ISSN 0869-5938, Stratigraphy and Geological Correlation, 2024, Vol. 32, No. 4, pp. 348–373. © Pleiades Publishing, Ltd., 2024.

Upper Pliocene–Lower Pleistocene Upper Molasse Belorechensk Formation of Western Ciscaucasia in Context of Regional Neotectonics and Paleogeography

Ya. I. Trikhunkov[a], D. M. Bachmanov[a], A. S. Tesakov[a], V. V. Titov[b, c], V. S. Lomov[a], S. A. Sokolov[a, *], A. V. Latyshev[d, e], A. N. Simakova[a], E. V. Syromyatnikova[f], H. Çelik[g], V. E. Shchelinsky[h], P. D. Frolov[a], E. A. Shalaeva[a], and P. P. Nikolskaya[a]

[a] *Geological Institute, Russian Academy of Sciences, Moscow, 119017 Russia*
[b] *Southern Scientific Center, Russian Academy of Sciences, Rostov-on-Don, 344006 Russia*
[c] *Academy of Biology and Biotechnology, South Federal University, Rostov-on-Don, 344006 Russia*
[d] *Schmidt Institute of Physics of Earth, Russian Academy of Sciences, Moscow, 119017 Russia*
[e] *Moscow State University, Moscow, 119991 Russia*
[f] *Paleontological Institute, Russian Academy of Sciences, Moscow, 117647 Russia*
[g] *Firat University, Elazig, 23119 Turkey*
[h] *Institute for the History of Material Culture, Russian Academy of Sciences, St. Petersburg, 191186 Russia*
**e-mail: sokolov-gin@yandex.ru*

Received July 4, 2023; revised September 15, 2023; accepted October 27, 2023

Abstract—Molasses of foredeeps are important indicators of the newest orogenic uplifts, as well as the source of data on climate and landscape changes. One of the fullest sections of Neogene–Quaternary deposits is studied in valleys of the Belaya, Pshekha, and Psekups rivers at the junction of the Western and Northwestern Caucasus with the Eastern Kuban and Western Kuban foredeeps. The formation of the deposits corresponds to the main evolution stages of the Great Caucasus orogen, as well as the foredeeps. A summary of extensive published and original tectonostratigraphic materials has shown that the lowland and then hilly relief in an axial zone of Western Caucasus existed at least from the Middle Miocene. At the same time, the northern flank of the present-day orogen and the foredeeps were located at sea level and were repeatedly flooded by the seas up to the Kuyalnikian (Piacenzian–Gelasian) time, and the Western Kuban Foredeep was flooded even later. The main data on stratigraphy of the upper molasses and Pliocene–Quaternary tectonic movements of the region are based on facies analysis and bio- and magnetostratigraphic studies of the Upper Pliocene–Lower Pleistocene Belorechensk Formation. Its sedimentation started at the beginning of the Kuyalnikian as a result of an increase in the energy of mountain rivers due to the uplift of the riverheads. It is stated that the minimum average rate of uplift of the Western Caucasus in the basin of the Belaya River is 0.8 mm/year over last 4 mln years with acceleration up to 1.7 mm/year from the beginning of the Calabrian. The Belorechensk Formation includes three subformations, which successively become coarser clastic and correspond to the main stages of the accumulation of upper molasses in the Late Pliocene and Early Pleistocene during the intensification of uplifts and landscape-climate changes of Western Caucasus and Ciscaucasia.

Keywords: Ciscaucasian Foredeep, Western Caucasus, Adygean Ledge, Belorechensk Formation, molasses, neotectonics, stratigraphy, magnetostratigraphy, biostratigraphy, paleogeography

DOI: 10.1134/S0869593824700059

INTRODUCTION

The study of Neogene–Quaternary molasses of the Ciscaucasian Foredeep, their sources, and runoff pathways provided the data on the newest tectonics and evolution of Caucasus. The coarse-clastic "upper" molasses of frontal foredeeps are indicators of the newest orogenic uplifts and the source of data on climate and landscape changes. The stratigraphic questions of Neogene–Quaternary deposits of the Ciscaucasian Foredeep, as well as the neotectonics, are considered in fundamental works of N.I. Andrusov, V.V. Bogachev, G.F. Mirchink, V.P. Kolesnikov, A.L. Reingard, S.I. Charnotsky, V.P. Rengarten, K.A. Prokopov, A.G. Eberzin, and others, which are summarized in a monograph "Stratigraphy of the USSR. Neogene System" (*Stratigrafiya SSSR*..., 1940). More detailed studies of the second half of the 20th century are published in works of Lebedeva (1961, 1963, 1978), Velikovskaya (1960, 1964), Steklov (1966), Safronov

(1957, 1961, 1972), Milanovsky (1968), A.N. Shardanov (*Geologicheskie*..., 1973), Alekseeva (1977), and others, as well as in explanatory notes to sheets of state geological maps on a scale of 1 : 200000 of the first edition (*Gosudarstvennaya*..., 1971). The works of that period are summarized in the monographs "Geology of the USSR. Volume 9. North Caucasus" (*Geologiya SSSR*..., 1968) and "Stratigraphy of the USSR. Neogene System" (*Stratigrafiya SSSR*..., 1986).

In the late and post-Soviet period, the studies were reduced. We should note the works (Vangengeim et al., 1990) and (Tesakov et al., 2014, 2017). The most detailed and fullest descriptions of the region were conducted by employees of OJSC Kabardino-Balkar Geological Exploration Expedition (Nalchik) and Federal State Unitary Geological Enterprise (FSUGE) Kavkazgeols'emka (Yessentuki) during the composing the second generation of geological maps on a scale of 1 : 200000 (*Gosudarstvennaya*..., 2004). In the framework of these works, E.V. Beluzhenko recognized many local stratigraphic subdivisions, in particular, the Belorechensk Formation (Beluzhenko and Burova, 2000; Beluzhenko, 2002a, 2002b, 2005, 2006, 2011; Beluzhenko et al., 2007; Beluzhenko and Pismennaya, 2016, 2018). The candidate's dissertation of Beluzhenko (2006) is the fullest and the most referent work on problems of stratigraphy of the Miocene–Pleistocene deposits, in particular, molasses of Western Ciscaucasia.

The study and, especially, dating of upper molasses of the Ciscaucasian Foredeep, however, remains topical to this day for a number of reasons: (i) the coarse character of material and poor palynological and faunistic record of deposits, (ii) the lack of sufficient material for paleomagnetic dating and a poor magnetic signal, (iii) the absence of material for radioisotopic dating, and (iv) hardly accessible sections: the natural outcrops of the Lower Miocene–Quaternary Gaverdovsky and Belorechensk formations mostly occur at high steep cliffs of the river terraces inaccessible without climbing equipment.

The paper presents the results of studies of the Belorechensk Formation as the first and the thickest chain of coarse molasses of the western part of the Ciscaucasian Foredeep. It was studied within the Adygean Ledge, which is a junction block between the high-altitude Western and low-altitude Northwestern Caucasus from one side and the Western Kuban and Eastern Kuban foredeeps from the other side. The region of studies is located within the Pshekha–Adler Fault Zone, which is the largest growth transverse fault of the Great Caucasus and Ciscaucasian region, which divides the high and low mountains and is a boundary of the occurrence of the Neogene–Quaternary deposits of the Ciscaucasian Foredeep (Fig. 1).

During the analysis of the results, we took into account that the accumulation of boulder–pebble molasses can be due to two factors: increasing energy of water streams as a result of (i) the uplift of drainage divides and (ii) a strong decrease in erosion basis. Taking into account the well-studied dynamics of Ponto-Caspian transgressive–regressive cycles of the Neogene–Quaternary (Nevesskaya et al., 2004; Popov et al., 2010; Yanina, 2012; Svitoch, 2014; Krijgsman et al., 2019), we omitted the deposits which accumulated in epochs of significant drops of erosion basis from indicators of orogenesis.

MATERIALS AND METHODS

The morphostructural analysis of the region of the Adygean Ledge is based on the interpretation of digital elevation models (*Consortium*..., 2017) with a resolution of 3 s and structural-geomorphological and geological-geophysical materials (*Gosudarstvennaya*..., 1971, 2004; *Strukturnaya*..., 1983; *Geomorfologicheskaya*..., 1987). The complex processing of data allowed us to refine the topographic morphology of tectonic structures, the estimation of the position and neotectonic significance of which require both detailed deciphering and the scope of consideration. The details of structural relief of Western and Northwestern Caucasus and Ciscaucasia were studied in the field, resulting in a new original scheme of regional neotectonic zonation. The elements of the newest tectonics described in the paper were distinguished according to their control of Neogene–Quaternary deposits and topographic manifestations. Deciphering of satellite images and digital topographic models, as well as structural-geological and geomorphological mapping and profiling, was conducted by D.M. Bachmanov and Ya.I. Trikhunkov.

Field works were carried out in 2019–2023 and dedicated to the study of the neotectonic structure of the Adygean Ledge, mainly, stratigraphy, lithology, and dating of the Neogene–Quaternary deposits. One of the fullest and most continuous sections of these deposits of the Ciscaucasian Foredeep is exposed in the valley of the Belaya River within the Adygean Ledge (Fig. 1). Here we studied the molasse deposits of the Neogene–Quaternary Blinov, Gaverdovsky, and mainly Belorechensk formations (Fig. 2, points 1–12). The deposits of the latter were also studied in the sections of valleys of the Pshekha and Psekups rivers.

The works were conducted by a group of paleontologists under the leadership of A.S. Tesakov (Geological Institute, Russian Academy of Sciences (GIN RAS), Moscow, Russia) and V.V. Titov (Southern Scientific Center, Russian Academy of Sciences (SCC RAS), Rostov-on-Don, Russia) with the participation of E.V. Syromyatnikova (Paleontological Institute, Russian Academy of Sciences (PIN RAS), Moscow, Russia), A.N. Simakova, P.D. Frolov, P.B. Randzhan, and P.P. Nikolskaya (GIN RAS), as well as a tectonostratigraphic group of GIN RAS under the leadership of Ya.I. Trikhunkov with the participation of S.A. Sokolov, V.S. Lomov, E.A. Shalaeva, and students of the

