ISSN 0145-8752, Moscow University Geology Bulletin, 2017, Vol. 72, No. 6, pp. 405–415. © Allerton Press, Inc., 2017.
Original Russian Text © A.V. Marinin, S.I. Stupin, L.F. Kopaevich, 2017, published in Vestnik Moskovskogo Universiteta, Seriya 4: Geologiya, 2017, No. 5, pp. 29–40.

The Structure and Stratigraphic Position of the Agoi Olistostrome, Northwest Caucasus

A. V. Marinin[a], *, S. I. Stupin[b], and L. F. Kopaevich[c]

[a]*Schmidt Institute of the Physics of the Earth, Russian Academy of Sciences, Moscow, Russia*
[b]*Geological Institute, Russian Academy of Sciences, Moscow, Russia*
[c]*Department of Geology, Moscow State University, Moscow, Russia*
**e-mail:*

Received March 31, 2017

Abstract—A sequence of clays and clayey siltstones with olistostrome horizons and olistoplaques of the Upper Cretaceous rocks occur in the coastal section northwest of the mouth of the Agoi River. The rocks of this sequence are mostly gray sandy calcareous clays with rare interlayers of siltstones. The horizons and lenses of olistostromes contain small clasts, large blocks, and olistoplaques of rocks of various ages. The microfauna from matrix and clasts of olistostromes of different horizons of the sequence was sampled and identified. The large blocks and olistoplaques are tectonized with formation of slickensides and cracks, which do not travel beyond the country rocks. The thickness of the sequence is 280 m.

Keywords: olistostromes, Paleogene, Eocene, foraminifers
DOI: 10.3103/S0145875217060084

INTRODUCTION

Recent years have provided data on the presence of abundant Cenozoic chaotic complexes along the periphery of the West Caucasus, the formation of which is related to the origination and growth of the fold structure of the Greater Caucasus (Borukaev et al., 1981; Kopp, 1990, 1991; Maisadze, 1994; Korsakov, Sorokina, 1997; Rastsvetaev, Marinin, 2001; Korsakov et al., 2002; Marinin et al., 2011). An important role among these complexes belongs to the Eocene olistostromes, the composition and occurrence of which indicate the complex tectonic evolution of the region. In this paper, we consider a coastal area with abundant Eocene sediments near the settlement of Agoi (Figs. 1, 2), which is located in the southern wing of the fold structure of the Northwest Caucasus (Novorossiisk synclinorium) and belongs to the Novorossiisk–Lazarevskoe lithotectonic zone (Anapa–Agoi subzone) according to recent geological mapping (Korsakov et al., 2002).

A series of various works have been dedicated to the structure of the Paleogene sequences of the region. Its geology was first studied by Vyalov (1931, 1934), who ascribed the coastal sediments between the Nebug and Agoi rivers to dark flysch (Danian Stage–Paleocene?). Later, it was divided into the Agoi, Kadosh, and Kazach'ya Shchel formations with a total thickness of ~300 m. No paleontological data supported their ages. According to similarity with the Kakhetiya and South Osetiya sections, these formations were ascribed to the upper parts of the Maastrichtian–Paleocene.

The formations of the Paleogene section of the Tuapse region were described in detail by Grossgeim (1960), who considered the structure of the Paleogene sediments between the settlements of Nebug and Agoi. Unfortunately, no structural position of the sequences and no description of the olistostrome complexes were provided in this work in contrast to foraminifers, which were determined by N.N. Borisenko, but became significantly obsolete.

The geology of this region was additionally studied (GDP-50) in the 1970s (works of V.M. Andreev, Yu.P. Posadnev, and others). It was shown for the first time that the sediments of the sequence located northwest of the settlement of Agoi occur in the form of a reclined synclinal fold (the descriptions of previous researchers omitted the structural position of the rocks).

Borukaev et al. (1981) described the features of the structure of the olistostrome sequence. Special attention was paid to the sizes and character of olistoliths and their relationship with the country rocks. In samples taken by Ch.B. Borukaev from the coastal cliff northwest of the Agoi beach, V.A. Krasheninnikov identified a Campanian to Middle Eocene foraminifera complex. The youngest forms *Acarinina bullbrooki* (Bolli) and *Turborotalia frontosa* (Subb.) indicate an age of the country rocks no older than the Late

