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Lithological–Stratigraphic Characteristics of the Aptian–Cenomanian Sediments of the Abkhazian Zone of the Western Caucasus

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Abstract—For the first time, a complex lithological–stratigraphic and facial study of the Aptian–Cenomanian sediments of the Abkhazian zone of the Northwestern Caucasus was carried in sections of the Mzymta and Khipsta river valleys. As a result, the areas of distribution of potential oil-source rocks in these sediments, which correspond to the events of the OAE-1 and OAE-2 global paleoecological crises, oil reservoir rocks and rocks-caps were defined.

Keywords: Western Caucasus, Aptian, Albian, Cenomanian, OAE-1, OAE-2

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INTRODUCTION

This work presents the results from the study of the lithological composition of the Aptian–Albian and Cenomanian sediments in the Abkhazian zone (in the Western Caucasus, in the Mzymta River valley) and in the area between the valleys of the Psou and Ingur rivers, which were carried out by the author's team in the 2008–2011 period, as well as presenting data that confirm the age of these sediments.

The study included:

a) a description of natural and artificial outcrops and the borehole cores from several tens of boreholes and their comparative analysis, *b*) selection of samples for petrographic and geochemical studies, as well as dating the Nanoplankton complex, and c) an analysis of the literature materials and their comparison with new data.

It was established that the data about the lithological composition of the Aptian–Albian and Cenomanian sediments, which were based mainly on the description of natural outcrops, differ from those that were obtained during the study of the sections of boreholes that were drilled in sediments of the same age. In particular, we found that the proportion of argillaceous rocks in the Aptian–Albian and Cenomanian sediments is much higher than was previously thought. The mapping of the territory made it possible to obtain the data on the material compositions of sediments by studying rare outcrops and numerous large landslide bodies, which contain rocky argillo–carbonaceous rocks (marls, rarely limestones). The argillaceous 1
parts of the section are hidden by landslide bodies and are not exposed at the surface. The new data were obtained due to drilling and construction works in the Mzymta River valley. Based on these works it became possible to study the lithology of this interval of the section in detail.

The sections we studied were tested for the occurrence of nanoplankton to distinguish landslide argillaceous rocks from primary clays. In addition, it was found that the proportion of argillaceous rocks in the section is much higher than previously thought.

This allows us to consider the Aptian and Albian bituminous strata not only as potential oil-source rocks, but also as a regional cap. In order to confirm this, a number of outcrops were described in the Mzymta River valley, in the area of the Kepsha settlement, and outcrops on the right bank of the Khipsta River, in the area of the village of Otkhara (Uatkhara). The scheme of the studied sections is shown in the insert map (Fig. 1).

Research Methods

During the field works we carried out, the natural outcrops and the borehole cores were studied. In the samples that were taken from sections, the nanoplankton complex was described by E.A. Shcherbinina (GIN RAS); 12 samples were analyzed by E.N. Samarin (Moscow

State University) using a MARC.GV X-ray fluorescent spectrometer (NGO Spectron, St. Petersburg). In addition, a petrographic microscope study of eight samples was made by G.K. Kozlova (Moscow State University).

Lithological–Stratigraphic Characteristics of the Aptian–Cenomanian Sediments

In the natural exposures on the right bank of the Mzymta River, upstream from the mouth of the Kepsha stream (point of observation 456), the Lower Aptian sediments were described in a bench of argillaceous Aleurites that were revealed at a road cut of the slope (Figs. 1A, 2).

The Aleurite is gray–brown, whitish-brown to pale-brown on the weathered surface, massive, with a pelitic texture and an unbedded or very thin-bedded structure, probably due to dispersion differentiation of terrigenous material. The rock is intensively bedded. Due to this, aleurites can be split easily into small 2–3 cm plates. In addition, the aleurite is low-strength and swells easily; small fragments can be ground to dust with little effort. In the texture of the rock, numerous bands of reddish and brownish color occur because of superimposed ferruginization.

Figure 1B shows the aleurite, which microscopi-
3 cally is fine-grained, polymictic, and greatly calcareous (40%), with poorly manifested horizontal bedding
2 due to an occurrence of interlayers enriched in calcareous material. Fractures are filled with fine-fiber calcite.

The nanoplankton complex that was found in the rock contains *Watznaueria barnesae*, *W. manivitae*, *Braarudosphaera batiliformis*, *Micrantolithus hoschulzii*, *Nannoconus boucheri*, *N. grandis*, *N. truittii*, *N. vocontiensis*, *Assipetra terebrodentarius*, *Flabellites oblongus*, and *Rhagodisucus gallagheri*. This complex corresponds to the Early Aptian age (Zone NC6b).

For the elements of the rock bedding, the dip in azimuth is 45° and the dip angle is 65°.

In the core of boreholes that were drilled on the left bank of the Mzymta River (Fig. 2), the Lower Aptian
1 sediments are presented by argillaceous marls, clays,
1 and marls (the proportion of each rock type in the section is about 30%).

The results of the geochemical analysis of 12 samples from the Lower Aptian sediments, which were revealed in borehole 569, are shown in the table.

1 These results show that most of the marls are argilla-
1 ceous marls [Gabdullin et al., 2011a], (Figs. 3A, 3B).

Nevertheless, the section also contains low-argilla-
1 ceous varieties of marls (Fig. 1C). For example, in borehole 569 (in the NC6b zone) marl was revealed at a depth of 22.0 m; it is microscopically micritic,
3 polymictic, unbedded, and low-argillaceous (5–7%), with patches and lenses of organic matter (7–10%); it contains an admixture of fine-grained and rarely medium-grained subrounded calcite and quartz grains (5%) with single large (up to 0.75 mm) shell remains of indeterminable detritus. The marl is partly gypsified (10–15%) and contains 65–70% carbonate material. Secondary changes occur via the development of iron oxides and pyrite.

Schematic facial profiles (Figs. 1D, 1E) of the Aptian sediments in the Abkhazian zone were compiled on the basis of the data from ([Ob"yasnitel'naya ..., 1971], modified). As seen in the profiles, the thickness of the Aptian sediments varies from 50 to 100 m; it increases in the southeastern direction and decreases in the Galidzga River valley. The Aptian sediments are presented by marls with subordinate limestones. In the 1
upper part of the section (the Gudauta subzone) a sandstone bed, which can serve as a collector, was distinguished. The macrofauna is presented predominantly by mollusks (belemnites) and rare ammonites. In the Gumista River valley, brachiopods were found; in the southeastern part of the Ochamchira subzone, Aucellina species occurred; other bivalves occurred rarely. The areal distribution of the Aptian sedimentary formations is shown in Fig. 4; the areas with good reservoir properties, regional caps, and potential oil-source rocks are shown in Figs. 5A and 5B.

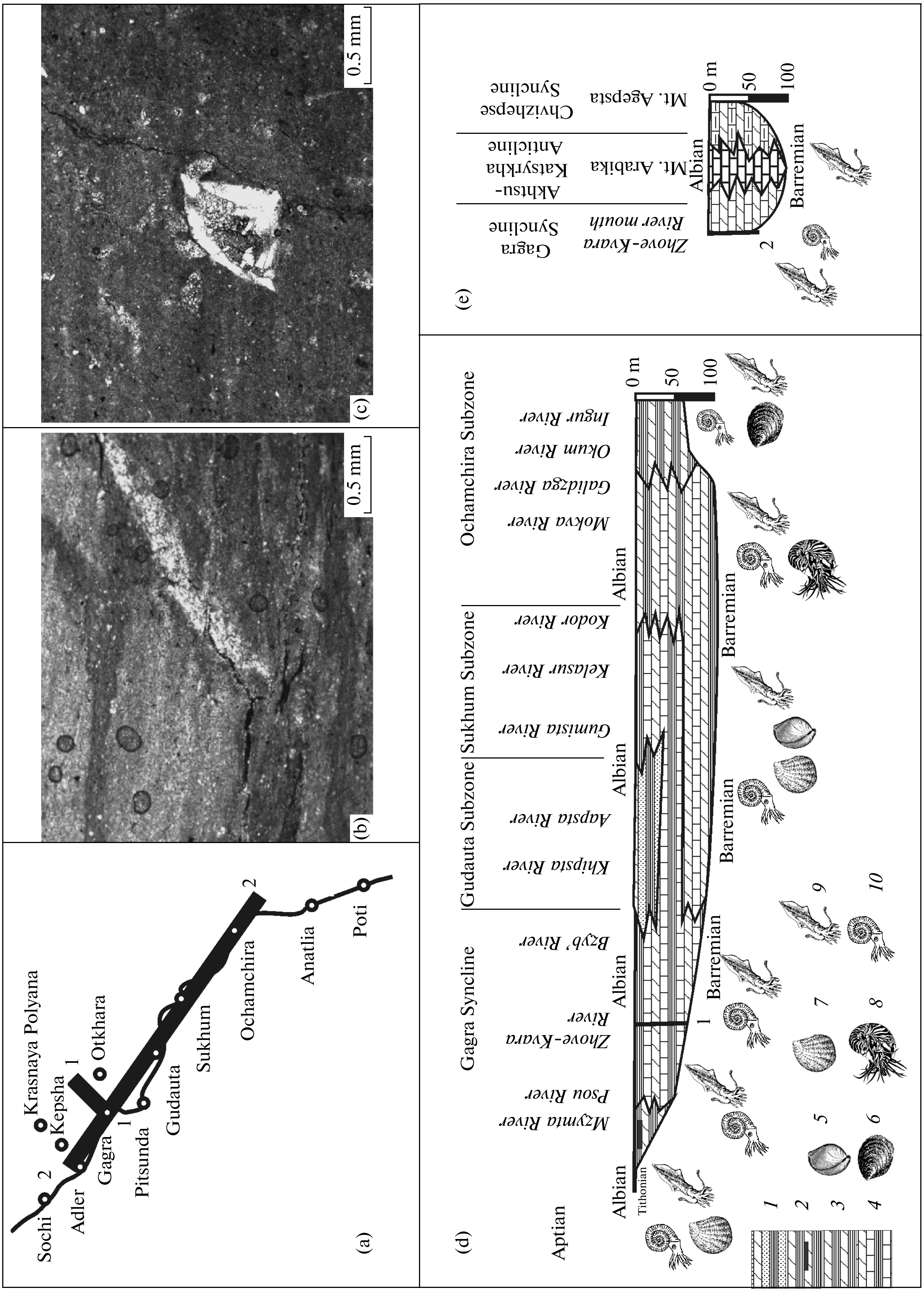
In a natural exposure (observation point 454) at the mouth of an unnamed stream on the left bank of the Mzymta River in the area of the village of Kepsha (at the northern entrance of the third combined rail and highway tunnel of the Adler–Alpika Route in the unbedded Upper Aptian (Zones NC7b, NC7c)–Lower Albian (NC8a, b) sediments were described (Fig. 2).