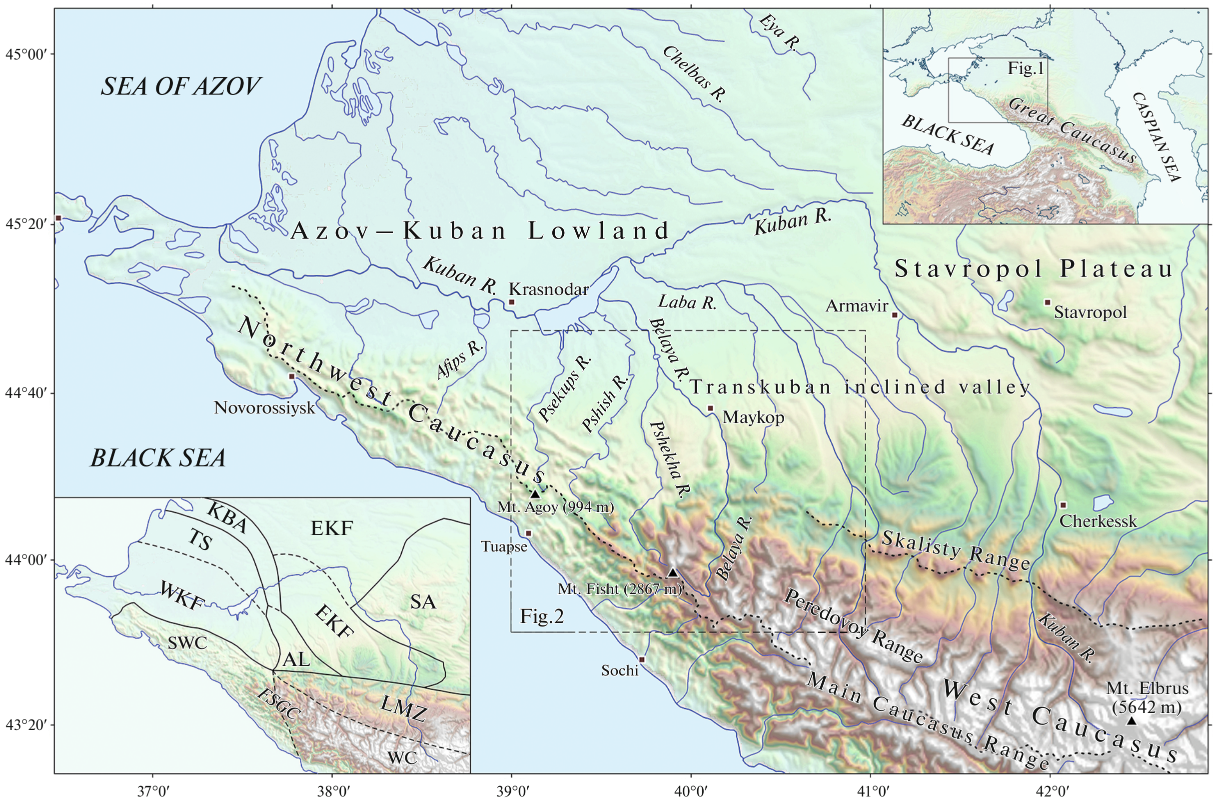

Fig. 1. Orohydrographic scheme of the Western Caucasus and Ciscaucasia. Inset shows the following tectonic structures: fold structure of the Great Caucasus (FSGC), Laba–Malka Zone of G. Caucasus (LMZ), Western Kuban Foredeep (WKF), Eastern Kuban Foredeep (EKF), Stavropol Arch (SA), Adygean Ledge (AL), Timashevsk step (TS), Kanevsko-Berezansky Arch (KBA), WC, Western Caucasus. Composed using data of Klavdieva (2007).

Department of Geology of Moscow State University (Moscow, Russia) and the Department of Geography of Moscow Pedagogical State University (Moscow, Russia) and St. Petersburg State University (St. Petersburg, Russia) A.O. Revunova, M.A. Vasil'eva, I.A. Nadutkin, A.A. Tuzov, L.N. Gavrilov, and A.Kh. Medvedev. The stratigraphy and lithology of sections of the Belorechensk Formation are studied in detail on the left bank of valleys of the Belaya, Pshekha, and Psekups rivers (Fig. 2). The tasks included the detailed description of sections, facies analysis of the deposits, analysis of pebbles for the determination of molasse provenances, paleomagnetic (473 samples), spore–pollen, and faunistic sampling (a vast collection was gathered and a new fauna assemblage was identified), and searching for the material for radioisotope dating. The low water level in the Belaya and Pshekha rivers during 2019–2023 led to the exposure of previously inaccessible fauna-bearing beds of the Belorechensk Formation and therefore the finding of faunistic remnants. We also studied the granulometric characteristics, the degree of roundness, and the quality of sorting of the material, which allowed the refinements of genetic peculiarities of deposits. The structural-facies analysis was conducted by the authors with help of sedimentologist Professor Hasan Çelik (Firat University, Elazig, Turkey).

The age of rocks was estimated on the basis of a combination of methods of bio- and magnetostratigraphy and archaeology. The paleontological samples considered in the work were manually extracted directly from the sections and using mass washing and manual sieves with mesh of 0.5 mm. The larger fractions were treated during the field works and the smaller fractions were sorted in laboratory. The results of fauna studies were compared with current Cenozoic biostratigraphic scales of the Ponto-Caspian region (Krijgsman et al., 2019). The faunistic collections were analyzed in the laboratories of GIN RAS, PIN RAS, and SCC RAS by A.S. Tesakov, E.V. Syromyatnikova, V.V. Titov, and P.D. Frolov. The pollen analysis was carried out by A.N. Simakova (GIN RAS). The archaeological material from the Ignatenkov Kutok site was studied and interpreted by V.E. Shchelinsky (Institute for the History of Material Culture, Russian Academy of Sciences, St. Petersburg, Russia).

The paleomagnetic samples were manually collected as oriented bedrock blocks by Ya.I. Trikhunkov, S.A. Sokolov, and V.S. Lomov. The samples were taken from steep and locally vertical cliffs alongside

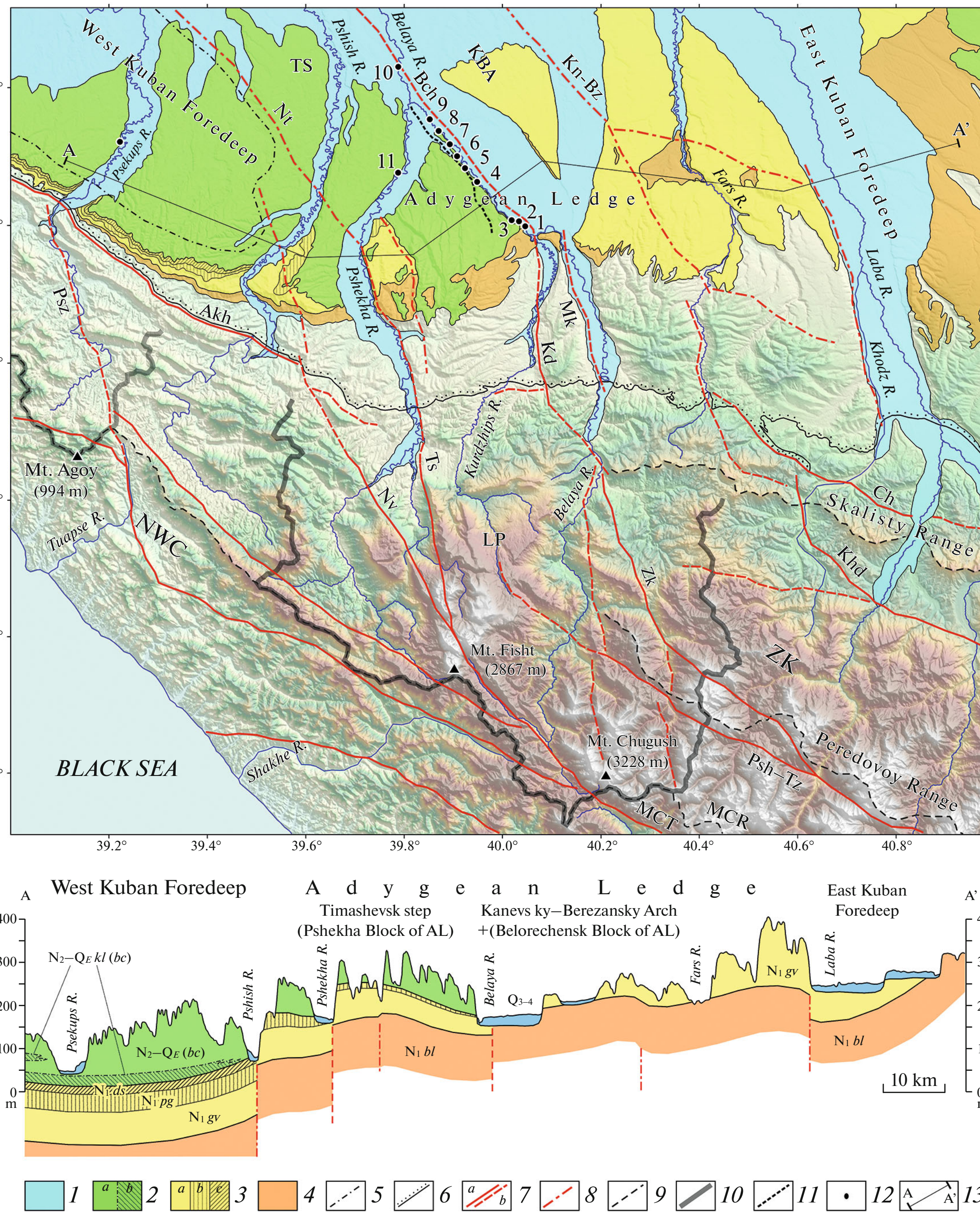

Fig. 2. Geological–geomorphological (without cover of the Middle Pleistocene deposits) and longitudinal geological–geomorphological profile of the junction zone of the Northwestern Caucasus, Western Caucasus, and Ciscaucasian Foredeep. (*1*) Upper Pleistocene, Holocene; (*2*) Pliocene–Quaternary subcontinental and continental deposits: (*a*) Belorechensk Formation (N2–QE*bc*, Piacenzian–Calabrian); (*b*) marine analogs of the Belorechensk Formation (N2–QE*kl* (*bc*), Kuyalnik); (*3*) supra-Sarmatian subcontinental deposits: (*a*) Gaverdovsky Formation (N_1*gv*, upper Tortonian–Messinian); (*b*) sandy–clayey sequence (N_1*pg*, Messinian); (*c*) Dyshevskaya Sequence (N_1*ds*, Zanclean); (*4*) Blinov Formation (N_1*bl*, Tortonian); (*5*) the bottom of the Maykop Group (P_3–lower Oligocene); (*6*) newest faults: (*a*) proven (Akh, Akhtyr; MCT, Main Caucasus Thrust; Zk, Zakan; Kd, Kurjips; Nv, Navaginsky; Psh–Tz, Pshekish–Tyrnyauz Zone; Khd, Khodz; Ts, Tsitsa; Ch, Cherkessk); (*b*) inferred (Bch, Belorechensk; Mk, Maykop; Psz, Psekups Fault Zone); (*7*) faults identified by geophysical methods (Kn–Bz, Kanevsko–Berezansky; Nt, Novotitarovsky); (*8*) orographic elements (MCR, Main Caucasus Range; WC, Western Caucasus; NWC, Northwestern Caucasus; LP, Lagonaki Plateau); (*9*) boundaries of drainage basins of Psekups and Belya rivers; (*10*) paleovalley; (*11*) studied sections (1, Tuapse bridge; 2, Gaverdovsky; 3, Volch'ya balka; 4, Shpil'; 5, Vesely; 6, Krugozor; 7, Belorechensk I; 8, Belorechensk II; 9, Belorechensk III; 10, HPP I and II; 11, Pshekha I and II; 12, Ignatenkov Kutok). The structures of the northern continuation of the Adygean Ledge (AL): TS, Timashevskaya step; KBA, Kanevsko–Berezansky Arch; (*12*) line of geological–geomorphological profile.

the Belaya, Pshekha, and Psekups rivers using climbing equipment. The orientation of samples was determined using a geological compass. The oriented samples were artificially filled with diluted silicate glue and collected using digging instruments. In the laboratory, the stone blocks were cut into cubes 2 × 2 cm in size. The local magnetic inclination was calculated using the IGRF model. The samples underwent stepwise demagnetization by an alternating magnetic field using a demagnetization device, which was mounted into a 2G Enterprises cryogenic magnetometer at the Laboratory of Main Magnetic Field and Petromagnetism by A.V. Latyshev (Schmidt Institute of Physics of Earth, Russian Academy of Sciences, Moscow, Russia). Demagnetization by an alternating field was conducted in 7–9 steps up to 130 nT with a gradual increase in step. The remnant magnetization was measured using the 2G Enterprises cryogenic magnetometer. The components of natural remnant magnetization (NRM) were distinguished in a software package (Enkin, 1994) by the method of principal component analysis (Kirschvink, 1980).