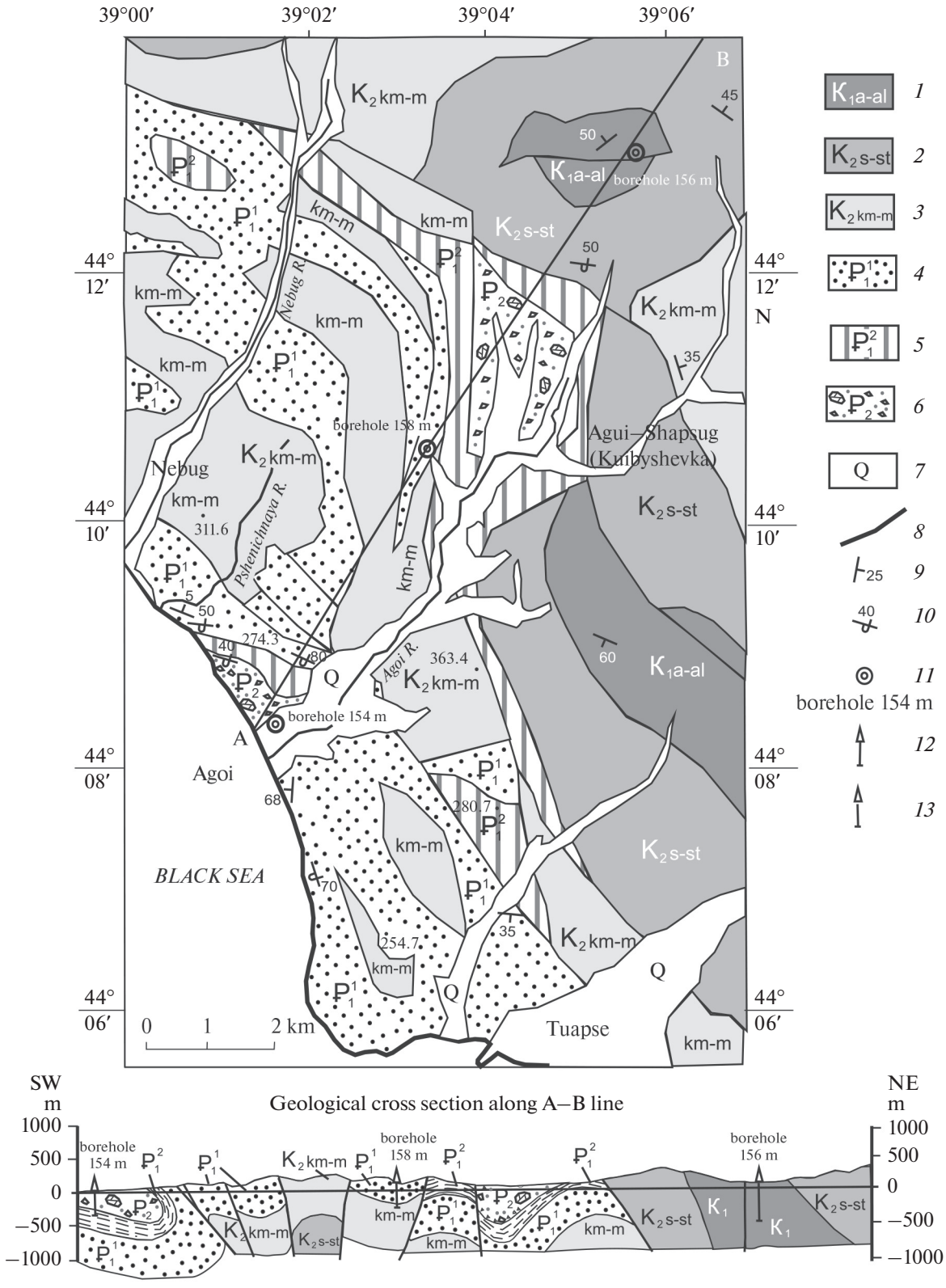

Fig. 1. A geological map and cross section of the region, composed using data of S.G. Korsakov, Yu.P. Posadnev, V.M. Andreev, and others. *1–7*, Areas of Albian (*1*), Senomanian–Santonian (*2*), Campanian–Maastrichtian (*3*), Lower Paleocene (*4*), Upper Paleocene (*5*), Eocene-Oligocene(?) (*6*), and Anthropogene (*7*) sediments; *8*, faults; *9*, *10*, bedding elements: *9*, normal; *10*, reclined; *11–13*, position of boreholes and their numbers: *11*, on map; *12*, in cross section; *13*, near the section line.

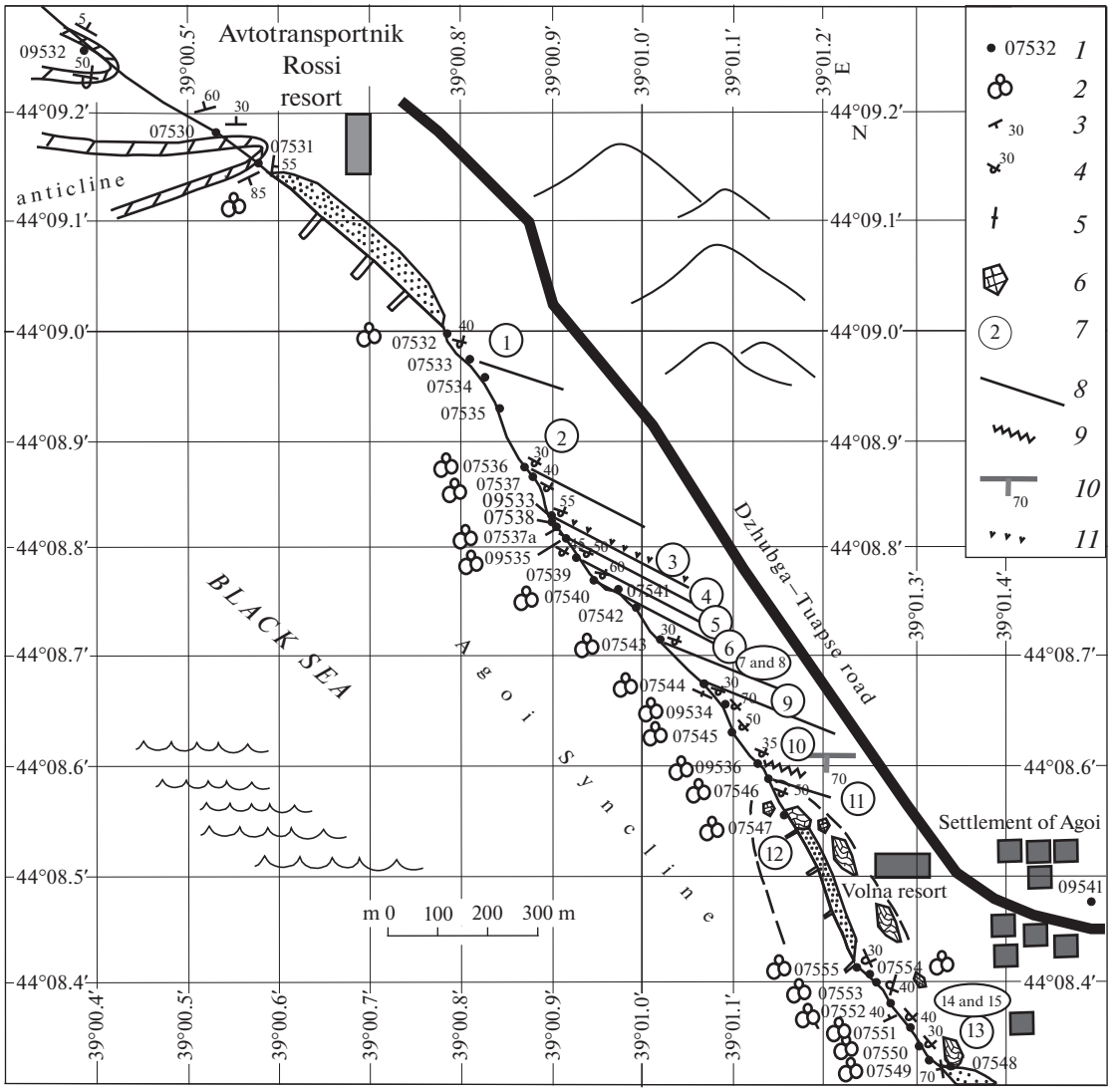

Fig. 2. A detailed geological scheme of the section of the Agoi olistostrome sequence. *1*, Numbers of observation points; *2*, points with identified microfauna; *3–5*, bedding elements: *3*, normal; *4*, reclined; *5*, vertical; *6*, horizon with large olistoplaques of the Upper Cretaceous and Paleogene rocks; *7*, numbers of the described members; *9*, position of the boundary with small angular unconformity; *10*, bedding elements of a small fault; *11*, horizons with tuffaceous interlayers.

Ypresian–Lutetian. This formation was formed in the Eocene.