On the left side of an erosional downcutting of about 30 m in height, at the base of the slope, the rhythmically stratified stratum, which is composed of argillaceous and aleuritic marls with interlayers of 1 2
bituminous marls and argilliceous aleurites, are 1
exposed as a separate bench with a thickness of about 8 m. Three rhythmic lithological varieties were distinguished: *aleuritic marls*, *foliated bituminous argilla-* 1
ceous marls, and *aleurites or aleuritic marls*. This inter- 1 1
val of the section is terrigenous–carbonate in composition with a substantial proportion of argillaceous material. Rocks dip in the northeastern direction at an angle of 20–30°.

When wet, the bedding in the section becomes much smoother, especially due to the occurrence of argillaceous material on the bedding surface.

Marls are aleuritic (often argillaceous), gray to 1
dark-gray, reddish to brownish-reddish on the weathered surface, massive, pelitic, thin-bedded, and low-strength. In addition, marls swell and can be easily 1
split into separate plates several millimeters in thickness.

In Figure 3A, a highly calcareous marl is shown, which contains up to 40% carbonate material) with indistinct horizontal bedding due to the unidirectional



(a)
Sochi
Adler
Gagra
Pitsunda
Gudauta
Sukhum
Ochamchira
Anatlia
Poti
Krasnaya Polyana
Kepsha
Otkhara
(b)
0.5 mm
(c)
0.5 mm
(d)
Aptian
Gagra Syncline
Gudauta Subzone
Sukhum Subzone
Ochamchira Subzone
Mzymta River
Psou River
Zhove-Kvara River
Bzyb' River
Khipsta River
Aapsta River
Gumista River
Kelasur River
Kodor River
Mokva River
Galidzga River
Okum River
Ingur River
Albian
Tithonian
Barremian
0 m
50
100
(e)
Gagra Syncline
Akhtsu-Katsyrkha Anticline
Chvizhepse Syncline
Zhove-Kvara River mouth
Mt. Arabika
Mt. Agepsta

Fig. 1. Characteristics of the Aptian Sediments in the Abkhazian Zone: A, Scheme for locality of sites of studied sections and profiles; B, microphotography of the thin section 456 (crossed nicols); C, microphotography of the thin section 456 (crossed nicols); D and E, the lithological-facial profiles of the Aptian Sediments in the Abkhazian Zone.

On the insert D: *1* and *2*, relatively shallow-water and *3* and *4*, relatively deep-water settings: *1*, alternation of clays, sandstones,
1 1 2 1 1 and marls; *2*, alternation of marls and clays with lenses and interlayers of bituminous marls or argillites; *3*, alternation of marls
1 and clays; *4*, alternation of clays, marls, and limestones; *5*, brachiopods; *6*, Aucellina and inoceramus species; *7*, other bivalves; *8*, nautiloids; *9*, belemnoids; *10*, ammonoids. Scheme was compiled by R.R. Gabdullin.

arrangement of microlenses of organic matter (5%) with an admixture (10%) of medium-to-fine-grained subrounded grains of plagioclase and quartz. The marl is substantially gypsified (5%). The content of the argillaceous material equals 40%. The secondary minerals are iron oxides and hydroxides.

1 Foliated bituminous marls are dark-gray, almost black, or brownish-black on the weathered surface, and are pelitic and thin-bedded.

The bedding is emphasized by the scatter of organic
1 material. Marls are very brittle, fragile, and can be easily split into thin plates. In addition, when wet, the
1 marls transform quickly to plastic loam. In Figure 3B an argillaceous marl (10–15%) is shown, which microscopically is micritic, with indistinctly manifested horizontal bedding due to the unidirectional arrangement of the lenses of organic matter (10%). In
1 addition, marls contain 10–15% foraminifera shells; single subrounded grains of fine-grained quartz occurs.

The content of $CaCO_3$ and $MgCO_3$ equals about 65%. The secondary minerals are iron oxides and pyrite.

Aleurite and aleuritic marl are gray, gray–brown, and brown to cherry–brown on the weathered surface, massive, and intensely schistose. The schistosity resembles false bedding, which leads to confusion. The rock swells and can be easily ground with the fingers into dust. The aleurite interlayers have a thickness 2
that varies from 15–20 cm to 1.5 m.

In Figure 3C, an argillaceous marl is shown, which microscopically is micritic and bedded, with a high content of foraminifera shells (45%). Single subrounded grains of quartz occur. The marl is dolomitized (5%); the bulk of the rock is consists of $CaCO_3$ and, to a lesser extent, by $MgCO_3$ (50%). Secondary minerals are iron oxides.

In the rocks the following nanoplankton complexes were identified in the section (from top to bottom): (1) *Watznaueria barnesae*, *Rotelapillus laffittei*, *Biscutum constans*, *Zeugrhabdotus embergerii*, *Z. diplogrammus*, *Z. scutula*, *Micrantolithus hoschulzii*, *Rhagodisus asper*, *Flabellites oblongus*, and *Tranolithus minimus*, which likely correspond to the Early Aptian age (Zones NC7b and NC7c); (2) *Watznaueria barnesae*, *Biscutum constans*, *Retecapsa crenulata*, *Zeugrhabdotus embergerii*, *Z. diplogrammus*, *Z. trivectis*, *Rhagodisus*

Results of Geochemical Analysis of 12 samples from Lower Aptian sediments (borehole 569*)

Depth, m; number of sample	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	$CaCO_3$	$MgCO_3$	$CaCO_3$ + $MgCO_3$	Name of the rock after the S.G. Vishnyakov's classification, with modifications
23.5; 1	48.9	18.8	4.6	13.7	1.7	24.5	3.6	28.0	Argillaceous marl
25.0; 2	46.1	18.8	7.0	14.8	1.9	26.4	4.0	30.4	
25.6–25.7; 3	43.3	16.3	5.2	16.8	1.5	30.0	3.1	33.1	
27.0; 4	42.8	17.1	9.3	16.1	1.8	28.7	3.8	32.5	
28.5; 5	45.2	19.3	8.8	14.2	2.1	25.3	4.4	29.7	
30.5; 6	46.8	19.1	5.8	14.5	1.9	25.9	4.0	29.9	
33.0; 7	46.3	18.6	5.7	14.9	1.7	26.6	3.6	30.2	
34.0; 8	44.2	18.7	10.6	13.8	2.4	24.6	5.0	29.7	Argillaceous dolomitized marl
35.0; 9	46.6	19.0	5.9	14.4	2.1	25.7	4.4	30.1	Argillaceous dolomitized marl
39.0; 10	44.9	17.2	7.3	14.8	1.6	26.4	3.3	29.8	
40.3; 11	48.1	19.7	6.0	13.2	2.3	23.6	4.8	28.4	Argillaceous dolomitized marl
40.5; 12	47.7	19.7	6.4	13.5	2.3	24.1	4.8	28.9	

Notes: * Analyses were performed using a MARC.GV X-ray fluorescent spectrometer (NPO Spektron, St. Petersburg), analyst E.N. Samarin (MSU).