The combination of stratigraphic, paleontological, paleomagnetic, and archaeological data allowed a consistent model of stratigraphic division of a sedimentary section of the Pliocene–Quaternary deposits of the Adygean Ledge and Western Kuban Foredeep.

GEOLOGICAL-GEOMORPHOLOGICAL STRUCTURE OF WESTERN CISCAUCASIA

The Ciscaucasian Foredeep includes a system of local foredeeps being distinguished by the Western Kuban Foredeep (the eastern part of the Indol–Kuban Basin) and Eastern Kuban and Terek–Caspian foredeeps, which are divided by the Adygean and Mineralnye Vody ledges, respectively (Fig. 1, inset). Both ledges continue inside the Scythian Plate in form of arched (in plan) systems of the Kanevsko–Berezansky and Rostov–Stavropol arches. Within the Adygean Ledge, the basement occurs at a depth of 3.5–5.0 km, increasing to 11–12 km in the adjacent Western Kuban Foredeep (*Strukturnaya*..., 1983; *Tektonika*..., 2009). The axis of the Western Kuban Foredeep is extended parallel to the orogen of Northwestern Caucasus along the line of Apsheronsk–village of Kaluzhskaya–village of Anastasievskaya. The foredeep formed at the junction of the Scythian Plate and the Northwestern Caucasus orogen and is divided from the latter by the Akhtyr Thrust. The bottom of the foredeep corresponds to the foot of the Maykop Group deposits (*Tektonika*..., 2009). The foredeep is composed of Oligocene, Neogene, and Quaternary marine and continental sediments. The absence of dissected relief and the predominance of accumulative alluvial-lacustrine plains can indicate the continuation of the evolution of the foredeep. This occurs under conditions of subsidence of the Scythian Plate basement below the Northwestern Caucasus along the line of the Akhtyr Thrust.

From the east, the Adygean Ledge has contact with the Eastern Kuban Foredeep, where the depth of the basement surface decreases to 8 km. The axis of the foredeep is marked by the valley of the Laba River between the villages of Akhmetovskaya and Temirgoevskaya. The valley is characterized by ravine–gully relief and the present-day sedimentation occurs only in the valleys of large rivers. This indicates the absence of active subsidence in contrast to the Western Kuban Foredeep.

The Adygean Ledge is longitudinally oriented and is located between the valleys of the Fars and Kurjips rivers according to (Beluzhenko et al., 2007), whereas its western boundary is confined to the valley of the Pshekha River according to our data given below. In the first scenario, the Khodz and Kurjips faults are structural boundaries of the ledge in the east and the west, respectively. Both faults have a reverse–shear kinematics and are growth faults. They result in different thicknesses of the Oligocene–Miocene deposits in their ascended and descended walls. The amplitude of the displacements along these subvertical faults decreased from the Late Cretaceous to Late Miocene time from 400–500 m to a few tens of meters and almost completely attenuated in the Pliocene–Quaternary time. According to (Beluzhenko et al., 2007), the Kurjips Fault is left-lateral and the amplitude of all displacements from the Late Cretaceous to the end of the Miocene is 3.5–4.0 km, whereas the right-lateral displacements along the Khodz Fault for the same period are estimated at 10–12 km. We suppose that the Khodz Fault is continued further to the northwest, ending at the echelon-like structures of the Kanevsko–Berezansky Thrust (*Tektonika*..., 2009), which limits the eponymous ledge from the north.

Our studies showed that the Kurjips Fault is further continued toward the foredeep, curving to the northwest. The valley of the Belaya River originates along this fault at the Maykop–Belorechensk segment and, probably, further almost to the mouth. At this area, the fault is manifested as a straight river valley. In addition, its northeastern wall hosts no deposits of the Belorechensk Formation, whereas the thicknesses of the Gaverdovsky and Blinov formations are reduced. The latter accumulated in a shallow marine basin, as will be shown below. The main part of the Gaverdovsky Formation, as well as the lower part of the Belorechensk Formation (Lower Belorechensk Subformation), accumulated in large lacustrine basins, probably, limans or lagoons. Apparently, the uplifted wall of the fault limited these basins within the Adygean Ledge according to the idea of previous researchers (Beluzhenko et al., 2007). It follows that the Kurjips Fault was active over the entire Pliocene–Quaternary. We suggest naming its northwestern continuation as the Belorechensk Fault (Fig. 2).

To the west, between the valleys of the Belaya and Pshekha rivers, i.e., in the descended wall of the Kurjips and Belorechensk faults (further, Kurjips–Belorechensk Fault), there is one more large block, which is comparable in width with the Adygean Ledge in the opinion of Beluzhenko et al. (2007). It is restricted from the west by the Tsitsa Fault, which is the main fault of the Pshekha–Adler Fault Zone with the largest amplitude of vertical deformations. The fault is traced by straighten valleys of the Tsitsa River and further the Pshekha River up to the settlement of Vpered to the north of Apsheronsk and is further absent on the surface, being overlain by young deposits of the foredeep. According to (*Tektonika*..., 2009), however, it continues to the north by the Novotitarovsky deep fault, which bounds the Western Kuban Foredeep from the east and divides the latter from the Timashevskaya step (Fig. 1).

Longitudinal geological–geomorphological profiling shows that, in neotectonic plan, a block in the Pshekha–Belaya interfluve is uplifted for 200 m above the main territory of the Western Kuban Foredeep (Fig. 2). It is also uplifted approximately for 40–50 m above the main territory of the block, which is located in the eastern wing of the Kurjips–Belorechensk Fault and associated (Beluzhenko et al., 2007) with the Adygean Ledge. This is evident from profiling (Fig. 2), as well as from field observations: the left wall of the valley of the Belaya River in the western wing of the fault is hypsometrically higher than the right wall, which is occupied by an accumulative valley. The inversion of the tectonic regime of this block is therefore evident: it was earlier situated in the descended wall of the growth Kurjips–Belorechensk Fault, but now is in contrast uplifted above. All the studied sections of the Belorechensk Formation in the left wall of the valley of the Belaya River thus now occur in the uplifted wall of the fault (Fig. 2). This block in the south is directly joined with a homocline of the Lagonaki Plateau and, judging from the continuation of its western fault boundary, is extended to the north by the Timashevskaya step, being part of it. On most known tectonic profiles and schemes, the Timashevskaya step is shown as a structure parallel to the Kanevsko–Berezansky Arch, which forms an entire basement uplift (Fig. 1, inset). We thus consider that the Adygean Ledge continues both of these structures to the south and consists of two blocks, which we propose to name Pshekha and Belorechensk.

Numerous field data, as well as the morphostructural analysis based on digital elevation models, indicate that, during the Pliocene–Quaternary stage of tectonic evolution of the region, all above listed faults, which bound or cross the Adygean Ledge, had only vertical displacements. Faults cross several paleovalleys within the ledge, as well as the Lagonaki step, without lateral deformations. This is also supported by the above geological data from Beluzhenko et al. (2007).

In general, the block of the Adygean Ledge has a homoclinal structure of the sedimentary cover, which is also typical of the Laba–Malka Zone and which is only locally violated by local poorly recognizable fold structures. Although the block is divided by the Cherkessk Fault from this zone, it is affected by a general uplifting of the Western Caucasus. The difference of the newest uplift is evident within the Adygean Ledge: its southern and especially southeastern parts are uplifted to 600–700 m, whereas the average heights vary from 100 to 200 m at the latitude of the village of Khanskaya and from 80 to 130 m in the northernmost area, near the section of the hydroelectric power plant (HPP) (Fig. 2, point 10). The homoclinal structure of the ledge is also visible from the northern dip of the Upper Sarmatian and Meotian (Tortonian) rocks (Blinov (N_1*bn*) and Gaverdovsky (N_1*gv*) formations). The angle of their dip at the latitude of Maykop is 16°–12° at several measurement points, decreasing to 14°–10° at the latitude of Belorechensk. It follows from drilling data that the beds of the Pontian (Messinian) marine deposits abundant to the north and west of village Khanskaya dip in a similar manner to the north (Beluzhenko, 2006). The deposits of the Belorechensk Formation have a more gentle dip, which will be described below.

STRATIGRAPHY OF LOWER MOLASSES OF WESTERN CISCAUCASIA

We follow the division of molasse deposits into the lower and the upper (Grossgeim, 1974). The lower molasses include marine mostly terrigenous deposits, which are mainly composed of gray clays, siltstones, and sandstones with interlayers of conglomerates and marls, whereas the upper molasses are mostly continental conglomerates with subordinate interlayers of sandy and clayey deposits.

Middle–Late Miocene Lower Molasses

The main territory of Western Ciscaucasia in the post-Maykopian time was covered by shallow seas for the entire Miocene, yielding more than a 1.5-km-thick sequence of mostly fine-grained deposits. In the valleys of the Belaya, Fars, and Laba rivers (Fig. 1), the basement of marine sequences of the Middle Miocene Chokrak and Karagan stages (Langhian–Serravallian), however, contains basal conglomerate beds with pebbles of sedimentary rocks (Buryak, 1960; *Geologiya*..., 1968). Together with finding of shells of terrestrial mollusks in the Karagan deposits (Steklov, 1966) and leaf flora imprints (Korsakov et al., 2013), this indicates the presence of the Caucasian landmass already in the Middle Miocene.

Marine deposits of the Konka Stage (Serravallian) include the Adygeya Formation (N_1*ad*), which consists of marine silts and sands with interlayers of clays and sandstones without coarse-clastic deposits.

The deposits of the Sarmatian Stage (upper Serravallian–Tortonian) within the Adygean Ledge include marine deposits with dominant clays, marls, limestones, silts, siltstones, sands, and sandstones of the Tulsky (N_1*tl*), Krasny Most (N_1*ks*), and Krasny Oktyabr (N_1*ko*) formations. The coarse-clastic deposits are described only in the Blinov Formation (N_1*bn*) of the upper parts of the middle–upper Sarmatian (Tesakov et al., 2017). The formation was studied by us in the Tuapse Bridge and Gaverdovsky sections (Fig. 2) and includes sandy–clayey lagoon deposits of a warm slightly saline marine basin, as well as organic–detritus limestones, which are overlain by a member of gravelites and conglomerates made up of boulders and blocks of limestones and small poorly rounded pebbles of clays and marls.