In the explanatory report of the geological map (Kaorsakov et al., 2002), these sediments are ascribed to the Suusan Sequence, the Oligocene age of which is based on the following microfauna (according to the materials of V.M. Andreev and Yu.P. Posadnev): *Bolivina missisipiensis* Cushman., *Cibicides amphysiliensis* (Andr.), *C.* aff. *oligocenicus* Samoilova, *Globigerina officinalis* Subb., *Globigerinella micra* (Cole), and *Caucasina schischkinskayae* (Samoilova). This sequence is probably widespread to the northeast in the area of the settlement of Agui-Shapsug (st. Kuibyshevka). According to the studies of V.M. Andreev, Yu.P. Posadnev, and S.G. Korsakov, the sequence contains fish scales and rare plant detritus (Korsakov et al., 2002).

In 1999, L.M. Rastsvetaev and A.V. Marinin collected samples 99544/1 and 99544/2 from various parts of the section during the field works (Fig. 3). In these samples, V.N. Ben'yamovskii and L.F. Kopaevich identified poorly preserved foraminifers, including Late Cretaceous and Early to Middle Eocene species. The Paleogene species are *Morozovella aragonensis* (Nutt.), *Globigerinatheka cf. tropicalis* (Blow et Banner) or *G. cf. subconglobata* (Schutz.), *Morozovella cf. caucasica* (Glaessner), *M. cf. formosa gracilis* (Bolli), *M. cf. convexa* (Subb.), *Globigerinatheka cf. micra* (Schutz.), *Subbotina ex gr. pseudoeocaena* (Subb.), *S. cf. frontosa* (Subb.) or *S. cf. turcmenica* (Khalil.), *S. ratusa*? (Kopaevich), and *Pseudohastigerina wilcoxensis* (Cush. et Ponton); the Late Cretaceous species are *Globotruncana ventricosa* White, *Pseudotextularia ele-*

gans (Rzehak) and others (Rastsvetaev, Marinin, 2001).

MATERIALS AND METHODS OF STUDY

This work is based on the field materials (observations, maps, images, and samples) of S.I. Stupin of 2005, L.M. Rastsvetaev, A.V. Marinin, E.Yu. Zakrevskaya, A.I. Yakovleva, and E.P. Radionova of 2007, and L.M. Rastsvetaev and A.V. Marinin of 2009. The scheme of observation points (OPs) and sampling places (for micropaleontological studies) is shown in Fig. 2. The intervals of sampling varied from 1 to 50 m. The weight of the samples was 150–250 g. More samples were collected from the most-important intervals (the boundaries of members of rocks with various lithologies). Thick olistostrome horizons occur in the observation area; samples were taken both from the matrix and olistoliths. In total, we collected 30 samples and microfauna were identified in more than 20 samples. A schematic geological map (Fig. 2) and stratigraphic columns (Figs. 3, 4) of the studied region were composed according to the field observations and micropaleontological studies.

THE GEOLOGICAL STRUCTURE OF THE NEBUG–AGOI REGION AND THE COMPOSITION OF THE SEDIMENTS

The region is described from the northwest from the valley of the Pshenichnaya River (a region of the Avtotransportnik Rossii resort, east of the mouth of the Nebug River) to the southeast up to the mouth of the Agoi River. The structural position of the sediments is important, because the rocks of the sequence are a reclined synclinal fold with a south dip (geological cross section is shown in Fig. 1) and a flat axial plane (Agoi Syncline), whereas most of the sediments are reclined. Because of the ambiguous conception of the volume and age of the local stratigraphic subdivisions, we describe the section with the correct geographic position of the members.

An anticlinal fold (OP 07531, 44°09.15′ N, 39°00.58′ E) is located northwest of the mouth of the Pshenichnaya River and a beach of the Avtotransportnik Rossii resort; the core of the fold is composed of intercalated sandstones (10–40 cm), marls (up to 60 cm), clays (10–20 cm), and limestones (up to 20 cm). The calcareous sandstones are characterized by a massive, oblique layered, and lumpy–hummocky structure. The clays are silicified and calcareous. The sediments, which, according to their exterior are ascribed to the Paleocene (Kazach'ya Shchel Formation), compose the lower part of the studied section. The northern wing of the fold is flat dipping at 30º in the northern rumbs; the southern wing is characterized by steep (up to vertical) dip of the beds (160∠85°).

These sediments (probably with a small angular unconformity) are overlapped by flatter black clays with clayey–carbonate nodules (Fig. 5). The clays are weakly compacted and are characterized by the presence of jarosite along the fractures; the bedding elements of layering vary from 90∠30° to 100∠55°. The clays (sample no. 07531/3) contain agglutinated benthic foraminifers *Rhabdammina sp.* and *Glomospira irregularis* (Grzyb.), as well as radiolarians, in particular, numerous representatives of *Druppulidae* (data of D.I. Vitukhin). An interlayer of red loose sand (tuff, gypsum?) occurs above. These sediments most likely correspond to the lower parts of the Plastunskaya Formation or the Goryachii Kluch Formation in the description of Grossgeim (1960). The visible thickness is more than 5 m.

A large area (~400 m of the beach) is covered by a concrete wall of the beach of the Avtotransportnik Rossii resort. In the coastal cliff east of the mouth of the Nebug River (probably before to the concrete wall of the resort beach), Grossgeim (1960) described dark gray noncalcareous clays with rare and fine interlayers of siltstones of the Goryachii Kluch Formation of a total thickness of 300 m. Southeast of the resort beach, almost continuous outcrops of sediments occur, which are traced up to the Volna resort (the settlement of Agoi).

All sediments are reclined and occur on the northeastern wing of the Agoi Syncline. The following members are distinguished from top to bottom:

(1) the member from OP 07532 (44°09.00′ N, 39°00.78′ E) to OP 07533 (44°08.98′ N, 39°00.81′ E) of fine intercalation of greenish gray and dark gray noncalcareous silty small rubble clays (20–60 cm) with fine interlayers (2–10 cm) of siltstones and poorly calcareous clays (Fig. 6); bedding elements of layering vary from 15∠40° (reclined) to 20∠60° (reclined). The member hosts a small fold of probably submarine landslide origin, because it bears all of the features of these folds (Frolov, 1992). Sample 42 (collections of S.I. Stupin) contains rare poorly preserved benthic agglutinated foraminifers and single benthic secrection *Bulimina sp.* The visible thickness of the member is 25 m;

(2) the member from OP 07533 (44°08.98′ N, 39°00.81′ E) to OP 07536 (44°08.88′ N, 39°00.87′ E) of dark calcareous clays, which are overlapped by marine Quaternary sediments in the upper part of the coastal cliff. The thickness of the member is ~70 m;