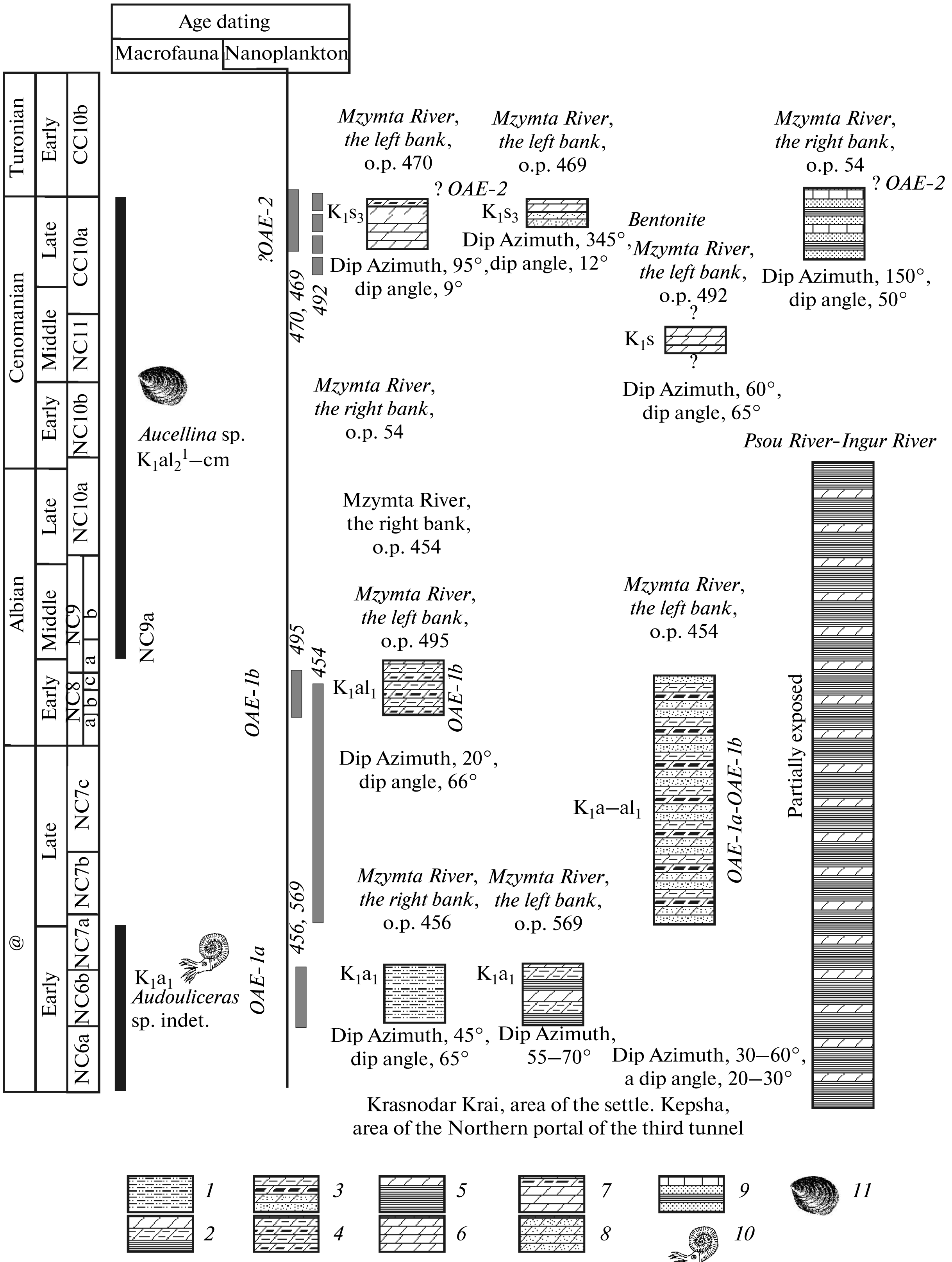


Fig. 2. Chronostratigraphic scheme of the studied sections of the Abkhazian zone, the Western Caucasus: *1*, aleurites and aleur-
2 1 1 2 olites; *2*, alternation of interlayers of marls, argillaceous marls, and clays; *3*, alternation of interlayers of sands or sandstones, sandy
1 1 2 1 marls, bituminous, and argillaceous marls; *4*, alternation of interlayers of bituminous and argillaceous marls; *5*, clays with subor-
1 2 1 1 2 dinate marl interlayers; *6*, marls; *7*, marls with interlayers of bituminous marls; *8*, sandy marls; *9*, alternation of interlayers of sands
or sandstones, clays, and limestones; *10* ammonites; *11* inoceramus species.

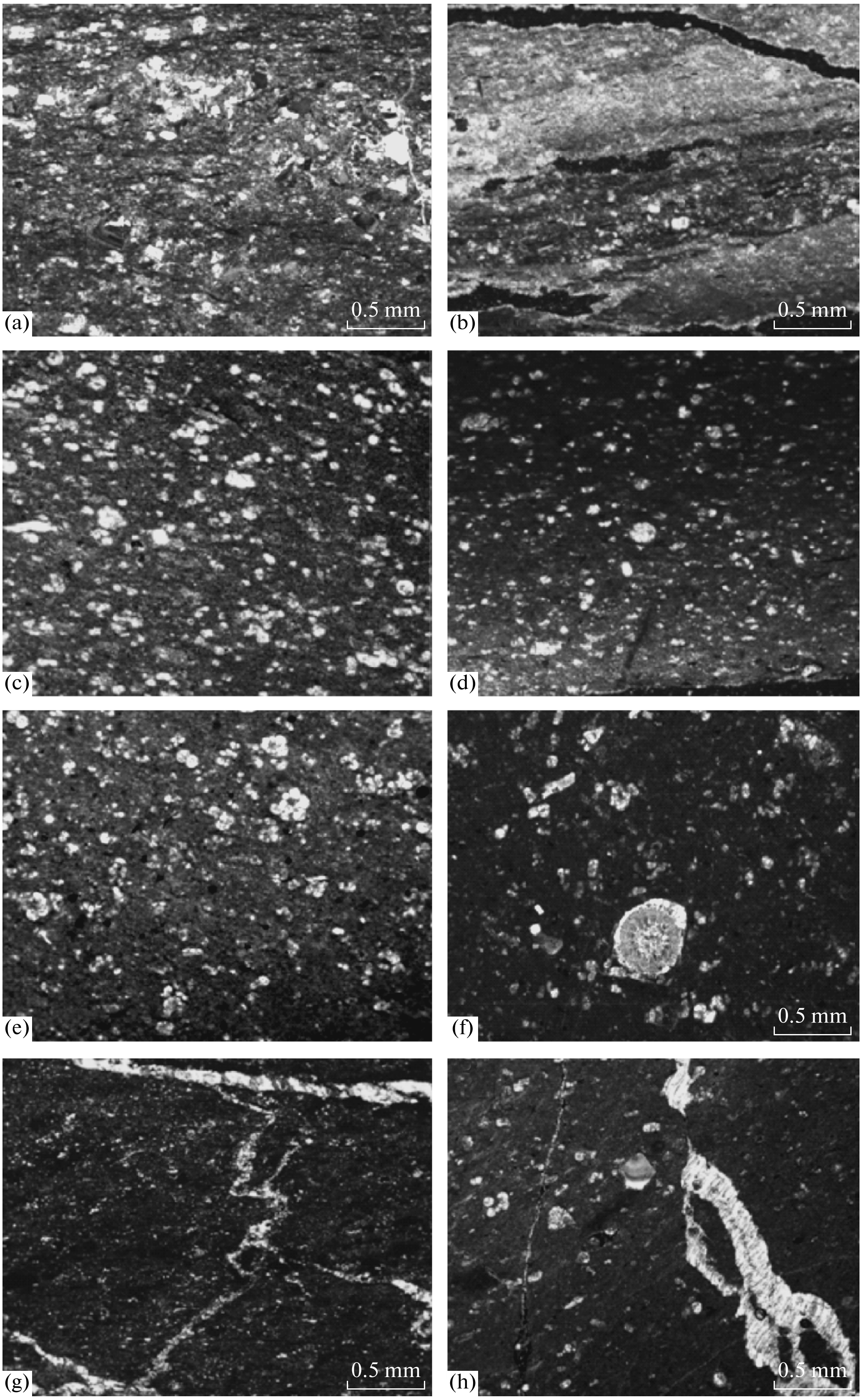


Fig. 3. Microphotographs of thin sections: A, thin section 454/6, crossed nicols; B, thin section 454/7, crossed nicols; C, thin section 454/2, crossed nicols; D, thin section 495, crossed nicols; E, thin section 470/2, one nicol; F, thin section 470/6, crossed nicols; G, thin section 469/2, crossed nicols; H, thin section 492, crossed nicols.