The conglomerates are also described within the Western Kuban Foredeep in the Psekups–Afips interfluve (area of the village of Kaluzhskaya) in the basement of middle Sarmatian shallow marine sequences of the Maltsevskaya Formation, which is an analog of the Blinov Formation according to (Beluzhenko, 2011). These coarse molasses were transported from the uplifted Northwestern Caucasus. The thickest Neogene facies of pebbles (up to 10 m) are described in the basement of the upper Sarmatian deposits of the eastern part of the Eastern Kuban Foredeep at its junction with the Stavropol Arch. The absence of clasts of crystalline rocks in their composition, however, indicates that the crystalline basement of the Caucasus orogen was buried during that period.

The Gaverdovsky Formation (N_1*gv*, Tortonian-Messinian) conformably occurs on the Blinov Formation and includes first deposits of a subcontinental series (in a common regional section): coastal marine, lagoonal, deltaic, river, lacustrine, and swampy (Beluzhenko and Burova, 2000), which are typical of the transition from coastal land to marine basin characterized by gradual NW regression. The Lower Gaverdovsky Subformation, which is studied in the Tuapse bridge (point 1 in Fig. 2; 44°35′56″ E, 40°02′49″ N), Gaverdovsky (point 2 in Fig. 2; 44°36′23″ N, 40°01′56″ E), and Volch'ya balka (point 3 in Fig. 2; 44°36′22″ N, 40°01′25″ E) sections, is composed of intercalated sands and clays with rare interlayers of loamy sands and gravels in the upper part. The sands are multigranular, locally obliquely bedded, with interlayers of sandstones and gravelites and are, locally, gray-black or brown owing to Mn and Fe minerals. The clays are nonbedded, lumpy, spotty (bluish gray with brown ferruginous spots), locally sandy, often with carbonate nodules up to 20–30 cm in size. The thickness of the formation along the Belaya River reaches 170 m (Korsakov et al., 2013). The palynospectra and the composition of herpetofauna show that the deposits of the Lower Gaverdovsky Subformation accumulated inside the late Sarmatian–Maeotian wet subtropical and moderately warm forest landscapes (Beluzhenko and Burova, 2000; Tesakov et al., 2017), which is supported by data on land mollusks (Steklov, 1966).

The basement of marine Maeotian analogs of the Gaverdovsky Formation (Klyuchevskaya Formation after (*Gosudarstvennaya*..., 2004)) along the southern flank of the Western Kuban Feoredeep contains basal conglomerates with large pebbles of sandstone, limestone, and siliceous rocks (*Geologiya*..., 1968). The evolution of similar deposits in the foredeep also indicates the presence of the Caucasus landmass in Maeotian time, which was a source of both fine- and coarse-clastic material.

The Pontian (upper part of Messinian) deposits within the area (in our understanding) of the Adygean Ledge are exposed on a small area of the left bank of the Pshekha River opposite the village of Kubanskaya (a sandy–clayey sequence after (*Gosudarstvennaya*..., 2004)) and include the intercalation of sands and clays with interlayers of limestones, which accumulated in a shallow marine basin. According to drilling data, these deposits up to 50 m thick occur above the sediments of the Lower Gaverdovsky Subformation and propagate from the northwest from the Western Kuban Foredeep toward the Adygean Ledge to the latitude of the village of Khanskaya and are pinched out from the section further to the southeast (Beluzhenko, 2006). Within the Western Kuban Foredeep, the thickness of the Pontian marine deposits increases to 300 m and they include combined sandy–clayey and Dyshevskaya sequences. Their basement hosts conglomerates up to 7 m thick (*Geologiya*..., 1968). These data also confirm the presence of the Western Caucasus landmass in the Pontian time.

The lower molasses of the Early Pliocene (Kimmerian Stage) are widely abundant within the Western Kuban and Eastern Kuban foredeeps. In the basin of the Psekups and Pshish rivers, they include the Dyshevskaya Sequence, which unconformably occurs on a sandy–clayey (Pontian regional stage) sequence. The basement of the section contains pebbles, which are locally transformed to conglomerates. The main part of the section consists of oxidized yellow and brown often obliquely bedded sands with interlayers of sandstones and rarely clays. The Kimmerian age and marine genesis are confirmed by fauna of bivalve mollusks (*Gosudarstvennaya*..., 2002).

Within the Western Kuban Foredeep, Lebedeva (1963, 1978) ascribed to the Kimmerian (Zanclean) sands and red and variegated clays of the "Above-Pont" Formation of the right coast of the Kuban River in vicinity of Armavir. The Kimmerian deposits within the Western Kuban Foredeep, however, are not shown on maps (*Gosudarstvennaya*..., 1971, 2004) or in their explanatory notes (*Gosudarstvennaya*..., 2021). The findings of mammal fauna in several levels of the Armavir Sequence indicate the late Sarmatian–Maeotian age of these deposits (Tesakov et al., 2013). No Kimmerian deposits within the Adygean Ledge are described by Velikovskaya (1960, 1964) and Steklov (1966).

The Upper Gaverdovsky Subformation >100 m thick is described in detailed works of Beluzhenko and his coauthors from the FSUGE Kavkazgeols'emka (Beluzhenko and Burova, 2000; *Gosudarstvennaya*..., 2004; Beluzhenko, 2006; Korsakov et al., 2013). It includes the intercalation of variegated nonbedded clays and yellow-gray clayey sands with interlayers and lenses of limestones. The age of the subformation, however, remains undefined. Its palynological assemblage was ascribed to the Pliocene (Beluzhenko and Burova, 2000); however, Beluzhenko (2006) rejected this interpretation and ascribed the Upper Gaverdovsky Subformation to the Maeotian–Pontian (Messinian). The paleomagnetic characteristic (Beluzhenko and Burova, 2000) allows its comparison with the upper part of chron C3A and the lower part of chron C3 with a typical long episode of reverse magnetization in its lower part (upper two-thirds of the section of the subformation); i.e., it is ascribed to the upper part of the Maeotian–Pontian. Beluzhenko and Pismenskaya (2016) indicated that the deposits of the northern age analog of the Belorechensk Formation (Azov–Kuban Formation) occur with unconformity on the Lower Pontian deposits.

A striking angular unconformity at 11°–13° between the Gaverdovsky Formation and overlying Belorechensk Formation is also evident of a hiatus in Kimmerian time within the Adygean Ledge. The deposits of the Gaverdovsky Formation in the Volch'ya balka section (Fig. 2, point 3) dip to the north at angles of 16°–12°. The contact of the formations is described in the valley of the Belaya River, approximately in the middle between points 3 and 4 (Fig. 2) (Beluzhenko and Burova, 2000); however, it is buried now. Note that the deposits of the Upper Gaverdovsky Subformation, which nearly horizontally occur at this segment of the valley, described by these authors are probably the lower parts of the Belorechensk Formation. Somehow or other, the deposits of the Lower Belorechensk Subformation in the Shpil' section (Member 1) dip to the north more gently than the dip of the river (~1°) (Fig. 3; Fig. 2, point 4). Below the section of the homocline of the Adygean Ledge, no similar unconformities are described; all the formations occur conformably or with erosion contacts. Such a significant angular unconformity indicates the involvement of the Adygean Ledge in the uplifts of the Laba–Malka Zone and the entire Western Caucasus in the Kimmerian time. This can explain the hiatus of this epoch, which is described in eastward regions of the Eastern Kuban Foredeep. There are data on Kimmerian uplifts of Central Caucasus and the eastern part of Western Caucasus, as well as Central Ciscaucasia (*Geologiya*..., 1968).

It follows from the aforesaid that the deposits of the Gaverdovsky Formation of the Adygean Ledge are the first (beginning from the Middle Miocene) facies, on one hand, of subcontinental deposits (alluvium of the pra-Belaya, pra-Phekha, and pra-Laba rivers) and deposits without coarse molasse, on the other hand. This proves the absence of mountains within the land, which was a provenance for the material before the Kimmerian time.

STRATIGRAPHY OF UPPER MOLASSES OF WEST CISCAUCASIA

The Belorechensk Formation (N_2–Q_1*bc*) was named by Beluzhenko (2006) and is an analog of the "Above-Pont" Formation, which was distinguished by G.N. Rodzyanko in 1943 and later renamed the Azov–Kuban Formation (*Stratigraficheskii*..., 1982). Until now, these deposits, however, were insufficiently studied because of the reasons described above. We studied the stratigraphy and lithology of ten sections of the Belorechensk Formation in the valleys of the Belaya, Pshekha, and Psekups rivers (Fig. 2): Shpil' (point 2, 44°39′43.96″ N, 39°56′52.21″ E), Vesely (point 5, 44°40′58.35″ N, 39°55′23.64″ E), Krugozor (point 6; 44°41′58.18″ N, 39°54′27.11″ E), Belorechensk I (point 7; 44°43′16.99″ N, 39°53′21.33″ E), Belorechensk II (point 8; 44°44′9.85″ N, 39°52′14.11″ E), Belorechensk III (point 9; 44°45′15.61″ N, 39°51′1.39″ E), Belorechensk HPP I and II (point 10; 44°49′45.99″ N, 39°47′19.70″ E), Pshekha I and II (point 11; 44°40′34.31″ N, 39°47′9.76″ E), and Ignatenkov Kutok (point 12; 44°43′22.15″ N, 39°13′35.24″ E).

A combined section of the formation is based on the correlation of all listed sections. It is subdivided into subformations, each of which, in turn, contains members with several beds. Some beds are repeated in several sections, whereas other beds are not. The correlation of the sections and their combination into a combined section were thus complex tasks, the solution of which became possible only owing to the detailed lithological description of beds, as well as paleomagnetic, paleofaunistic, and partly palynological sampling. The combined section is described at the level of subformations and members, because the bed-by-bed description is difficult because of variability of stratigraphic elements of members from section to section. The numbering of members from the lower to the upper subformation is through. We distinguished three main members of the formation, which ubiquitously occur on each other with erosion contacts and which differ in lithology: the Lower (N_2^2*bc1*), Middle (N_2^2–Q_E*bc2*), and Upper (Q_E*bc3*) Belorechensk subformations.

The Lower Belorechensk Subformation (N_2^2*bc1*) occurs in the Shpil', Vesely, Pshekha, Krugozor, and Belorechensk sections. It overlies the Gaverdovsky Formation with angular unconformity at 10°–13° and dips to the north at an angle of 1°–2° (slightly steeper than the dip of the Belaya River). The deposits of the formation are exposed in coastal cliffs of valleys of the Belaya and Pshekha rivers from the village of

Fig. 3. (a) General view of the Shpil' section; (b) member 1, alluvial pebblestones of the Lower Belorechnesk Subformation (N_2^2 *bc1*); (c) contact of lacustrine–liman clayey–silty deposits of member 2 (N_2^2 *bc1*) and alluvial obliquely layered sands and gravelites of member 3 (N_2^2–Q_E *bc2*). Arrow shows the flow direction of the Belaya River.

Khanskaya to Belorechensk, forming a basement of their ancient terraces, and fully submerge at point 9 (Fig. 2, points 4–9, 11). The subformation is composed of two members.