(3) the member from OP 07536 (44°08.88′ N, 39°00.87′ E) to OP 07538 (44°08.83′ N, 39°00.90′ E) of greenish gray calcareous clays with rare interlayers of clayey limestones with bedding elements of layering of 30∠30° (reclined). A small folding zone and a small fault (0∠80°) with a steep N-dipping plane are observed in the OP 07537 (44°08.86′ N, 39°00.88′ E). Upward the section, the green clays and light clayey limestones of the upper part of the member sharply

System	Period	Stage	No. of described member	Formation	Lithological column	Thickness, m	Sample numbers	Description
Paleogene	Eocene	Ypresian	12	Agoi olistostrome sequence		>15	99544/2	Horizon with olistoplaques of the Upper Cretaceous rocks. The rocks of the olistoplaque contain *Marginotruncana marginata* (Reuss), *M. angustricarinata* (Gandolfi), and *M. pseudolinneiana* Pessagno (determination of L.F. Kopaevich)
			11			15	07-26-07 07-26-08 07-26-09 07-26-10	Strongly calcareous clays. Olistostrome horizon in the basement. There are *Morozovella aragonensis* and redeposited Upper Cretaceous and Paleogene foraminifers.
			10			40	07-26-11 P-2(09534/1) P-3(09534/2) 07545 07-26-12	Calcareous fine platy gray clays, clayey limestones. A small angular unconformity in the upper part. There are *Subbotina spp*. (poorly preserved), *Subbotina cf. turcmenica* (Khal.), *Morozovella aragonensis*, and redeposited Upper Cretaceous and Paleogene foraminifers.
			9			25	07543	Calcareous layered clays. Sample 07543 contains *Pseudohastigerina wilcoxensis* (Cush. et Ponton) and P. micra (Cole).
			8			30	07-26-13 07-26-14	Calcareous gray clays with olistostrome horizon (0.3 m) in the basement.
			8			30	07-26-15 99544/1	Calcareous ash gray clays with typical (“concrete”) olistostrome horizon (35 cm) in the basement. Sample 99544/1 contains *Anomalina granosa* (Hantken.), *Morozovella aragonensis* (Nuttall), *Globigerinatheka cf. tropicalis* (...) or cf. subconglobata (Schultz), *Globorotalia aragonensis* (Nuttall), and *Globotruncana ventricosa* (determinations of L.F. Kopaevich and V.N. Ben’yamovskii).
			6			15	07-26-15 07-26-16 07-26-17 07539	Calcareous ash gray clays with olistostrome horizons. Sample 07539/4 contains *Morozovella marginodentata* (Subb.) and *Acarinina bullbrooki* (Bolli).
			5			20	07-26-18 07-26-18a	Ash gray silty clays with olistostrome horizon (2.6 m) of trash siltstones in the basement of the member.
			4			25	07537/1	Calcareous silty ash gray clays. Sample 07537/1 contains *Morozovella marginodentata* (Subb.), *Subbotina linaperta* (Finlay), *S. eocaena* (Gümbel), *Parasubbotina inaequispira* (Subb.), *Acarinina coalingensis* (Cush. et Hanna), *Pseudohastigerina wilcoxensis* (Cush. et Ponton), and *P. micra* (Cole).

Fig. 3. The stratigraphic column of the Agoi olistostrome sequence (main part of the section).

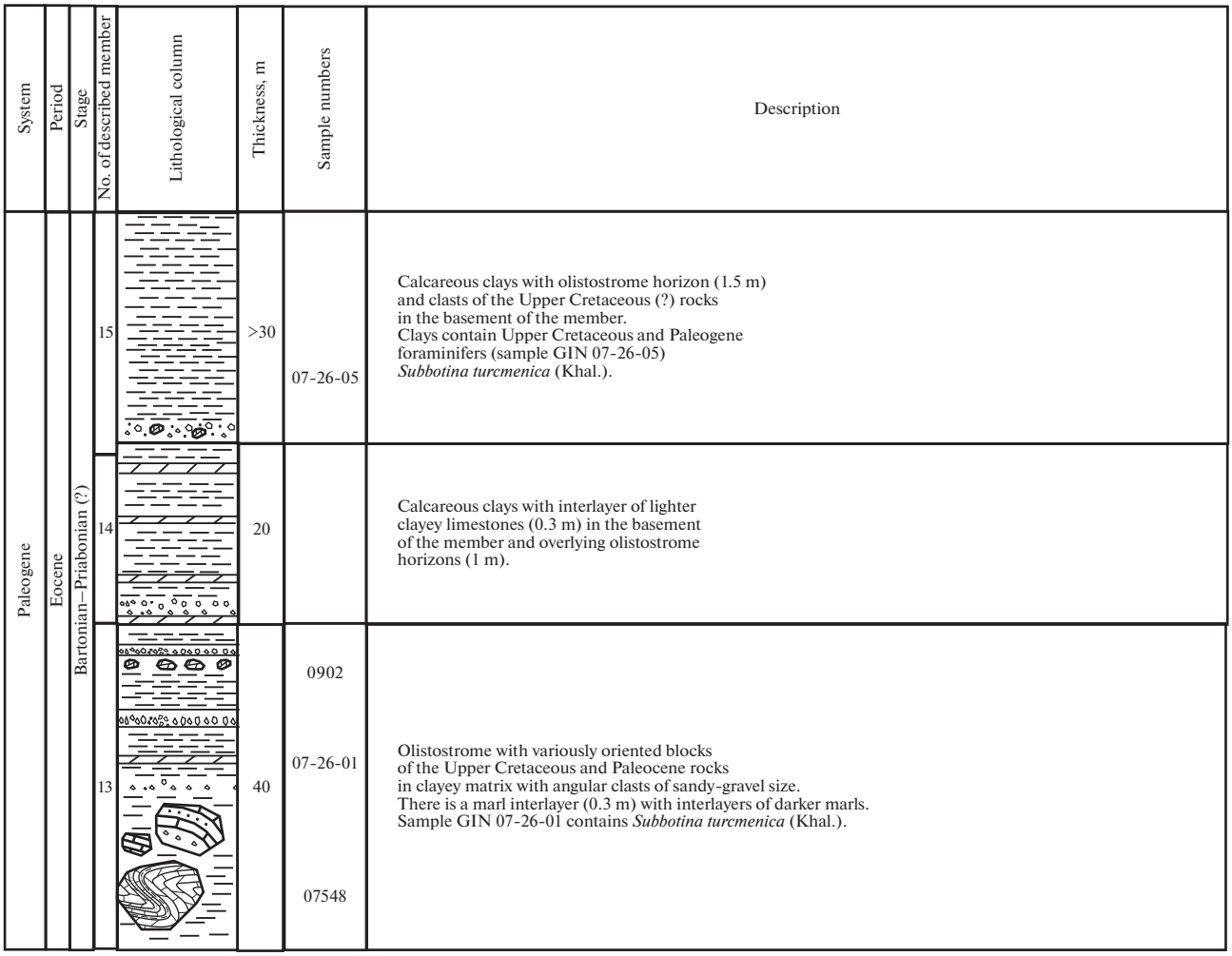

Fig. 4. The stratigraphic column of the upper part of the Agoi olistostrome sequence (continuation of the main part of the section in the southeast).