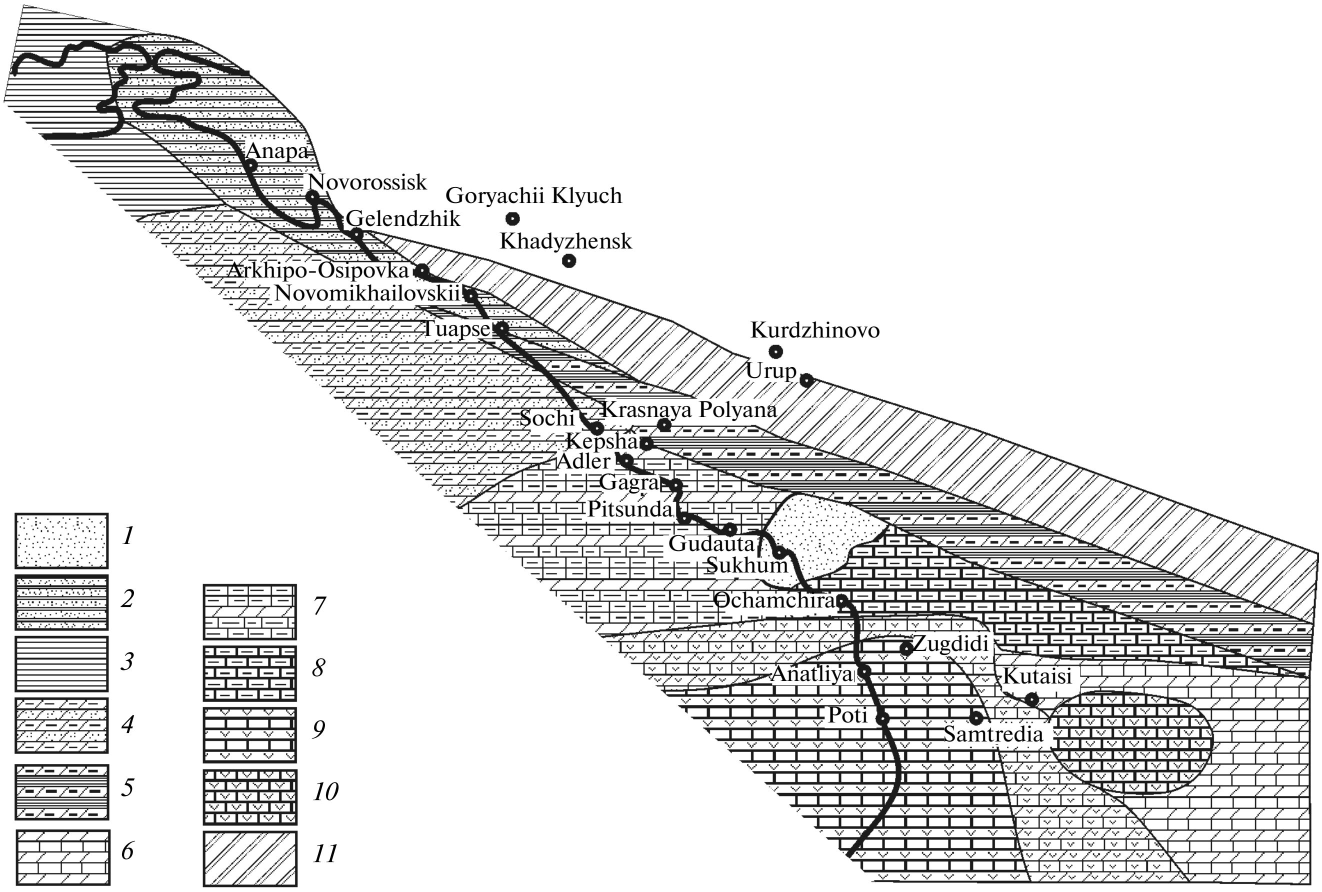


Fig. 4. The paleofacial scheme of the Aptian sediments for the East Black Sea region: *1*, sands and sandstones; *2*, alternation of
2 2 1 interlayers of sands, sandstones, clays, and argillites; *3*, clays; *4*, alternation of interlayers of sandy and argillaceous marls; *5*, alter-
2 1 2 nation of interlayers of clays (argillites) and bituminous argillaceous marls (OAE-1a); *6*, alternation of interlayers of limestones
1 2 1 1 2 and marls; *7*, alternation of interlayers of marls and limestones; *8*, argillaceous marls; *9*, alternation of interlayers of limestones and volcanogenic rocks (tuffs); *10*, limestones with an admixture of ash; *11*, terrigenic flysch of the Great Caucasus trough. Compiled by R.R. Gabdullin.

asper, *R. angustus*, *R. achlyostaurian*, *Eprolithus floralis*, *Manivitella pemmatoidea*, and *Prediscosphaera columnata*, which correspond to the Early Albian (Zones NC8a and NC8b).

In the upper part (the Albian sediments) the stra-
1 2 tum is more monotonous; interlayers of dark marls occur less frequently and have substantially less thickness.

Aptian–Albian sediments were reliable identified in situ in only one borehole section in the intervals of 39.2–39.5 and 30.3–30.5 m, where the following rock types were revealed (from top to bottom: gray fine-
1 grained unbedded aleuritic marls and dark-gray argil-
1 liceous thin-bedded marls. In these sediments the following nannoplankton complex was described: *Watznaueria barnesae*, *Rotelapillus laffittei*, *Assipetra infracretacea*, *A. terebrodentarius*, *Nannoconus bonetii*, *Biscutum constans*, *Zeugrhabdotus embergerii*, *Z. diplogrammus*, *Z. scutula*, *Micrantolithus hoschulzii*, *Rhagodisus asper*, and *Eprolithus floralis*, which are characteristic of Late Aptian sediments.

The natural exposure of the Albian sediments was described at observation point 495, in the thalweg of the upper reaches of an unnamed stream on the left bank of the Mzymta River in the area of Kepsha (Fig. 2). Here, rhythmically bedded coarse-grained marls 1
extend along the dip. In the section, the irregular alternation of argillaceous and bituminous marls is 1
observed.

The section here is as follows:

(1) Marl, argillaceous, gray, pelitomorphic, indistinctly bedded, highly bioturbated, medium-strength, with interlayers up to 10–15 cm in thickness; 2

(2) Marl, bituminous, black, pelitomorphic, and thin-bedded, highly foliated, massive, and strong. In addition, upon hammering, the rock can be easily split into thin plates. The interlayers of bituminous marl 2
have a thickness varying from a few centimeters to several tens of centimeters.

Figure 3D shows the marl, which microscopically is highly calcareous and bituminous, with indistinct horizontal bedding because of the occurrence of