Member 1 consists of horizontally bedded pebblestones and gray sands of various sizes: the pebblestones transit upsection to small-grained sands and silts. The visible thickness of the member is 4.5 m. The basement consists of polymictic pebblestones of small (to 5 cm) fraction with interlayers of ocherous–brown medium-grained sand up to 3 cm thick. The pebblestones are composed of dominant clasts up to 5 cm in size of first–third classes of roundness, which include gray muscovite granites, pelitic limestones, quartz, cherts, and less commonly gray sandstones and metamorphic rocks. Upsection, the pebblestones are replaced by a 1-m-thick bed of horizontally bedded gray and ocherous quartz sands and further by a 0.5-m-thick bed of gray silts. The member occurs only in the Shpil' section (Figs. 3a, 3b). These pebble deposits are the first reliable portion of upper continental molasses of the Adygean Ledge and the Western Kuban Foredeep.

Member 2 consists of horizontally bedded gray and ocherous clays and clayey silts with lenses of sands and small-pebble conglomerates in the upper part. The bedding inside the member is clear and mostly lacustrine: the beds are rhythmic, parallel to each other, and

Fig. 4. Vesely section, member 2 of the Lower Belorechnesk Subformation (N_2^2 *bc1*): (a) clayey–silty lacustrine–liman deposits with carbonate cementation; (b) lacustrine–liman deposits with parallel layering.

extended for many kilometers along the Belaya and Pshekha rivers in their lower reaches (Figs. 3a, 3b, 4, 5). The deposits are exposed in all sections of the Belorechensk Formation along the coasts, as well as in the Belaya River (during low water) over 13 km between the Shpil' section (on the left bank of the river opposite to the southern part of the village of Khanskaya) and the Belorechensk III section opposite to a new city park of Belorechensk (Fig. 2, points 4 and 9), where they are submerged beneath the sequences of the Middle–Upper Quaternary alluvium. The total thickness of the member reaches 21 m. Owing to the flat-homoclinal dip of the member, its foot and top are observed at points 4 and 9, respectively.

The deposits of the member underwent carbonate cementation enhanced upsection: carbonatization is poor in the Shpil' and Vesely sections, which contain the lower part of the member, in contrast to more striking carbonatization in the lower parts of the Pshekha, Krugozor, and Belorechensk (in the upper part of member 2) sections. There are typical various forms of caliche carbonate nodules: branches, ellipsoids, cones, and columns.

In the upper beds of member 2 in the Krugozor, Pshekha, and Belorechensk sections, the clay and silt sequences with carbonate cement contain abundant lenses and interlayers of small-pebble conglomerates with oblique deltaic bedding described below. The predominance of pebble deltaic series in the sections occurring downstream and in the upper part of the subformation can indicate their deposition during regression of a large lacustrine basin, in which the main part of member 2 accumulated. The subformation is generally characterized by a decrease in granulometric composition of deposits upsection.

The Middle Belorechensk Subformation (N_2^2–Q_E*bc2*) also most fully occurs in the Shpil', Krugozor, and Belorechensk sections and is strongly reduced in the Vesely and Pshekha sections because of erosion by paleorivers (Fig. 2). Its deposits in various outcrops overlie various parts of the combined section of the Lower Belorechensk Subformation with erosion unconformity and generally differ from the latter in the coarser composition and more striking carbonate cementation. The trend of a decreasing size of the clasts upsection remains. The thickness of coarse alluvium within its limits, however, is significantly higher than that of fine lacustrine deposits. The bedding elements of the deposits coincide with those for the lower subformation.

Member 3 mostly includes oxidized ocherous sands with interlayers of gravels and pebblestones of small fraction, gravelites, and small-pebble conglomerates with carbonate clay cement. The deposits of the member are most complete in the Krugozor and Belorechensk sections, where their thickness is 9.2–9.5 m and the total thickness of the combined section of the member reaches 13.5 m.

Member 3 in the Shpil' section includes oxidized obliquely bedded sands with interlayes of gravels, small pebbles, silts, and carbonate clays. Its deposits intrude member 2 as a lens comparable with the present-day Belaya riverbed (Fig. 3c). The bedding inside the lens is typically alluvial: oblique series are parallel to each other and dip upstream and the coarser material is focused in the lower part of the beds. The pebblestones are polymictic and include the clasts of gray muscovite granites, pelitic limestones, quartz, cherts, and metamorphic rocks. Upsection, the material becomes finer up to small-grained sands and silts with interlayers of carbonate clays.

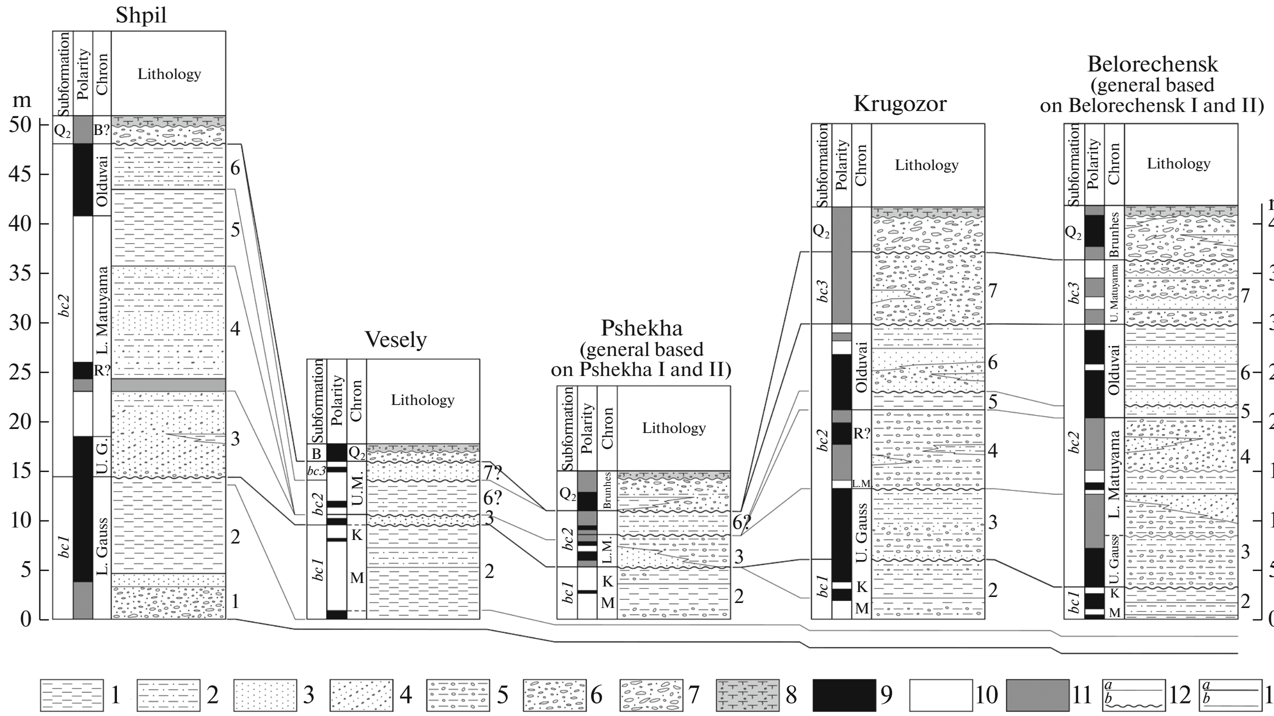

Fig. 5. Schematic correlation of main cross sections of the Belorechensk Formation within the Adygean Ledge. (1) Clay; (2) silt; (3) sand; (4) sand with gravel; (5) pebble conglomerate; (6) pebblestone; (7) pebblestone–boulder stone; (8) present-day soils on pebblestone and loess loamy sand; (9) normal polarity; (10) reversed polarity; (11) gaps in sampling; (12) boundaries of beds: (*a*) conformable occurrence; (*b*) erosion unconformities; (13) correlation curves: (a) between subformations; (b) additional. The numbers of members are shown to the left from the sections. U.G., the upper part of the Gauss chron; M, Mammoth subchron; K, Kaena subchron; U.M., the upper part of the Matuyama chron; L.M., the lower part of the Matuyama chron; R, Reunion subchron; B, Brunhes chron; bc1, Lower Belorechnesk Subformation; bc2, Middle Belorechnesk Subformation; bc3, Upper Belorechnesk Subformation.

In the Vesely section, the deposits of this member are strongly reduced in the lower part of the top of the section. They are composed of coarse- and medium-grained oxidized sands with interlayers of gravels and silts. The combined section of the Pshekha section exhibits enhanced carbonate cementation of member 3. It consists of a lens of gray obliquely bedded sands, which have weak carbonate cement and intrude the clays of member 2 in much the same way as the Shpil' section. The oblique beds also dip upstream of the present-day Pshekha River. They are overlain by a sequence of small–medium-pebble conglomerates with Ca carbonate cement. The clasts are dominated by light beige limestones, pale purple–pink or pale reddish purple marbleized limestones, gray or light brown sandstones, gray–black claystones, and cherts.

In the Krugozor and Belorechensk sections, the deposits of member 3 form the riverbed cliffs, locally occurring in the basement of the floodplains. They are contrasting against the clayey–silty deposits of member 2. In these sections (especially, in the Belorechensk section, which occurs downstream in comparison with other sections), the small-pebble conglomerates have striking deltaic oblique bedding that is supported by (i) the dip of oblique beds downstream of the present-day Belaya River and pra-Belaya River (toward the different sides within the northern hemisphere) (Fig. 6c); (ii) a wedge profile of oblique beds and the presence of the coarsest material in the middle part of the beds rather than in the basement, which is typical of river obliquely bedded alluvium of the Shpil' and Pshekha sections; and (iii) the concave basement of oblique series. The formation of this bedding can be related to numerous changes in direction of the flow in the mouth part of the pra-Belaya River and/or fluctuations of water level of the receiving basin. This scenario is also typical of the upper part of member 2 (see above) and indicates the regression stage of the lacustrine basin, which formed its deposits.

Member 4 includes the intercalation of small-pebble conglomerates with carbonate cement, sands with interlayers and lenses of gravel, and clayey silts, which occur with erosion on underlying deposits. The deposits are most complete in the Shpil' section, where their thickness is 11.5 m, as well as in the Krugozor and Belorechensk sections (6.5 and 7.7 m, respectively), whereas the total thickness of the combined section reaches 16 m.