Fig. 5. Paleocene sediments (OP 07531, northwest of the valley of the Pshenichnaya River and Avtotransportnik Rossii resort).

change by overlying dark clays of member 4 (Fig. 7). Sample P-1 (09533/3) from the upper part of the member contain *Subbotina eocaena* (Gümbel), *Globigerinatheka korotkovi* (Keller), *Pseudohastigerina micra* (Cole), *Morozovella* sp, and *Acarinina praetopilensis* (Blow). The thickness of the member is 20 m.

The sediments of this part of the section (members 1–3) probably correspond to the Plastunskaya (member 1) and Inal (members 2 and 3) formations (Korsakov et al., 2002). The total thickness is more than 110 m.

The members 4–15 of the section, which are composed of clays with numerous horizons of olistostromes, form the Agoi olistostrome sequence. The upper boundary of the sequence is undefined (no overlapping of the younger rocks is observed). The youngest sediments compose the core of the Agoi Syncline (member 13–15). Further studies will allow substantiation of the Agoi Formation in this part of the section, while, at present, there is no need to distinguish it because of its unclear areal occurrence. This

Fig. 6. Intercalation of greenish gray and dark gray noncalcareous silty clays with fine interlayers of reclined siltstones (OP 07532, member 1, southeast of the valley of the Pshenichnaya River and Avtotransportnik Rossii resort).

Fig. 7. The contact between green and black clays at the OP 07538 (reclined occurrence).

Agoi Formation is distinct from the one that was distinguished by O.S. Vyalov in the Lower Paleocene (Maastrichtian?) rocks. Later, the formation was mentioned by Keller and Menner (1945), who ascribed it to the Danian Stage. The term "Agoi Formation" is omitted in the current stratigraphic charts. According to Stupin (2008), the lower part of the Agoi Sequence contains sapropel interlayers 10–30 cm thick, no description of which is provided because of the lack of their correct geographic position.

The following members are distinguished from bottom to top:

(4) the member from OP 07538 (44°08.83′ N, 39°00.90′ E) to OP 07537a (44°08.82′ N, 39°00.91′ E) of ash gray calcareous silty clays (Fig. 7) with bedding elements of layering of 20∠55° (reclined). The member contains plankton foraminifers (sample 07537/1) *Morozovella marginodentata* (Subb.), *Subbotina linaperta* (Finlay), *S. eocaena* (Gümbel), *Parasubbotina inaequispira* (Subb.), *Acarinina coalingensis* (Cush. et Hanna), *Pseudohastigerina wilcoxensis* (Cush. et Ponton), and *P. micra* (Cole), which are typical of the Ypresian Stage (without its lowermost part). The thickness of the member is 25 m;

(5) the member of ash gray silty clays from OP 07537a (44°08.82′ N, 39°00.91′ E) to OP 07539 (44°08.79′ N, 39°00.93′ E). The basement of the member is the first olistostrome horizon (2.6 m) of trash siltstones and angular marl clasts. The bedding elements of layering are 30∠45° (reclined). The thickness of the member is 20 m;

(6) the member of calcareous clays with olistotrome horizons from OP 07539 (44°08.79′ N, 39°00.93′ E) to OP 07540 (44°08.77′ N, 39°00.94′ E) with bedding elements of layering of 20∠50° (reclined). The lower part (5 m) of the member is composed of ash gray weakly calcareous silty clays with microfauna no younger than Ypresian: *Subbotina linaperta* (Finlay), *S. yeguaensis* (Weinzierl et Applin), *S. eocaena* (Gümbel), and *Pseudohastigerina micra* (Cole) (sample 07539/2).

The main 4-m thick olistostrome horizon occurs in the intermediate part of the member (Fig. 8) and contains blocks of Eocene greenish clays (marls) of 10 × 10 to 30 × 30 cm, dark Paleocene marls, and light Upper Cretaceous limestones (Fig. 9). The matrix of the olistostrome horizon (sandy clays) contains *Morozovella marginodentata* (Subb.) and *Acarinina bullbrooki* (Bolli) (sample 07539/4). These species are probably redeposited beginning from the Upper Cretaceous to the Upper Ypresian. The clasts of green calcareous clays (sample 07539/5) contain *Morozovella lensiformis* (Subb.), *Subbotina corpulenta* (Subb.), and *Pseudohastigerina micra* (Cole).

The upper part of the member 6-m thick is dominated by trash sandstones and grus with clasts up to 1 cm in size and a coarse-sandy matrix. The maximum size of the unoriented clasts (olistoliths) reaches 1 m. A lens of dark organoliths up to 3-cm thick is observed within the clays. The upper part of the member contains few unidentified radiolarians (sample 07539/3). The total thickness of the member is 15 m;

(7) the member of calcareous clays from OP 07540 (44°08.77′ N, 39°00.94′ E) to OP 07541 (44°08.77′ N, 39°00.95′ E). The basement (OP 07540) contains typical olistostrome horizon (0.35 m). Its structure and exterior are similar to a handmade concrete with angular grus clasts in the matrix (Fig. 10). The bedding elements of layering are 10∠60° (reclined). The matrix of the olistostome contains Late Cretaceous (Campanian–Maastrichtian) and Eocene microfauna (sample 99544/1) (determinations of L.F. Kopaevich) (Rastsvetaev, Marinin, 2001): *Anomalina granosa* (Hantken.), *Morozovella aragonen-*

Fig. 8. Main olistostrome horizon 4-m thick (reclined member 6) with clasts of Eocene greenish clays (marls), Paleocene dark marls, and Upper Cretaceous light limestones 10 × 10 to 30 × 30 cm in size.