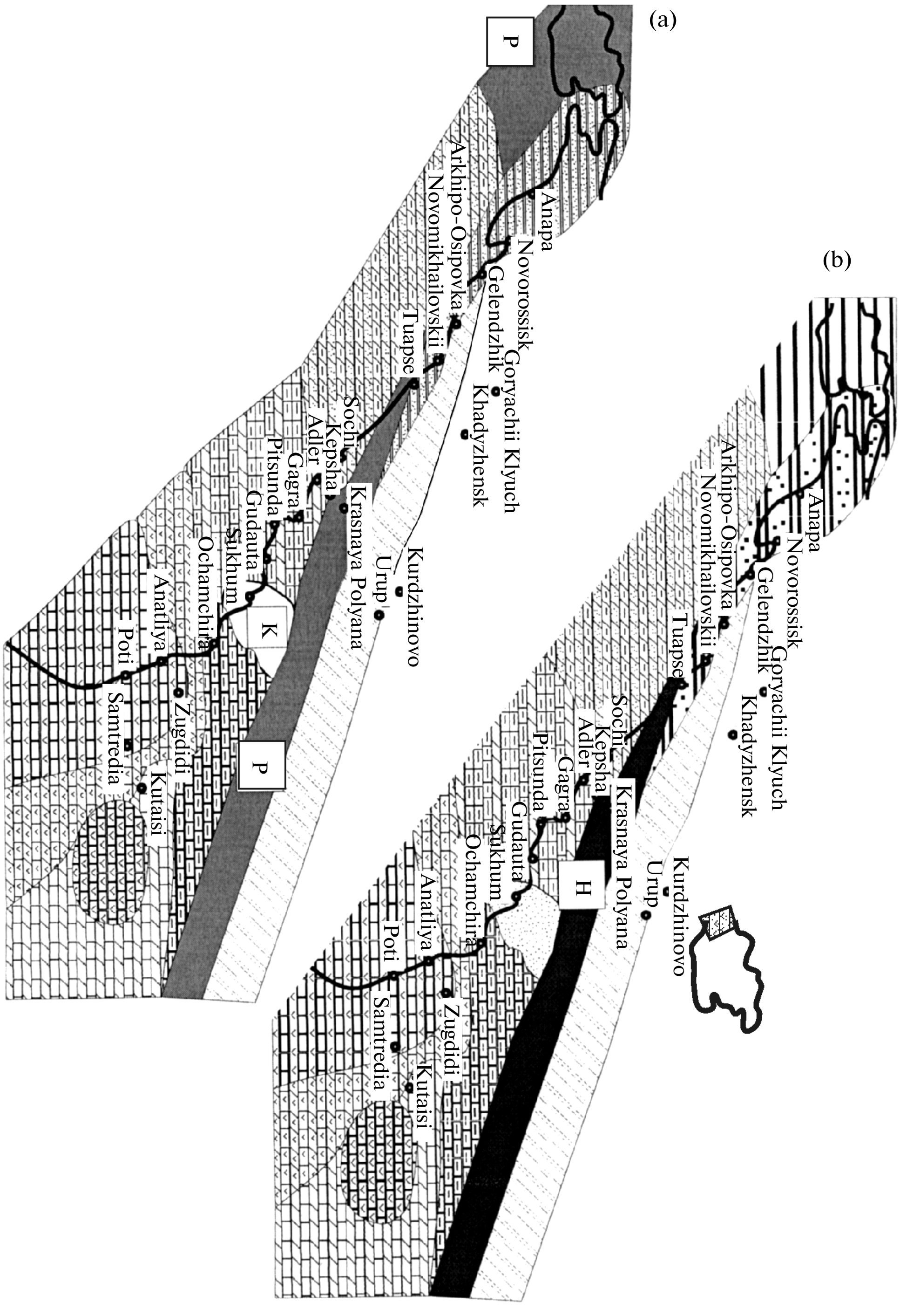


Fig. 5. A map of the facial distribution of the Aptian sediments in the East Black Sea region. A, collectors (white, “K”) and caps (gray, “P”) and B, oil-source rocks (black, “H”). Compiled by R.R. Gabdullin. The legend is the same as in Fig.3.

2 microlenses and micro-interlayers of organic matter (10%), containing rare fine-grained unrounded and subrounded grains of quartz and calcite (5%) and with the remnants of foraminifera shells and undetectable detritus (20–30%). The proportion of the argillaceous material is 50–55%.

In eight samples the common nanoplankton complex was identified: *Watznaueria barnesae*, *Rotelapillus laffittei*, *Assipetra infracretacea*, *A. terebrodentarius*, *Biscutum constans*, *Zeugrhabdotus embergerii*, *Rhagodisus asper*, *Flabellites oblongus*, *Hayesites irregularis*, *Grantarhabdus coronadventis*, *Helicolithus trabeculatus*, *Eprolithus floralis*, and *E. varolii*, which is characteristic of the Early Albian (Zones NC8b and NC8c).

For the elements of rock bedding, the dip azimuth is 20° and the dip angle is 66°.

In the higher section of the stream valley a cataclastic zone of more than 10 m in thickness was noted. This zone is characterized by variations in elements of 2 rock bedding, boudinage of single interlayers, and chaotic bedding of softer lithological varieties.

The above-described sediments in the stratigraphic volume correspond to the Kepsha Formation (K_1kp); it is analogous in age to the Medoveevo Formation, which is exposed in the southern subzone of the Chvezhipsinskaya structural-facial zone in the core of the Dagomys Anticline [Stratigraficheskii Slovar, .., 1979]. This formation is concordantly underlain by sediments of the Agepsta Formation. The overlying sediments in the studied area are unknown. In the area of the Solokh-Aul settlement the section consists of greenish-gray fucoid marl. At the bottom of the section limestone layers of up to 50 cm in thickness occur; 1 at the top of the section, horizons of brownish marls 2 (up to 10–15 m) and interlayers of aleurolites and cherts (1–5 cm) are found. The thickness of the section is more than 380 m; to the east, in the Mzymta River valley, it is estimated to be 460 m. The Early Cretaceous age of sediments was established on the basis of the numerous remains of ammonoids and belemnites [Stratigraficheskii Slovar..., 1979].

Among the macrofauna that are found in the area of the Kepsha settlement the following microfauna should be noted: mollusks, which are found in large landslide blocks of marl: ammonite *Audouliceras* sp. indet. (K_1a_1; found by E.A Sherbinina (GIN RAS), identified by E.Yu. Baraboshkina (MSU)) and the inoceramus species: *Aucellina* sp. ($K_1a_2^1$–K_2cm, found by R.R. Gabdullina (MSU) and identified by E.Yu. Baraboshkina (MSU)). These dates are less accurate, but they do not contradict the age data that were obtained from the nanoplankton complex or those based on existing ideas (Fig. 2).

The schematic facial profiles of the Albian sediments of the Abkhazian zone are shown in Fig. 6 ([Ob"yasnitel'naya..., 1971], modified]. These profiles show that the thickness of Aptian sediments varies from 100 to 200 m and decreases in the Sukhum subzone by up to several tens of meters. According to the literature data, the Albian sediments mainly consist of an argillaceous-marly stratum with subordinate sandstones, which occur rarely; they are chaotically distributed in the section from top to bottom. Throughout the upper part of the section a horizon of bitumi- 1 nous marls and clays is noted. The macrofauna consists only of mollusks. Belemnites occur almost everywhere within the northwestern part of the Abkhazian zone. Ammonites were found in the Gagra Syncline and further to the southeast. In the Ingur River basin oyster beds are known and bivalves occur almost everywhere.

In Abkhazia, between the basins of the Psou and Ingur rivers natural outcrops of Aptian–Albian sediments are absent or occur extremely rarely, indicating that these sediments, which are overlain by numerous landslide argillaceous bodies, have a substantial argillaceous component. Facial maps were compiled according to field observations and an analysis of the literature materials and fund reports (Figs. 4, 7). Based on the interpretation of facial maps, maps of collectors, caps, and oil-source rocks were constructed (Figs. 5, 8).

The areal distribution of facies of Albian sediments and the areas of regional caps and potential oil-source rocks are shown in Figs. 7 and 8, respectively.

A Summary of the Data That Were Obtained From Aptian–Albian Sediments in the Abkhazian Zone

The Aptian–Albian sediments in the Abkhazian zone are mainly marly-clayey rocks with bituminous interlayers, which resulted from the OAE-1 oceanic 2 anoxic event (C_{min} is up to 6.88 wt % with C_{org} less than 1 wt%; Table 3 [Gabdullin et al., 2011a]). In the Western Caucasus single bituminous horizons occur; in the Eastern Caucasus, most of the Aptian sediments contain bituminous materials. The clay content increases distinctly in the southeastern direction from the Russian Federation border and stratigraphically from the Aptian sediments to the Albian ones (Figs. 1, 4–8). There is no evidence that bituminous facies in the upper part of the Aptian sediments spread from the Mzymta River valley to the south and southeast of Abkhazia, but in the Albian sediments bituminous rocks are widespread facies. This can be seen on profiles and facial maps, as well as on maps of the distribution of rocks-collectors, caps, and oil-source rocks (Figs. 1, 4–8).

One can see that the oil-source facies of bituminous marls and clays are both good regional caps. In 1 particular, during drilling works in the Mzymta River valley they serve as a confining bed. In the Aptian–Albian sediments that were revealed by more than 100 boreholes in the Mzymta River valley, the interlayers 2 of bituminous clays with marl concretions and rare concretion-bearing interlayers, as well as calcareous 2 clays, dominate [Gabdullin et al., 2011a, b]. In the area of the Kepsha settlement marly rocks occur in a number of rare exposures of Aptian–Albian bedrock; in argillaceous rocks landslides occur. Due to this, these rock types can be studied only in the cores from boreholes. This makes it clear that argillaceous rocks play a substantially greater role in this interval of the section.

An example of the structure of the Aptian interval in the borehole sections and its lithological and geochemical characteristics, including the oil-source potential of the Aptian–Albian bituminous sediments in the area of the Kepsha settlement, were given in [Gabdullin et al., 2011a, 2011b]).