In the Vesely and Pshekha sections, these deposits are fully eroded. In the Shpil' section, they mostly include clayey silts with various forms of caliche car-

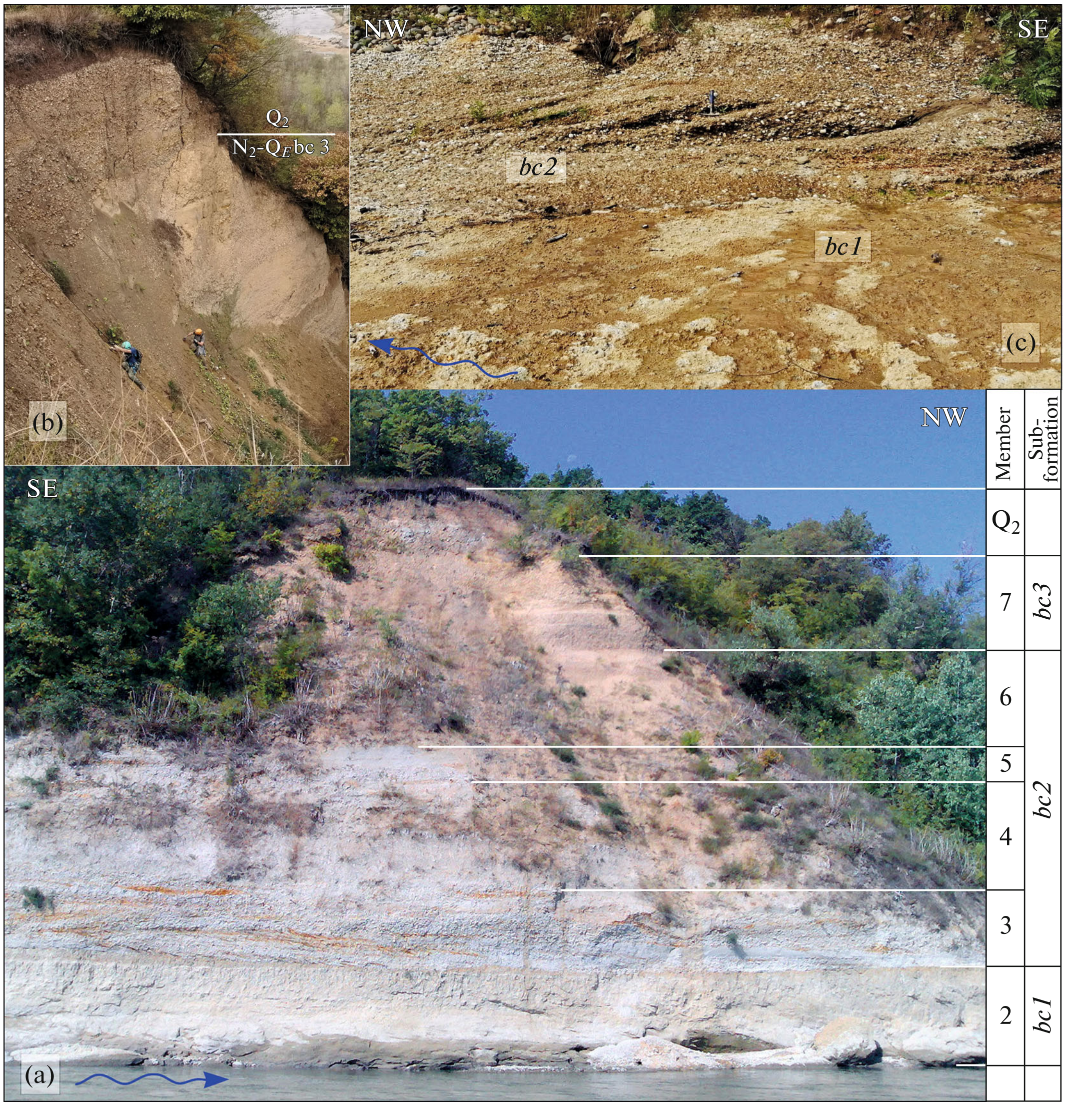

Fig. 6. (a) General view of the Belorechensk I section; (b) the upper part of the Belorechensk II section, the contact of sandy–clayey alluvium of the Upper Belorechensk Subformation (Q_E*bc3*) and the Middle Pleistocene pebblestone; (c) the contact of lacustrine–liman clayey–silty deposits (member 2, N_2^2 *bc1*, the main fauna-bearing horizon of the Belorechensk Formation) and pebble conglomerate with deltaic layering (member 3, N_2^2–Q_E*bc2*). Arrows show the flow direction of the Belaya River.

bonate nodules and interlayers and lenses of sands and gravel. In the Krugozor and Belorechensk sections, the interlayers and lenses of clayey silts, as well as sands with gravel, are subordinate, whereas the main volume is occupied by small- and medium-pebble conglomerates with pervasive carbonate cementation. The clasts are composed of gray and red granites, pelitic light beige or pale purple–pink limestones, quartz, cherts, rare gray sandstones, gray–black silts, clayey shales, and dark and green metamorphic rocks.

Member 5 consists of horizontally bedded splintered light gray to white carbonate clays, locally with oxidized spots. They contain diverse forms of the caliche carbonate nodules: branches, ellipsoids, cones, and columns. The deposits are most complete in the Shpil' section, where their thickness is 7.2 m, as well as in the Krugozor and Belorechensk sections (1.8 and 1.2 m, respectively). In the Vesely and Pshekha sections, these deposits are fully eroded. The deposits are probably lacustrine. This member is most striking in the Krugozor section: the deposits above this member are devoid of carbonate cementation (Fig. 7).

Member 6 contains horizontally bedded ocherous and brown, locally clayey silts, horizontally bedded small- and medium-grained sands with lenses of gravels and polymictic pebblestones. Pebble is small to medium of second–third class of roundness. The member stands out in the combined section because of

Fig. 7. General view of the Krugozor section: the lower lacustrine–liman (N_2^2*bc1*), middle alluvial–deltaic (N_2^2–Q_E*bc2*), and upper alluvial (Q_E*bc3*) subformations of the Belorechensk Formation overlain with erosion by alluvial–proluvial cover of pebblestone and boulder stone (Q_2).

absent carbonate cementation in comparison with carbonate clays of member 5. Member 6 occurs in the Shpil' (5.8 m), Krugozor (4.8 m), and Belorechensk (4.5 m) sections, whereas its total thickness is 6.5 m. Its presence in the Vesely section is discussible (Fig. 5).

The Upper Belorechensk Subformation (*QEbc3*) includes only member 7 in the Krugozor and Belorechensk sections and is an example of typical alluvium of a mountain river (Figs. 5, 6b). Its presence in the Vesely section is a matter of debate. The subformation consists of polymictic pebblestones with interlayers of ocherous medium- to small-grained sands and silts, which are overlain by the Middle Belorechensk deposits with erosion contact. The pebble is medium-sized of second–third class of roundness. The pebblestones are characterized by oblique bedding with beds dipping to the south upstream of the Belaya River. The subformation lacks carbonate cementation typical of the Lower Belorechensk (member 2) and Middle Belorechensk (members 3–5) subformations. The maximum thickness of 7 m of the subformation is observed in the Krugozor section.

The combined section of the deposits of the Belorechensk Formation within the Adygean Ledge thus reaches 76 m and has a three-member structure: its three subformations reflect three stages of the accumulation of upper molasses in the Pliocene–Quaternary. The Lower and Middle Belorechensk subformations reflect the erosion–accumulative cycles, which began from the accumulation of coarse river alluvium (pebblestones, gravels, and sands) and which were finished by lacustrine accumulation of clays and silts. The Lower Belorechensk Subformation begins from pebblestones, which are the first chain of upper coarse molasses of the Western Kuban Foredeep and Adygean Ledge. The Upper Belorechensk Subformation includes pebblestones with subordinate sands and gravels and reflects the stage of intensified formation of the riverbeds because of the uplift of the river basins.

Middle Pleistocene Deposits

A brown pebble–boulder sequence 5–7 m thick occurs in the upper part of all studied sections in the valleys of the Belaya, Pshekha, and Psekups rivers.

The composition of clasts is similar to that of the Upper Belorechensk Subformation: the rocks of the crystalline basement of the orogen occur in all sections except for the Ignatenkov Kutok section. The deposits occur with erosion unconformity on various members of the section of the Belorechensk Formation, often forming the riverbed cuttings (Fig. 7), and compose an accumulative cover of the upper terraces. This pebble–boulder sequence, however, is also described in the interfluve areas of the Adygean Ledge (Korsakov et al., 2013), which makes it similar to a frontal apron forming by merging fans of large mountain rivers, when they leave gorges toward the accumulation zone of the frontal foredeep.

BIO- AND MAGNETOSTRATIGRAPHY OF THE UPPER MOLASSE DEPOSITS

The Lower Belorechensk Subformation (N_2^2bc1)

The basement of the Lower Belorechensk Subformation (member 1) is exposed only in the Shpil' section and includes a sequence (4.5 m) of pebblestones and sands, which are devoid of carbonate cementation and are normally magnetized in the upper part. They are overlain by carbonate clays and clayey silts of member 2 with similar magnetization. Among the deposits with poor pollen material, only these deposits from sections of the Belorechensk Formation yielded the palynological data. The pollen spectrum is dominated by gymnosperm plants (81%), mostly pine. There are grains of *Cathaya*, *Picea*, *Cedrus*, *Podocarpus*, *Abies*, and Taxodiaceae. The broadleaf trees include single pollen of Fagaceae, *Carya*, and *Liquidambar*. The amount of grasses and spores does not exceed 5% from the total composition of the spectrum (Asteraceae, Cyperaceae, and Polypodiaceae). The spectrum shows the dominant pine forests and reflects a cool and wet climate, which explains the absence of carbonate cement in the lower part of the subformation. Upsection of member 2, however, the carbonate content of deposits strongly increases, probably, indicating warming and aridization. It is likely that exactly this was responsible for the absence of spores and pollen from members 2, 3, 4, and 5.

It can be suggested that the age of the deposits of member 1 in the basement of the Shpil' section is the Early Pliocene and their pollen spectra could be correlated with the upper Kimmerian (Zanclean) spectra of Western Georgia (Shatilova et al., 2011). The absence of the reverse polarity in the basement of the Belorechensk Formation (Fig. 5, Shpil' section) typical of the Gilbert epoch, however, indicates the beginning of the accumulation of its deposits in the middle part of chron C2A in the early Kuyalnikian in cool wet climate before the beginning of the Late Pliocene climate optimum.

Rich vertebrate fauna of the early Villafranchian (Late Pliocene) was collected for the first time for the Northern Caucasus in the Belorechensk and Pshekha sections on a limited area from the surface of member 2 represented by clayey silts with carbonate cement (Figs. 6a, 6c), which are exposed on a dried bottom of the Belaya and Pshekha Rivers: hares *Hypolagus* cf. *brachygnathus* (Kormos, 1930), moles *Talpa* sp., chipmunks *Eutamias* ex gr. *orlovi* (Sulimski, 1964), beavers *Trogontherium* cf. *minus* (Newton, 1890), blind mole-rats *Spalacidae* gen., hamsters cf. *Neocricetodon*, primitive heather voles *Mimomys* cf. *stehlini* (Kormos, 1931) and *Pliomys jalpugensis* Nesin, 1983, forests mice *Apodemus* sp., raccoon dogs *Nyctereutes* sp., bears *Ursus minimus* Devèze et Bouillet, 1827, lynx *Lynx* cf. *issiodorensis* (Croizet et Jobert, 1828), mastodons *Anancus* sp., ancient elephants *Archidiskodon meridionalis* cf. *rumanus* (Stefanescu, 1924), rhinoceroses *Stephanorhinus* sp., deers *Arvernoceros* cf. *ardei* (Croizet et Jobert, 1828) and *Procapreolus* sp., and pigs *Sus* cf. *arvernensis* Depéret 1885, as well as frogs cf. *Pelophylax*, protea *Mioproteus* sp., giant salamanders *Andrias* sp., and freshwater turtles of family Emydidae. There are also caps of terrestrial mesophyle mollusks *Pomatias*, as well as freshwater forms *Valvata* sp. and *Lymnaea* sp.