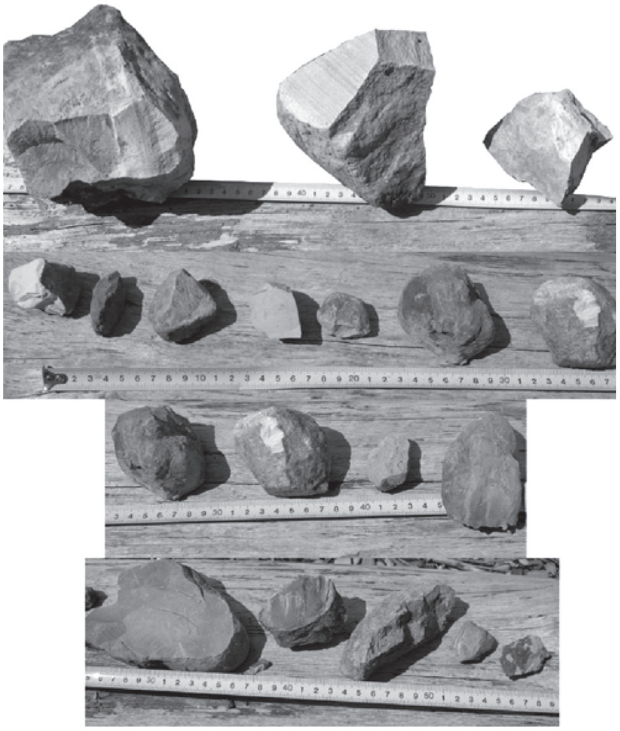

Fig. 9. Clasts (olistoliths) of the main olistostrome horizon of member 6.

sis (Nuttall), *Globigerinatheka cf. tropicalis* (Blow et Banner) or *cf. subconglobata* (Schultz), *Globorotalia aragonensis* (Nuttall), *Globotruncana ventricosa* White. The thickness of the member is 30 m;

(8) the member of gray layered calcareous clays with large (up to 2 m) blocks of chaotic clasts of various rocks: from OP 07541 (44°08.77′ N, 39°00.95′ E) to OP 07543 (44°08.72′ N, 39°01.02′ E) with bedding elements of layering of 20∠35°(reclined). A 0.3-m thick olistostrome horizon occurs in the basement of the member. It is probably an outcrop of the "concrete" horizon of the member 7 along the strike. In this case, member 8 is a repetition of member 7. The thickness of the member is ~30 m;

(9) the member of calcareous clays from OP 07543 (44°08.72′ N, 39°01.02′ E) to OP 07544 (44°08.69′ N, 39°01.07′ E). The clays occur as layers 5–15 cm thick with bedding elements with a layering of 20∠30° (reclined); it contain microfauna no younger than Ypresian (sample 07543): *Pseudohastigerina wilcoxensis* (Cush. et Ponton) and *P. micra* (Cole). The thickness of the member is 25 m;

(10) the member of strongly calcareous gray fine platy clays with interlayers of clayey limestones from OP 07544 (44°08.69′ N, 39°01.07′ E) to the OP 07546 (44°08.59′ N, 39°01.14′ E). The bedding elements of layering are 50∠50° (reclined). The intermediate part of the member contains two interlayers (2–3 m) of lighter clayey limestones with fine brownish (1–2 cm) interlayers of clays with tuffaceous material. The bedding elements of layering are 40∠55° (reclined). A small angular unconformity is observed stratigraphically above. The overlying sediments occur steeper in the present-day reclined position (dip azimuth of 30∠60°, reclined). The change of inclination of older layers may indicate consedimentation growth of the Agoi Syncline during accumulation of the layers (Fig. 11). The Eocene foraminifers *Subbotina spp.* (poorly preserved)

Fig. 10. The "concrete" horizon of member 7 (reclined occurrence).

and *Subbotina cf. turcmenica* (Khal.) are identified in samples P-2 and P-3. The thickness of the member is 40 m;

(11) the member of strongly calcareous gray clays from OP 07546 (44°08.59′ N, 39°01.14′ E) to OP 07547 (44°08.56′ N, 39°01.15′ E) with olistostrome horizon 1-m thick in the basement. The bedding elements of layering are 30∠40° (reclined). The different parts of the member (samples 07-26-07, 07-26-08, 07-26-09, 07-26-10) contain *Morozovella aragonensis* (Nuttall), as well as redeposited Late Cretaceous and Paleogene foraminifers. The thickness of the member is 15 m;

(12) the member of olistostromes with large blocks of the Upper Cretaceous rocks from the OP 07547 (44°08.56′ N, 39°01.15′ E) to the pier of the Volna resort. A complex of Late Turonian–Coniacian (sample 99544/2) microfauna was identified by L.F. Kopaevich in a large olistoplaque of the alternated carbonate–terrigenous rocks (Fig. 12) (Rastsvetaev, Marinin, 2001): *Marginotruncana marginata* (Reuss), *M. angustricarinata* (Gandolfi), and *M. pseudolinneiana* Pessagno. The thickness is more than 15 m.

The total thickness of this part of the section is 215 m (members 4–12, Fig. 4).

Another fragment of the section (judging from the spatial and structural position), which crowns the studied sequence, is located northwest of the beach of the settlement of Agoi and is traced to the pier of the Volna resort. It composes the same northeastern reclined wing and the core of the Agoi Syncline and its eastern centroclinal end (Fig. 2). The following members are distinguished here from bottom to top (the numbers of the members are proposed according to above suggestion):

(13) the olistostrome member from the OP 07548 (44°08.32′ N, 39°01.34′ E) to the OP 07549 (44°08.34′ N, 39°01.30′ E). Its lower part includes variously oriented blocks of the Upper Cretaceous and Paleocene rocks in the clayey matrix, which also contains angular sandy to gravel clasts 1 to 10 m in size of the Upper Cretaceous intercalated sandstones, siltstones, and white limestones (the thickness of the layers is 15–20 cm). According to their exterior, the intercalated rocks are similar to the rocks of the Geniokh Formation (the Santonian sediments of the Novorossisk–Lazarevskoe zone). The sediments of these blocks are characterized by various (up to horizontal reclined!) bedding elements (Fig. 13). They contain numerous calcite slickensides and veins, which are observed only within the clasts. An interlayer of gray strongly clayey limestone 0.3 m (44°08.33′ N, 39°01.31′ E) with layers of darker calcareous clays is observed in the intermediate part of the member (Fig. 13). There are also brown clay interlayers, as well as strongly clayey limestones (marls) with brown weathered surfaces. The dip symbols of layering are 260∠75° (normal). The clays contain redeposited Late Cretaceous and Paleogene foraminifers (sample 07-26-01) including *Subbotina turcmenica* (Khal.), which is typical of the Bartonian Kuma Formation. An olistostrome horizon consistent by thickness is present in the upper part of the member. The visible thickness of the member is ~40 m;