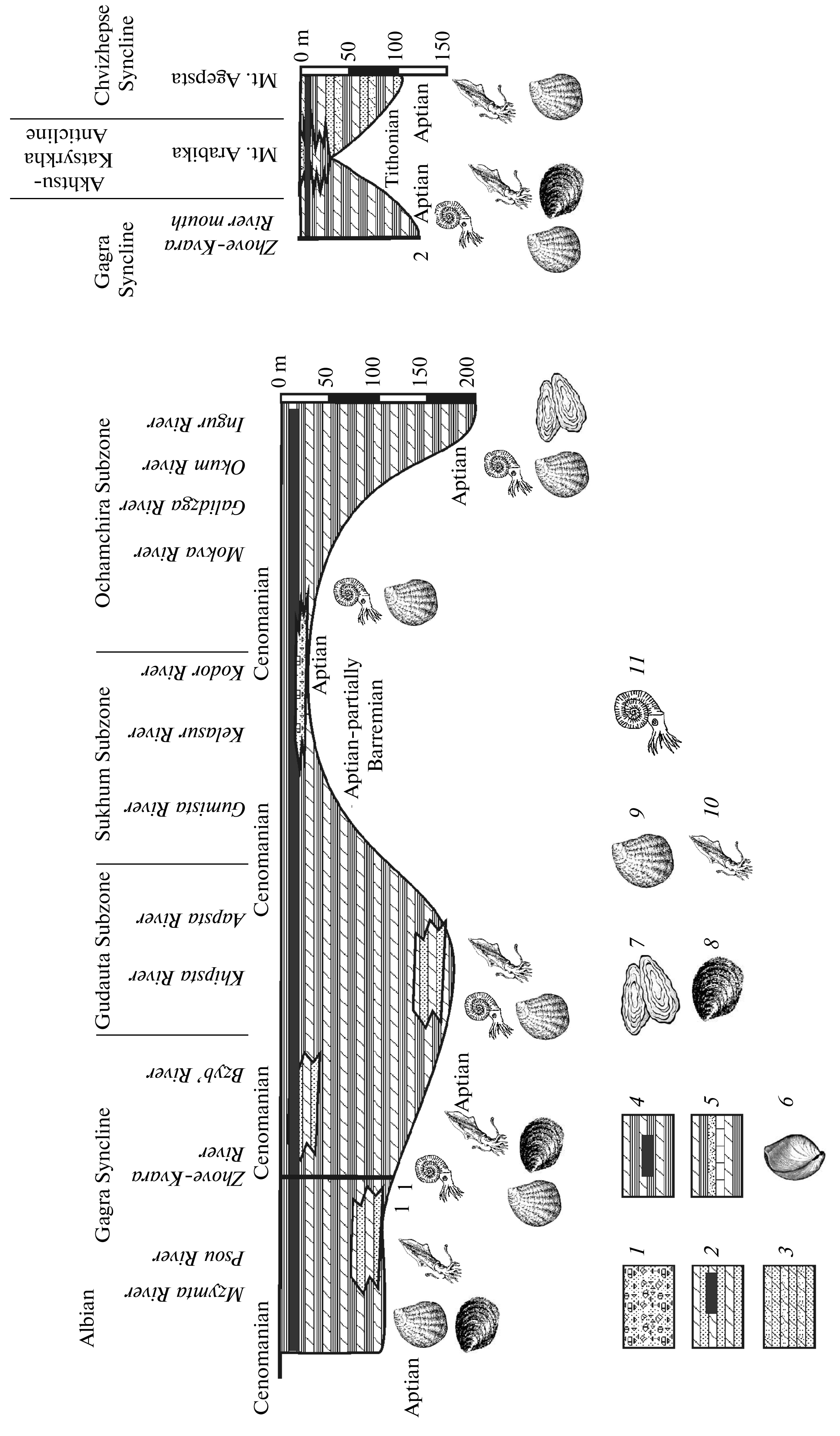
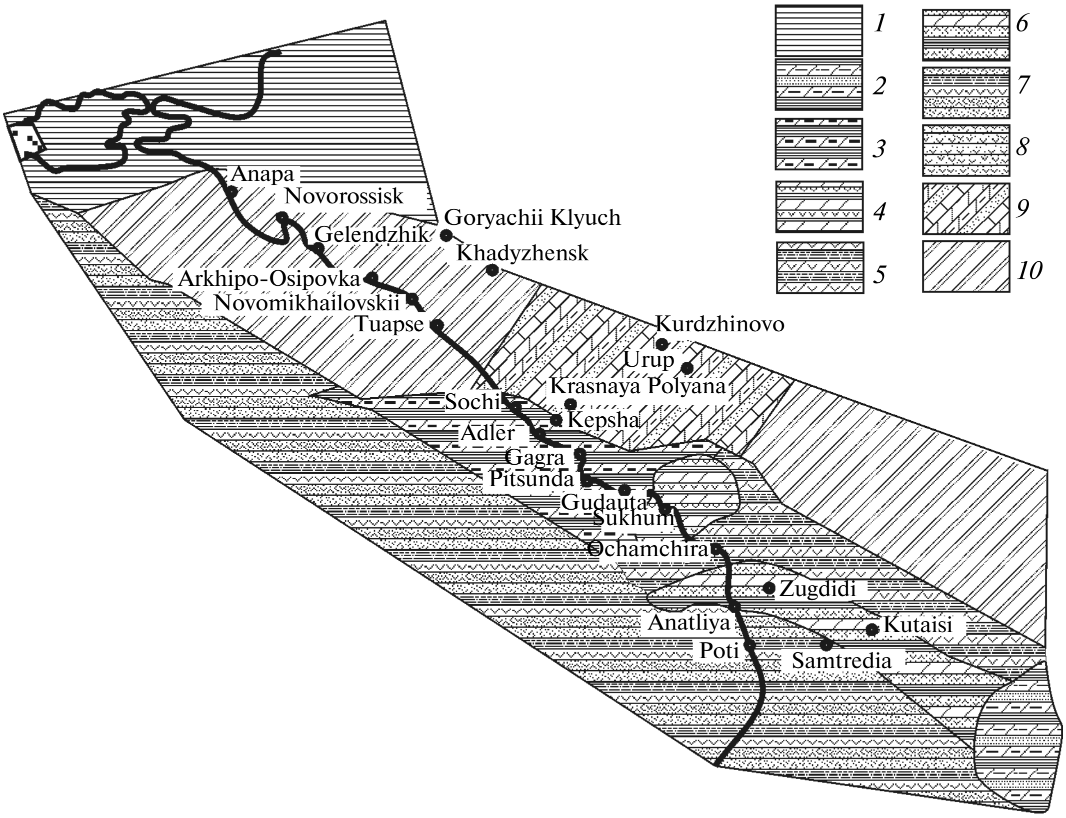


Fig. 6. Lithological-facial profiles of the Albian sediments in the Abkhazian zone: *1*, sandy calcareous breccias with the Barremian rewashed limestones; *2*, alternation of interlayers of sandstones and marls with lenses and interlayers of bituminous marls or argillites; *3*, sandy marls with lenses and interlayers of bituminous marls or argillites; *4*, alternation of interlayers of marls and clays with lenses and interlayers of bituminous marls or argillites; *5*, alternation of limestones, marls, clays and tuffs, and tuffosandstones; *6*, brachiopods; *7*, oysters; *8*, Aucellina and inoceramus species; *9*, other bivalves; *10*, belemnites; *11*, ammonoids; Scheme was compiled by R.R. Gabdullin.



2 **Fig. 7.** The paleofacial scheme of the Albian sediments in the East Black Sea region: *1*, clays; *2*, alternation of interlayers of clay
1 2 1 marls, sands (sandstones), and clays (argillites); *3*, alternation of interlayers of clayey (argillites) and bituminous marls (OAE-1b,
2 1 2 1 c); *4*, alternation of interlayers of tuffs, clays, and marls; *5*, alternation of interlayers of marls and clays with an admixture of ash;
2 1 2 *6*, alternation of interlayers of tuffosandstones, clays (argillites), and marls; *7*, alternation of interlayers of sandstones, tuffosand-
2 stones, tuffs, and tuffoargillites; *8*, sands with an admixture of ash with rare argillite interlayers; *9*, carbonate flysch of the Great Caucasus trough; *10*, terrigenous flysch of the Great Caucasus trough; The scheme was compiled by R.R. Gabdullin.

The Lithological–Stratigraphic Characteristics of the Cenomanian Sediments

The Cenomanian sediments (Fig. 2) were studied in four sections.

1 In greenish-gray bituminous marls, which are exposed on the left bank of the Mzymta River in the area of the Kepsha settlement on the left side of a large landslide on the slope above temporary bridge no.6 across the Mzymta River (observation point 470), the following nanoplankton complex was studied: *Rhagodiscus asper*, *Eprolithus floralis*, *Cylindralithus biarcus*, *Quadrum intermedium*, and *Microstaurus chiastius*.
1 These finds indicate that these marls have a Late Cenomanian age (the upper parts of the CC10 subzone). The lithological composition of rocks indicates their probable connection with oceanic sediments that resulted from the OAE-2 anoxic event (throughout the section of the Upper Cenomanian sediments, from Italy to Caucasus (Dagestan) many intervals occur in the section that are enriched in bituminous material).

Here, there are exposures of the rhythmic alterna-
1 tion of gray and black bituminous marls. The elements of the bedding are as follows: the dip azimuth is 95°; the dip angle is 9°.

Layer 1. Marl, gray, cream-colored, highly bioturbated, medium-strength, with calcite veins at the bottom. The thickness of the layer is 10 cm.

Layer 2. Marl, dark gray, highly-argillaceous, pelitomorphic, thin-bedded, low-strength, with calcite veinlets (from 1 to 5 mm). The thickness of the layer is a few centimeters.