The composition and the degree of the evolutionary level of this vertebrate fauna allow its comparison with the early Villafrachian, early Villanyan, and zone MN16a of the European Mammal Biochronological Scale (Hilgen et al., 2012) and the so-called warm period of the middle of the Late Pliocene in a range of 3.3–3.0 Ma. The composition of fauna indicates the predominance of closed forest biotopes and near-water stations, whereas the presence of relics of giant salamanders probably additionally indicates a very warm climate period of the Pliocene climatic optimum. The reversed to normal change in magnetic polarity sign in a bone-bearing bed of clayey silts of the Belorechensk section allows the suggestion of their correlation with magnetochrons 2An.2r (Mammoth) and 2An.2n, the boundary between which is dated at 3.207 Ma (Ogg, 2012). At the same time, this paleomagnetic dating makes fauna younger than the known isotopic-oxygen event M2 (3.312–3.264 Ma), which marks a short intense global glaciation (Tan et al., 2017) and extinction of thermophile elements of the Neogene fauna, which allows us to consider a scenario of dating of the Belorechensk thermophile fauna older than 3.3 Ma.

Numerous searches for mammal fauna, as well as multiple washing of bones of small vertebrates, yielded no results in sections upstream of the river, where member 2 is exposed. Single unidentified bones and caps of terrestrial mollusks *Pomatias* sp. were collected at this level only in the Krugozor section. Similar occurrence on a limited area in the Belorechensk and Pshekha sections is explained by removal of vertebrate remains by the pra-Belaya and pra-Pshekha rivers and their accumulation in river deltas, which is supported by the deltaic character of pebble conglomerates described

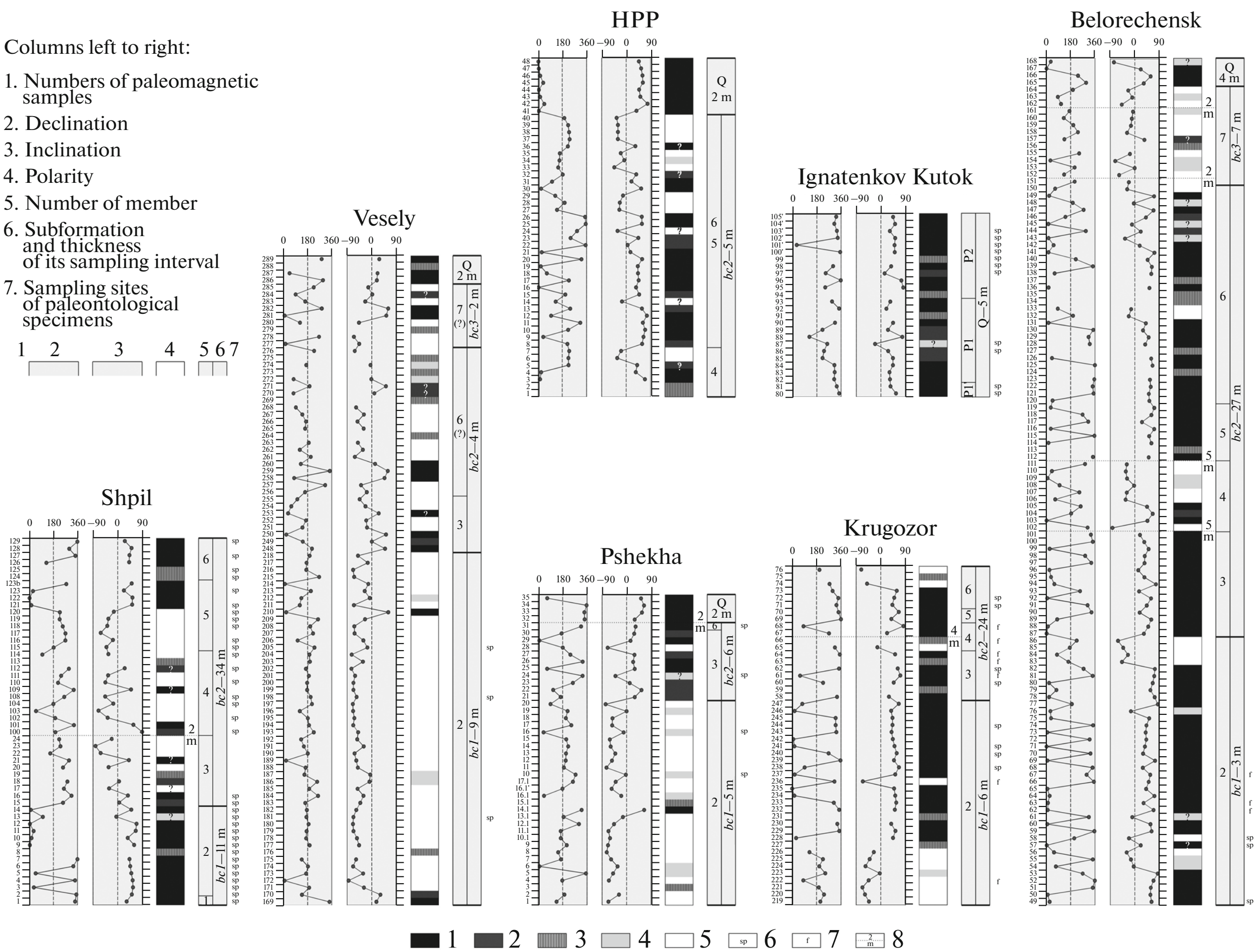

Fig. 8. Paleomagnetic characteristics of the studied sections of the Belorechensk Formation. (1–5) Results of determination of magnetization of paleomagnetic samples: (1) reliable normal polarity; (2) possible normal polarity; (3) undetermined polarity; (4) possible reversed polarity; (5) reliable reversed polarity; (6) places of sampling for spore–pollen specimens; (7) faunistic samples; (8) sampling gaps with indicated thickness of the missing interval of the section. The height of the columns is proportional to the amount of samples and does not correspond to the real thickness of the sections. The Ignatenkov Kutok section was studied only in the upper part.

in the upper part of member 2, as well as member 3 in these sections. The taphonomic signatures show the burial of intact corpses or parts of animal skeletons. We suggest that they were transported by large paleorivers to their mouths, where they accumulated in near-deltaic limans. The presence of freshwater fishes (tench cf. *Tinca*, roach *Rutilus* sp., catfish *Silurus* sp., and pike *Esox* sp.; determinations by S.V. Kurshakov) and freshwater stagnophile mollusks in an assemblage with oxidized plant relics indicates the presence of a stagnant water basin.

The deposits of the Lower Belorechensk Subformation (member 2) are characterized by the predominance of normal polarity in the Shpil', Krugozor, and Belorechensk sections and the presence of one or two intervals of reversed polarity in the Vesely, Pshekha, Krugozor, and Belorechensk sections (Figs. 5, 8). The faunistic assemblage corresponds to the epoch of the Pliocene climate optimum with a warm dry climate, which can explain the higher carbonatization of the main part of the section of the subformation. All given data allow dating of the Lower Belorechensk Subformation in a range of 3.5–3.0 Ma (the most part of the Gauss Epoch with Kaena and/or Mammoth episodes, i.e., chron C2An).

The Middle Belorechensk Subformation (N_2^2–Q_E*bc2*)

In much the same way as the Lower Belorechensk Subformation, this subformation includes alluvial facies of obliquely bedded sands, gravelites, and pebble conglomerates in the lower part of the combined section of the subformation (members 3 and 4) and lacustrine facies of clays, silts, and fine-grained sands in the upper part (members 5 and 6).

The alluvial deposits of member 3 normally magnetized in the lower part of all sections are characterized by reversed polarity in the upper part (Shpil',

Fig. 9. HPP II section, deposits of the Middle Belorechensk Subformation (N_2^2–Q_E*bc2*): lenticular intercalation of alluvial pebblestone and lacustrine–deltaic clayey facies.

Vesely, and Pshekha sections) (Figs. 5 and 8). Taking into account the biostratigraphic characteristics of the Lower Belorechensk Subformation, this gives us grounds to recognize the Gauss–Matuyama boundary within this member and ascribe it to the upper part of chron C2An–the lower part of chron C2r. The alluvial deposits of member 4, which occur in the Shpil', Krugozor, and Belorechensk sections and are eroded in the Vesely and Pshekha sections, preserve mostly reversed magnetization with a short zone of normal polarity, which we associate with the Reunion episode.

The lacustrine deposits of members 5 and 6 are abundant in all studied sections and are mostly divided lithologically: member 5 has a clayey composition and striking carbonatization in contrast to clays, silts, and sands of member 6 (Fig. 7). The deposits of member 5 have reversed and normal magnetization in the lower and upper parts, respectively. Stable normal magnetization of member 6 changes to reversed in its upper part (Vesely, Krugozor, Belorechensk, and HPP sections) (Fig. 9).

The faunistic relics of the Pshekha and HPP sections include the bones of southern elephants *Archidiskodon meridionalis meridionalis* (Nesti, 1825), horses *Equus* sp., rhinoceroses *Stephanorhinus* cf. *hundsheimensis* Toula, 1902, deer *Arvernoceros* sp., hyenas (coprolites), beavers *Trogontherium* cf. *cuvieri* Fischer, 1809, and water turtles (*Emys* sp.). The vertebrate fauna belongs to the Psekups faunistic assemblage (2.1–1.6 Ma, Gelasian–Calabrian). The burial found in the area of the village of Verkhnevedeneevsky (point 10 in Fig. 2, HPP section) includes mostly animals which preferred feeding on woody and bush vegetation. The lithological peculiarities of host deposits, the relics of freshwater swamp turtles, and leaf–branch plant relics indicate the presence of a community in forested coastal biotope. The Psekups assemblage of fauna was generally characterized by savanna-like landscapes.

These data suggest that the deposits of members 5 and 6 belong to the upper part of the lower Matuyama, the Olduvai episode, and the lower part of the upper Matuyama (the upper part of chron C2r–the lower part of C1r). The lower part of the Matuyama epoch also includes the most part of the bottom of the Ignatenkov Kutok section in the valley of the Psekups River (Fig. 10), which is a typical locality of the Psekups faunistic assemblage (Vangengeim et al., 1990).

The Upper Belorechensk Subformation ($Q_E$bc3, Member 7)

The subformation is developed in the Krugozor and Belorechensk sections and, probably, in the Vesely section. It mostly includes medium-sized pebblestones with interlayers and lenses of sands, which occur with erosion on deposits of member 6. The deposits of member 7 in the Belorechensk section have reversed magnetization, which allows us to associate it with the upper supra-Olduvai part of the Matuyama epoch (the lower part of C1r) in a general stratigraphic context. The presence of coarser molasses and the absence of lacustrine deposits of a significant thickness in this subformation indicate that it accumulated as a result of increasing slopes and energy of rivers due to activation of orogenic uplifts of drainage divides.