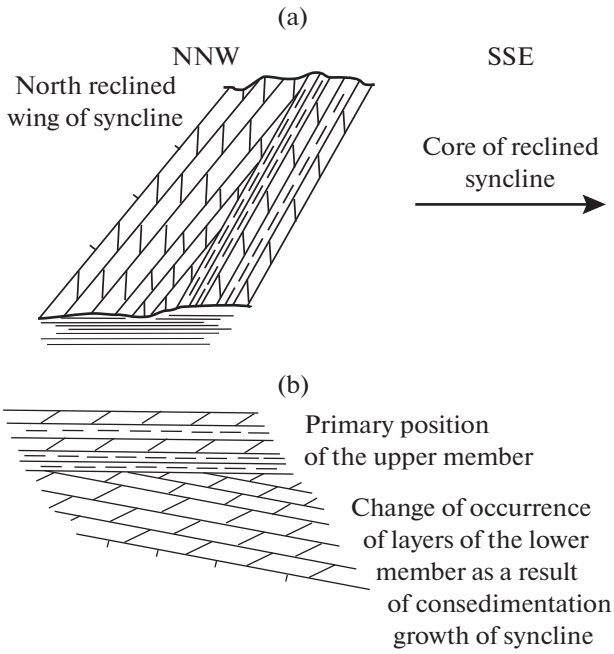

Fig.11. A small angular unconformity at the OP 07534, the intermediate part of member 10. Inclination of the lower layers indicates consedimentation growth of the Agoi Syncline during accumulation of layers (A, current position; B, position during accumulation of the upper part of the sediments).

Fig. 12. A horizon with Upper Cretaceous olistoplaques (complex of microfauna of the Upper Turonian–Coniacian, OP 07547, northwest of pier of the Volna resort).

(14) the member of calcareous clays with interlayers of lighter clayey limestones from the OP 07549 (44°08.34′ N, 39°01.30′ E) to the OP 07550 (44°08.35′ N, 39°01.30′ E). There are interlayers of brown clays with jarosite. The basement of the member contains an

Fig. 13. Member 13 of the Agoi Sequence. Left, an interlayer of clay-bearing clayey limestones, which divides the nonlayered sequence of the olistostrome; right, an Upper Cretaceous reclined vertical olistolith, which represents intercalation of limestones and fine interlayers of silstones.

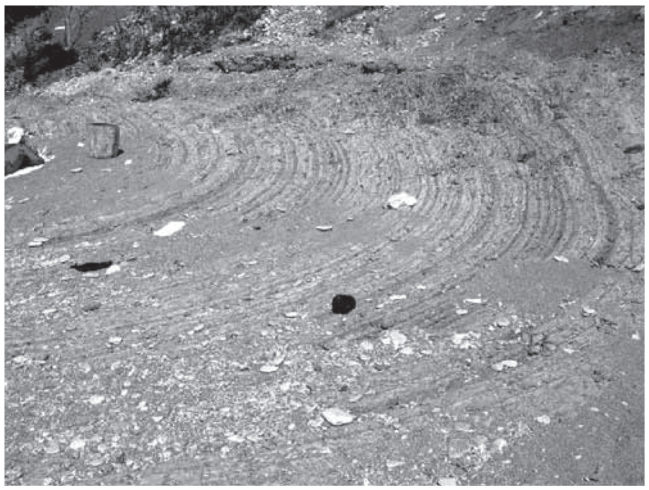

Fig. 14. The core of the Agoi Syncline (southeast centroclinal of the fold) northwest of the beach of the settlement of Agoi composed of younger sediments of the Agoi olistostrome sequence.

interlayer of gray clayey fine platy limestones (0.3 m), which is overlapped by an olistostrome horizon (1 m) with angular clasts of Paleocene and Upper Cretaceous (according to their exterior) limestones up to 20 cm in size. The bedding elements of the layering are at 50∠30° (reclined). The thickness of the member is 20 m;

(15) the member of calcareous clays from the OP 07550 (44°08.35′ N, 39°01.30′ E) to OP 07552 (44°08.38′ N, 39°01.27′ E). An olistostrome horizon (1.5 m) with clasts of the Upper Cretaceous(?) rocks occurs in the basement of the member. The dip symbols of layering are 50∠40° (reclined). The clays contain Late Cretaceous and Paleogene foraminifers (sample 07-26-05). The youngest form also includes *Subbotina turcmenica* (Khal.) typical of the Kuma Formation. The thickness of the member is greater than 30 m.

The total thickness of this part of the section is greater than 90 m (members 13–15, Fig. 5). The sediments of the upper member compose the core of the Agoi Syncline, the centroclinal closing of which is clearly seen in Fig. 14. To the west, up to the pier of the Volna resort, two more members occur, which represent the reverse (to the NNE from the syncline core) repetition of above-described part of the section (members 13–15):

(i) a member of gray strongly clayey limestones from the OP 07555 (44°08.42′ N, 39°01.24′ E) to the OP 07554 (44°08.41′ N, 39°01.25′ E). The bedding elements of layering is 65∠30° (reclined). The outcrops of the olistostrome horizon and large blocks of the Upper Cretaceous (according to their exterior) rocks are observed close to the Volna resort. Sample 07-26-06 contains redeposited Late Cretaceous and Paleogene foraminifers. Sample 22 (collection of S.I. Stupin) contains *Acarinina pentacamerata* (Subb.), *A. bullbrooki* (Bolli), *Subbotina yeguaensis* (Weinzierl et Applin), *Pseudohastigerina wilcoxensis* (Cush. et Ponton), and *P. micra* (Cole), as well as many redeposited Cretaceous and Paleogene species (the youngest age, which can be determined by these species, is the Late Ypresian–the beginning of Lutetian). The reduced complex of probably Middle Eocene nanoplankton was identified in clays by E.A. Shcherbinina (personal communication). The thickness of the member is greater than 20 m.

(ii) olistostrome horizon from the OP 07554 (44°08.41′ N, 39°01.25′ E) to the OP 07553 (44°08.40′ N, 39°01.30′ E) with Upper Cretaceous blocks, which, according to their exterior, are similar to the sediments of the Geniokh Formation (Santonian Stage of the Novorossiisk–Lazarevskoe lithofacial zone). The thickness is greater than 10 m.

The total thickness of all parts of the section, which we described between the valleys of the Pshenichnaya and Agoi rivers, is greater than 400 m. The thickness of the part of the section with horizons of olistostromes and olistoplaques (Agoi olistostrome sequence) is ~300 m.