Figure 3E shows limestone with a large number of foraminifera shells (15%) and indeterminate shell detritus (25%), which microscopically is micritic and not laminated. Single shells are filled with gypsum. Grains of quartz (0.1 mm) and rare grains of pyrite and iron oxides occur. The bulk consists of $CaCO_3$ (60%). The content of organic matter is up to 1%.

Layer 3. Marl, greenish-gray, thick-plated, medium-strength, with high bioturbation. At 25 cm below the top of the layer weak rare bioturbation (several millimeters) was noted. The thickness of the layer is 80 cm.

Layer 4. This is similar to layer 2. The thickness of the layer is 45–50 cm.

Layer 5. This is similar to layer 3. The thickness of the layer is 60 cm.

Layer 6. Marl, black, highly bioturbited. The thickness of the layer is 5 cm.

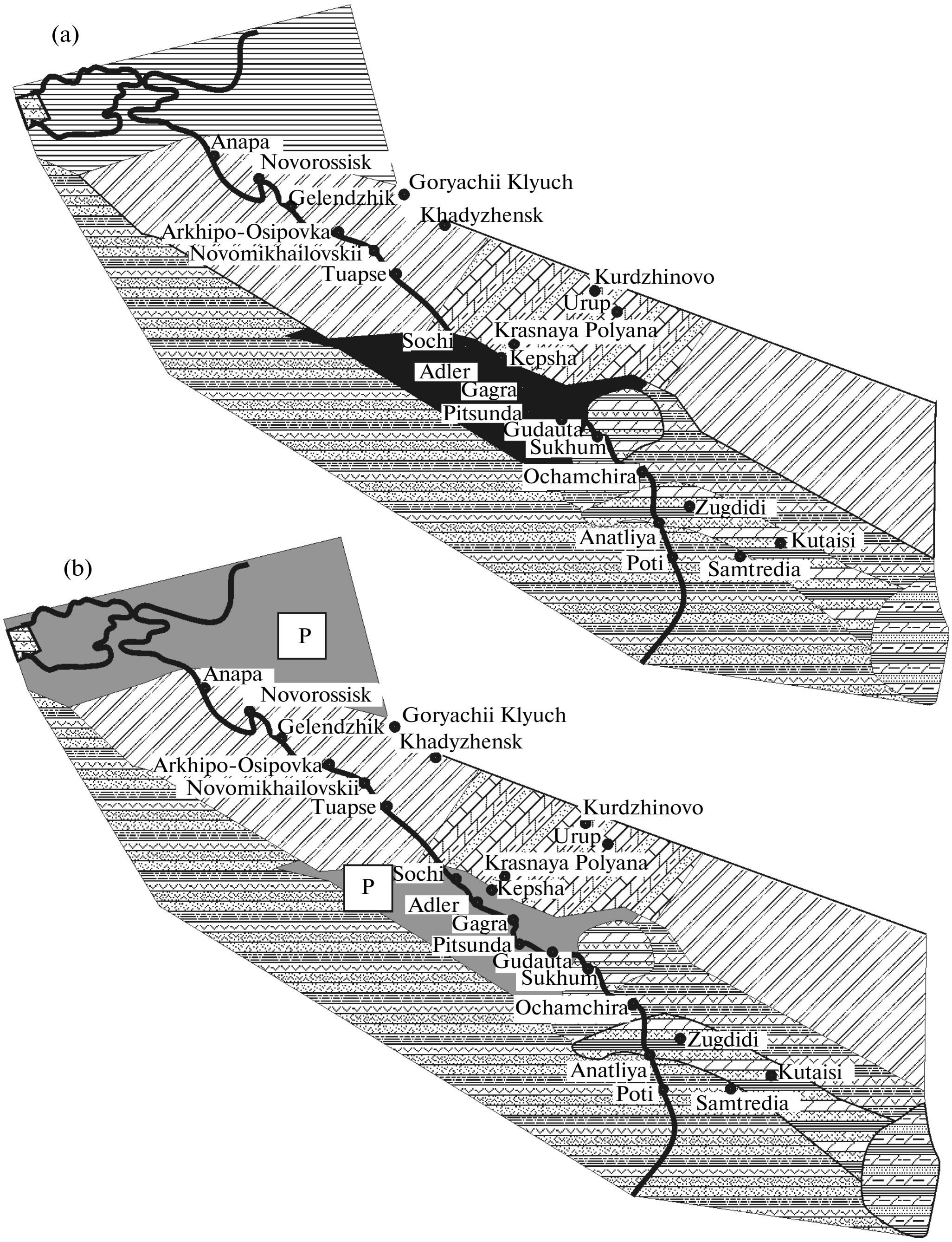


Fig. 8. The paleofacial scheme of the Albian sediments in the East Black Sea region. A, caps (gray, "P") and B, oil-source rocks (black, "H"). Compiled by R.R. Gabdullin. The legend is the same as in Fig.7.

Figure 3F shows limestone, which is micritic,
3 polymictic, unbedded with an admixture of fine-grained and grains of quartz and biotite that are not surrounded (10%), with microlenses filled with organic matter (15%) and with the remnants of foraminifera shells and undetectable detritus (5%). The carbonate content is 70%. Small fractures (up to 0.02 mm) vary in their orientation and branch at an angle of 90°. Large fractures (up to 0.6 mm) are encrusted by micritic calcite. Rare grains of iron oxides and pyrite occur.

Layer 7. Marl grey, thin-bedded, low-strength. The thickness of the layer is 75 cm.

Layer 8. This is similar to layer 2. The thickness of the layer is 5 cm.

The layer is separated by intersecting fractures filled with calcite. Calcite druses with crystals of up to 2.5 cm occur.

In the central part of a large landslide that developed on the slope above temporary bridge no. 6 across the Mzymta River, on the left bank of the Mzymta

River, (observation point 469; Fig. 2) a rhythmically bedded section is exposed on the cracked wall.

For the elements of bedding the azimuth of the dip is 345° and the angle of the dip is 2°.

Layer 1. Marl, sandy, medium-strength, interbedded with layers of darker rocks (15 cm) and bentonite in the middle part of the layer. The total thickness of the layer is 50 cm.

Layer 2. Marl, dark gray, highly argillaceous, thin-bedded, pelitomorphic, with intersecting veinlets of pale-pink calcite along bedding planes (from 1 to 5 mm). The thickness is more than 15 cm.

The layer is cut by two intersecting subvertical fractures filled with calcite. The displacement is 10–15 cm.

Figure 3G shows the marl, which is microscopically micritic, highly argillaceous, bedded, with an admixture of aleurite (30%), and unrounded and subrounded grains of quartz and calcite, with a few large (up to 1–5 mm) grains of plagioclase and up to 45% of carbonate material. The rock is highly gypsified (20%). Iron oxides occur. There are two systems of fractures, which are completely or partly filled with coarse-grained calcite. The completely filled fractures are oriented at an angle of 30° to the partly filled ones.

The next nannoplancton complex was identified in samples:

Watznaueria barnesae, *Cylindralithus sculptus*, *Eiffellithus turriseffellii*, *Rhagodiscus asper*, and *Broinsonia matalosa*, which are evidence of the Cenomanian age of the CC10a zone.

In the thalweg of the right tributary of the main stream, opposite the Kepsha settlement, (observation point 492; Fig. 2) marls are exposed on the left bank; these are microscopically gray, massive, bioturbated, with an evident thickness of up to 10 meters. For the elements of bedding the dip azimuth is 60° and the dip angle is 65°.

Higher in the succession marls occur, which are pale-gray, pelitomorphic, with chaotic bedding, with thin calcite veinlets along the planes of schistosity. The thicknesses of single layers are 15–20 cm.

Figure 3F shows limestone, which is microscopically micritic, bedded, low-argillaceous (5–10%), with lenses of organic matter (10–15%) and with an admixture of medium-to-fine-grained, rarely aleuritic-size and single unrounded grains of quartz (5–7%), as well as fine-grained prismatic biotite grains (<5%), with the remnants of foraminifera shells, some of which are replaced by chalcedony, and indeterminable detritus (10–15%). The content of $CaCO_3$ is up to 60%. Iron oxides occur. Secondary changes consist of partly gypsified limestone. Large (0.7-0.8 mm) and small (0.05–0.2 mm) veinlets are encrusted with coarse-grained calcite and organic matter.

The nanoplankton complex is quite poor. This fact indicates that these sediments are likely to have ages no younger than Cenomanian (the SS10a zone): *Watznaueria barnesae*, *Rhagodiscus asper*, *Zeugrhabdotus diplogrammus*, *Z. embergerii*, *Eprolithus apertior*, and *Retecapsa crenulata*.

A geochemical characterization of the above-described Cenomanian sediments was given in [Gabdullin et al., 2011 a; Table 3].

