) but thin (0.1–0.3 m) sulfide interlayers with a subordinate quantity of fish bone detritus (up to 5–6%). However, phosphate matter of the bone detritus is marked by the high U content (up to 0.36%). Such value is characteristic of Upper Oligocene U-bearing deposits of fish bone detritus (Stolyarov and Ivleva, 2004).

In the Ritsa Formation (Borehole SG-12000), the fish facies are less typical and sometimes accompanied by significant concentrations of sandy–silty material. Therefore, the U content in fish remains is lower in these sediments (0.158%).

We have discovered that the Lower Miocene clayey sediments are characterized by the high Sc content (up to 0.0016–0.0018% versus 0.0020–0.0025% in Oligocene clays). However, the Sc concentration increases to 0.006–0.008% in the phosphate matter of fish remains and reaches 0.01% in coprolites.

In conclusion, it should be noted that the lithological–geochemical characteristic of the Lower Miocene sediments presented in this communication based on the best-studied sections of central and western Ciscaucasia combined with materials on the entire central part of the Eastern Paratethys (Stolyarov and Ivleva, 2006) terminates our long-term detailed study of the composition, structure, metallogenic potential, and formation environments of the Maikop Group as a whole. The results obtained can foster the analysis of the general evolutionary–geological formation model of the Maikop Group and its unique metal potential.

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