CONCLUSIONS

The Agoi olistostrome sequence is characterized by regular positions of angular clasts and olistoliths. Its lower parts contain endo-olistostromes with clasts of the same age; their lithology is identical to that of the matrix. Upward in the section, the sequence contains blocks with clasts of Eocene rocks (often with olistoliths from olistostrome horizons) followed by Paleocene and further Upper Cretaceous rocks. The size of the clasts increases to the upper part of the sequence;

a large olistoplaque of the alternated carbonate rocks similar to the rocks of the lower part (Turonian–Coniacian) of the Upper Cretaceous of the Novorossiisk–Lazarevskoe zone is located in the syncline core. The rocks of the olistoplaque contain Late Turonian–Coniacian microfauna. It should be emphasized that the Upper Cretaceous rocks of the olistoplaque are folded and complicated by small faults (slickensides and cracks), which are sharply unconformable relative to the host structure. This allows us to conclude that the formation of the fold structures of the near-axial parts of the Novorossiisk–Lazarevskaya depression of the Northwest Caucasus began no later than the period of the formation of the Agoi olistostrome sequence. During this period, the near-axial uplifts, which occur in the region of the present-day location of the Goitkh Anticlinorium and large anticlinal folds of the Novorossiisk Synclinorium (Dolmen and Semigorskaya anticlines), were eroded under marine conditions.

Our findings of microfauna indicate that the upper age boundary of the formation of the Agoi Sequence is no later than the Kuma period (Middle Eocene). The position of the olistostrome sequence in the section and the presence of redeposited microfauna, however, can indicate the younger age of its formation. The conclusions on the possible younger age of this sequence (according to various estimations, Early Oligocene or Late Oligocene–Early Miocene) were made by various researchers on the basis of the analysis of other micropaleontological data (Afanasenkov et al., 2007). Further lithological, geochemical, and complex paleontological study of the Agoi Sequence will allow determination of the temporal limits of its formation.

ACKNOWLEDGMENTS

The authors are grateful to V.M. Andreev, V.N. Ben'yamovskii, D.I. Vitukhin, S.M. Gorbova, E.Yu. Zakrevskaya, S.G. Korsakov, A.M. Nikishin, E.P. Radionova, T.O. Fedorov, E.A. Shcherbinina, and A.I. Yakovlev for help in field works, determination of microfauna, and valuable criticism. Special thanks go to L.M. Rastsvetaev, who initiated these works and participated in all studies of the Agoi olistostrome sequence.

REFERENCES

Afanasenkov, A.P., Nikishin, A.M., and Obukhov, A.N., *Geologicheskoe stroenie i uglevodorodnyi potentsial Vostochno-Chernomorskogo regiona* (Geological Structure and Petroleum Potential of the East Black Sea Region), Moscow: Nauchn. Mir, 2007.

Borukaev, Ch.B., Rastsvetaev, L.M., and Shcherba, I.G., Mesozoic and Cenozoic olistostromes on the south slope of Western Caucasus, *Byull. Mosk. O-va. Ispyt. Prir., Otd. Geol.*, 1981, vol. 56, no. 6, pp. 32–43.

Frolov, V.T., *Litologiya. Kn. 1* (Lithology. Book 1), Moscow: Mosk. Gos. Univ., 1992.

Grossgeim, V.A., Paleogene of Northwestern Caucasus, in *Tr. Krasnodar. fil. Vsesoyuz. nefte-gaz. nauch.-issl. in-ta* (Proc. Krasnodar Br. All-Union Petrol. Res. Inst.), 1960, vol. 4, pp. 3–190.

Keller, B.M. and Menner, V.V., Paleogene deposits of the Sochi area and the associated submarine landslides, *Byull. Mosk. O-va. Ispyt. Prir., Otd. Geol.*, 1945, vol. 20, nos. 1–2, pp. 33–44.

Kopp, M.L., Transgression–regression cyclicity during the Late Cretaceous–Paleogene and phases of olistostromes formation within the limits of the southern slope of Eastern Caucasus. Part 1, *Byull. Mosk. O-va. Ispyt. Prir., Otd. Geol.*, 1990, vol. 65, no. 4, pp. 97–109.

Kopp, M.L., Transgression–regression cyclicity during the Late Cretaceous–Paleogene and phases of olistostromes formation within the limits of the southern slope of Eastern Caucasus. Part 2, *Byull. Mosk. O-va. Ispyt. Prir., Otd. Geol.*, 1991, vol. 66, no. 1, pp. 13–23.

Korsakov, S.G. and Sorokina, A.R., Problems of chaotic complexes of Western Caucasus, in *Mater. II mezhd. nauchn. konf.* "*Problemy geologii i geoekologii yuga Rossii i Kavkaza*", *vol. 1* (Proc. II Int. Sci. Conf. "Problems of Geology and Geoecology of Sourth Russia and Caucasus", Vol. 1), Novocherkassk, 1997, pp. 24–26.

Korsakov, S.G., Semenukha, I.N., Gorbova, S.M., Zarubin, V.V., Sokolov, V.V., Tuzikov, G.R., Chernykh, V.I., Tereshchenko, L.A., and Andreev, V.M., *Gosudarstvennaya geologicheskaya karta Rossiiskoi Federatsii masshtaba 1 : 200 000. Izd. 2-e. Seriya Kavkazskaya. List K-37-XXXIV (Tuapse). Ob"yasnitel'naya zapiska* (The 1 : 200000 State Geological Map of the Russian Federation, 2nd ed., Ser. Caucasian. Sheet K-37-XXXIV (Tuapse). Explanatory Note), St. Petersburg: Kartogr. Fabr. Vseross. Nauchno-Issled. Geol. Inst., 2002.

Maisadze, F.D., On the Upper Eocene olistostromes from the southern slope of the Greater Caucasus, *Stratigr. Geol. Korrel.*, 1994, vol. 2, no.1, pp. 95–102.

Marinin, A.V., Kopaevich, L.F., and Stupin, S.I., Geological structure of the Ubinka River valley (Northwestern Caucasus), *Moscow Univ. Geol. Bull.*, 2011, vol. 66, no. 5, pp. 331–340.

Rastsvetaev, L.M. and Marinin, A.V., Paleogene olistostromes and age of North-Western Caucasus folded structure, in *Mater. V regional. nauchno-tekhn. konf. "Vuzovskaya nauka, Severo-Kavkazskomu Regionu," Stavropol'* (Proc. V Reg. Sci. Tech. Conf. "University Science – North Caucasus Region", Stavropol), 2001, pp. 31–32.

Stupin, S.I., Analysis of foraminiferal paleocoenoses from the upper Ypresian sapropelic layers of the northeastern Peri-Tethys, *Stratigr. Geol. Correl.*, 2008, vol. 16, no. 2, pp. 198–203.

Vialov, O.S., Short geological essay on the Tuapse area, *Izv. Vsesoyuz. Geol.-Razv. Ob"ed.*, 1931, no. 97, pp. 1449–1466.

Vialov, O.S., Geological studies in Western Caucasus in 1931, *Zap. Vseross. Min. Ob-va*, 1934, vol. 63, no. 1, pp. 271–292.

Translated by I. Melekestseva

SPELL: 1. OK