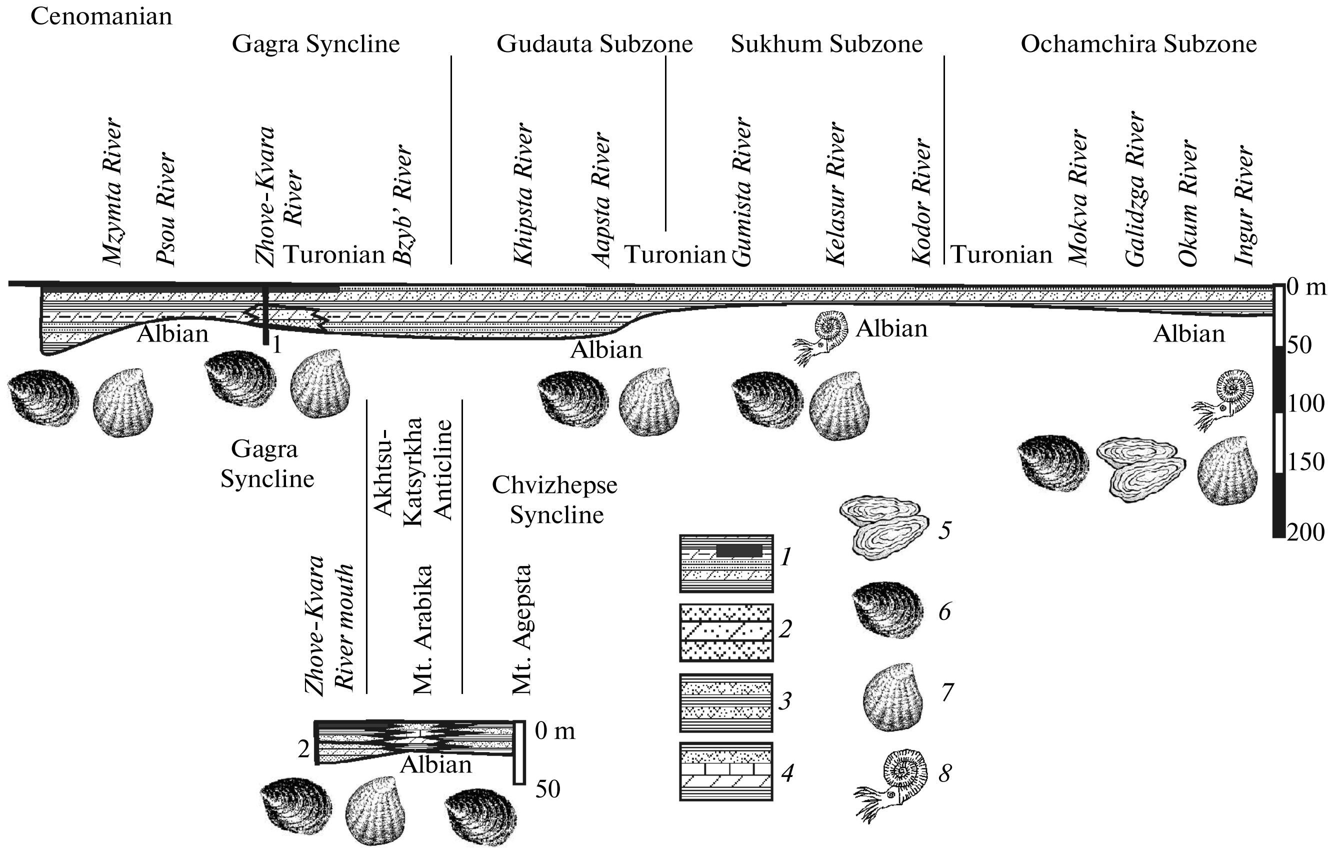
In the Gudauta subzone, on the eastern outskirts of the settlement of Otkhara (Uatkhara) (observation point 54, Fig. 2), Cenomanian–Turonian boundary sediments are exposed on the right bank of the Khipsta River. These consist of rhythmically interbedded sands, to varying degrees, bituminous or completely non-bituminous clays and marls, which corresponding to the OAE-2 event. The thickness of the section is more than 55 m. The thickness of the most bituminous interlayer does not exceed 5 m.

For the elements of rock bedding, the dip azimuth is 150° and the dip angle is 50°.

In the upper part of the section sandstones and tuffosandstones dominate; in the middle part, bituminous clays and marls dominate; in the lower part-limestones and calcareous marls dominate. At the bottom of the section, multi-colored inequigranular sandstones with graded, parallel, wavy, and oblique bedding dominate. Here, the transgressive nature of the section is distinctly evident.

In the section the alternation occurs of gray bituminous argillaceous limestones (10 cm layers), brown bituminous clays (10 cm layers), and bituminous silicified marls (10 cm layers) with fine-grained ferruginized sands (very loose sandstones) (10–50 cm). In addition, many small inoceramus shells and thin-walled bivalves occur in the sediments. These compose horizons in weakly bituminous argillaceous varieties. On bedding surfaces signs are observed of large bottom-burrowing organisms, filled by limonitized marcasite. Bioturbation sometimes makes up to 50% of the total volume of the weakly bituminous rock. Higher in the succession, the proportion of sand decreases. The sands at the bottom are poorly sorted and/or not sorted, anisometric, sometimes micaceous, multi-colored, variegated, with pebbles of carbonate rocks and small shells of bivalves. Sands occur at the bottom of the section; they are fine-grained, brown to pale-brown, almost orange, with wavy and oblique bedding (the dip azimuth is 90°). Approximately in the middle part of the section an interlayer of black bituminous clays with a thickness of approximately 3–5 cm is exposed. Limonitized marcasite concretions occur. Below this interlayer, the proportion of sandstones in the section is up to 40–50%; higher, it is about 60–70%. The proportion of clays and argillaceous marls in the section is up to 35%.

The time interval from the Barremian to Cenomanian in the Abkhazian zone corresponds to the joint system of the multi-collared carbonate Agura Formation and the Dzykhra stratum. The section consists of limestones, marls, and sandstones with a total thick-



2 **Fig. 9.** Lithological-facial profiles of the Cenomanian sediments in the Abkhazian zone: *1*, alternation of interlayers of sandy and 1 1 argillaceous marls with clays and aleurolites; *2*, alternation of sandstones, tuffosandstones, rare tuffs, and sandy marls; *3*, alter- 1 nation of clays and sandstones, tuffosandstones, and rare tuffs; *4*, alternation of limestones, marls, clays and tuffs, and tuffosandstones; *5*, oysters; *6*, inoceramus species; *7*, other bivalves; *8*, ammonoids; Scheme was compiled by R.R. Gabdullin.

ness of up to 230 m [Gocudarstvennaya Geologicheskaya..., 2000].

The schematic facial profiles of the Cenomanian sediments of the Abkhazian zone, based on ([Ob"yasnitel'naya..., 1971], modified) are shown in Figure 9. These profiles show that the thickness of the Cenomanian sediments is much lower compared to the underlying sediments and does not exceed 50 m; they decrease in the Sukhumi and Ochamchira subzones by up to several tens of meters. According to the literature data and field observations, the studied sediments mainly consist of strata of alternation of terrigenous–carbonate rocks with rare volcanic (tuffs) and volcanogenic–sedimentary rocks (tuffoturbidites). In the upper part of the section, up to the watershed between 1 Zhove-Kvara–Bzyb', the horizon of bituminous marls and clays was established. Macrofauna are represented only by mollusks (predominantly bivalves), which form a stable paleocoenosis of inoceramus species and other bivalves.

In the Sukhum subzone and further to the southeast, ammonites are widespread; oysters occur in the Ochamchira subzone.

A Summary of the Data That Were Obtained from Cenomanian Sediments in the Abkhazian Zone

The layers of bituminous marls, argillaceous marls, 1 1 or clays that are confined to the upper part of the Cenomanian sediments or the Cenomanian–Turonian boundary are characterized by an areal distribution in the northwestern part of the Abkhazian zone. In fact, most of the sediments consist of one facies of alteration of sandy and argillaceous marls with clays and 1 aleurolites.

Locally, in the northern part of the Abkhazian zone horizons that are enriched in tuffaceous material were noted.

CONCLUSIONS

The lithological and stratigraphic analysis of the sediments of the Aptian–Cenomanian age interval allowed us to obtain new age data. On the basis of lithological and stratigraphic analysis of the Aptian–Cenomanian sediments of the Abkhazian zone that are exposed in natural exposures and quarries, clays play the essential role, reaching 30–35% in the section. This allows us to distinguish vast areas of distri-

bution of argillaceous and argillo-carbonate facies as
2 regional caps. The occurrence of bituminous interlayers in this interval, which probably correspond to the OAE-1 and OAE-2 events makes it possible to consider these sediments as potential oil-source rocks.
2 The sand interlayers, which are locally distributed, can serve as reservoirs.

The facial profiles along and across the Black Sea coast, as well as a series of facial maps that were compiled on the basis of field observations and an analysis of the literature sources (including fund reports), can be used in the future for paleogeographic interpretation of oil sources and the directions of the drift of terrigenous material.

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SPELL: 1. marls, 2. interlayers, 3. polymictic