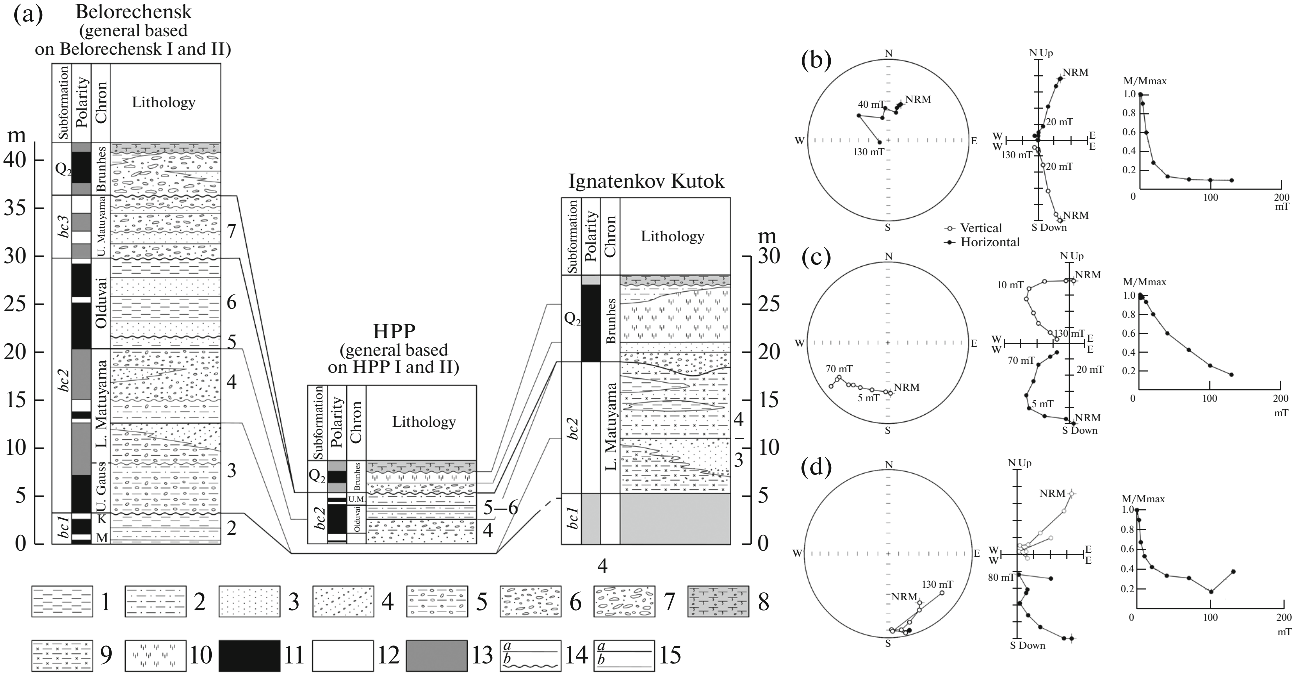

Fig. 10. (a) Schematic correlation of the Belorechensk and HPP sections of the Belorechensk Formation within the Adygean Ledge and Ignatenkov Kutok section within the Western Kuban Foredeep (valley of the Psekups River); (b–d) results of magnetic cleaning by alternating field: (b) Sample 234, Krugozor section, Lower Belorechensk Subformation; (c) Sample 39, HPP section, Middle Belorechensk Subformation; (d) Sample 161, Belorechensk section, Upper Belorechensk Subformation. (1) Clay; (2) silt; (3) sand; (4) sand with gravel; (5) pebble conglomerate; (6) pebblestone; (7) pebblestone–boulder stone; (8) present-day soils on pebblestone and loess loamy sand; (9) sandy clay; (10) loamy sand; (11) normal polarity; (12) reversed polarity; (13) sampling gaps; (14) boundaries of beds: (*a*) conformable occurrence; (*b*) erosion unconformities; (15) correlation curves: (a) between subformations; (b) additional. The Ignatenkov Kutok section (valley of the Psekups River) was studied only in the upper part. The column of the lower part of the section is composed after (Vangengeim et al., 1990).

The Middle Pleistocene Deposits

No paleontological relics were found in these deposits, however, rare sandy and clayey lenses of the Vesely, Pshekha, Belorechensk, and Ignatenkov Kutok sections yielded paleomagnetic samples. Their normal polarity in combination with a stratigraphic position of the sequence and its general appearance allows us to ascribe it to the Brunhes epoch and consider it a frontal apron, which formed during one of the Middle Pleistocene deglaciation stages. The age of these cover pebblestones is also proved by the findings of Acheulean tools in the upper normally magnetized part of the Ignatenkov Kutok section (Shchelinsky et al., 2021). Note that the sequences of the cover pebblestones, which crown all described sections, as well as the deposits of the Upper Belorechensk Subformation, are promising for searching of the Acheulean sites, because they could have been a source of material for stone tools and were located during that time close to the water level of Western Caucasus paleorivers.

The pebblestones of the HPP section are overlain by a member of brown platy loess loamy sands 1.5–2.0 m thick (Fig. 9). The deposits have normal magnetization and belong to the Brunhes epoch. The same sequence is described in the upper parts of other sections of the region (Korsakov et al., 2013). In particular, the subaerial aeolian-talus deposits up to 50 m thick are located in the section of the middle reaches of the Kuban River between the Neopleistocene deposits and the Belorechensk Formation. Beluzhenko (2006, 2011) ascribed these deposits to the upper part of the Apsheronian (Calabrian)–the lower part of the Neopleistocene and named them the Temizhbek Formation. They are probably locally overlapped with the Upper Belorechensk Subformation in age.

DISCUSSION

Geochronology of the Upper Molasse Belorechensk Formation of Western Ciscaucasia

All above data indicate the lower boundary of the Belorechensk Formation near the lower boundary of the Gauss epoch (3.59 Ma). We date this boundary at 3.5 Ma. The Lower Belorechensk Subformation spans the most part of the Gauss epoch with Kayena and Mammoth episodes, i.e., two-thirds of C2An chron. We refer the episode of the accumulation of pebble alluvium of member 1 to the stage of erosion of the Kimmerian uplifts of the Western Caucasus. Their significant scale is evident from the presence of rocks of the crystalline basement of the mountain system in structure of pebblestones, which were absent in the underlying molasses.

The upper boundary of the subformation is substantiated by the following. First, biodiversity, which is described in lacustrine deposits of the upper part of member 2, is strongly reduced above the Mammoth episode, which supports the supposed evolution of the described faunistic assemblage before the isotopic-oxygen event M2 (3.312–3.264 Ma). Second, one more reversed magnetized episode within normally magnetized deposits of the Lower Belorechensk Subformation is recognized below the faunistic beds of member 2. We correlate it with the Kaena episode. In the Krugozor section, this episode is capped by ~3 m of normally magnetized sandy–clayey deposits (Fig. 5, the upper part of member 2), which are ascribed to the upper part of the Gauss epoch. Therefore, we put the upper age boundary of the Lower Belorechensk Subformation inside 3 Ma (Fig. 11).

The age characteristics, fine-clastic deposits of the 21-m-thick member 2, consistent thickness and parallel character of its beds, broad area occurrence (hundreds of square kilometers) beyond any prominent depression, the presence of deltaic series, and the faunistic data indicate that its deposits formed in a large shallow stagnant basin with an unstable coastal line and mostly arid sedimentation type. The mouths of the Caucasian paleovalleys opened here. It is likely that the basin was similar to the present-day Kiziltash or Vityazevo limans of the Taman Peninsula. The deposits of the Lower Belorechensk Subformation have early Kuyalnikian (Gelasian) age. In the area of the villages of Saratovskaya and Bikinskaya (basin of the Psekups River, point 12, Fig. 2), 45–50 km west of the valley of the Belaya River, the age-related analog of the subformation includes typical marine deposits of the Kuyalnik basin (Kuyalnik Regional Stage of the Black Sea Neogene Scale, according to (Nevesskaya et al., 2004) characterized by malacofauna. Here in the axial zone of the Western Kuban Foredeep, their top is described in boreholes at a depth of 150 m and their thickness attains 200–300 m (*Geologiya*..., 1968; *Stratigrafiya*..., 1986). All data allow us to consider that the deposits of the main part of the Lower Belorechensk Subformation (member 2) have liman-deltaic origin and accumulated within the coastal accumulative lowland with numerous deltas of meandering rivers, which is similar to the present-day Kuban–Azov lowland and which underwent periodic ingressions of the brackish water early Kuyalnik basin. The cessation of cutting and the accumulative regime of the evolution of the lowland during the accumulation of deposits of member 2 is explained by the reduction of erosion ability of rivers due to a significant uplift of erosion basis during transgression. Over the past 3 mln years, this lowland, against the background of ongoing accumulation, was uplifted by only 100–200 m to present-day altitudes, which indicates the continuing development of the Western Kuban Foredeep.

The data above indicate that the lower boundary of the Middle Belorechensk Subformation conditionally corresponds to 2.9 Ma. It is taken into account that the deposits of member 3 span a significant part of the upper Gauss, but they ubiquitously occur on member 2 with erosion. The upper boundary of the subformation also conditionally follows the date of 1.6 Ma because its upper part (member 6) falls to the zone of reversed magnetization above the Olduvai episode but does not cover the Gilsa paleomagnetic episode (1.584 Ma). The age of the subformation is thus estimated in a range of 2.9–1.6 Ma (the upper part of the Gauss epoch, the lower part of the Mammoth episode with the Reunion episode, Olduvai episode, and the lower part of the top of the Matuyama epoch, i.e., the last 300 k.y. of chron C2An, chrons C2r and C2n, and the lower part of chron C1r).

The lacustrine deposits of member 5 and 6 of the Middle Belorechensk Subformation similar to above described deposits of member 2, as well as their age characteristics, indicate their accumulation during late Kuyalnik transgression. The predominance of lacustrine facies is related to the formation of a lacustrine–alluvial lowland on a flat territory of Western Ciscaucasia under conditions of a rising erosion basis of paleorivers of the Kuban basin. The formation of these deposits within the Adygean Ledge thus also occurred in lakes–limans within a low (close to sea level) accumulative flatland.

Dating of boundaries of the Upper Belorechensk Subformation is also conditional inside a range of 1.6–0.9 Ma (Gurian/Calabrian). The deposits of the subformation are typical pebble alluvium of mountain rivers, which formed at the final stage of cutting of the Western Kuban lacustrine–alluvium lowland of upper Kuyalnikian (Gelasian) age. The lower boundary of the subformation is justified by the reversed magnetization of sediments, obviously belonging to the upper part of the Matuyama epoch above the Olduvai episode and described as the upper part of the Middle Subformation. The upper part of the Upper Subformation in the section of the Vesely forms a striking paleovalley (Fig. 2) cut into the deposits of the Middle Belorechensk Subformation. The upper part of the section contains a striking episode of normal magnetization, above which we collected several reversely magnetized samples. This episode could be interpreted either as Jaramillo (1.071–0.990 Ma) or Cob Mountain (1.208–1.187 Ma). The first scenario is most likely owing to the larger duration and thus the higher possibility of finding.

We therefore estimate the age boundaries of the Belorechensk Formation at 3.5–0.9 Ma. It is the first and thickest chain of coarse molasses of the western part of the Ciscaucasian Foredeep, which formed as a result of increasing surface slope and energy of rivers owing to activation of orogenic uplifts.

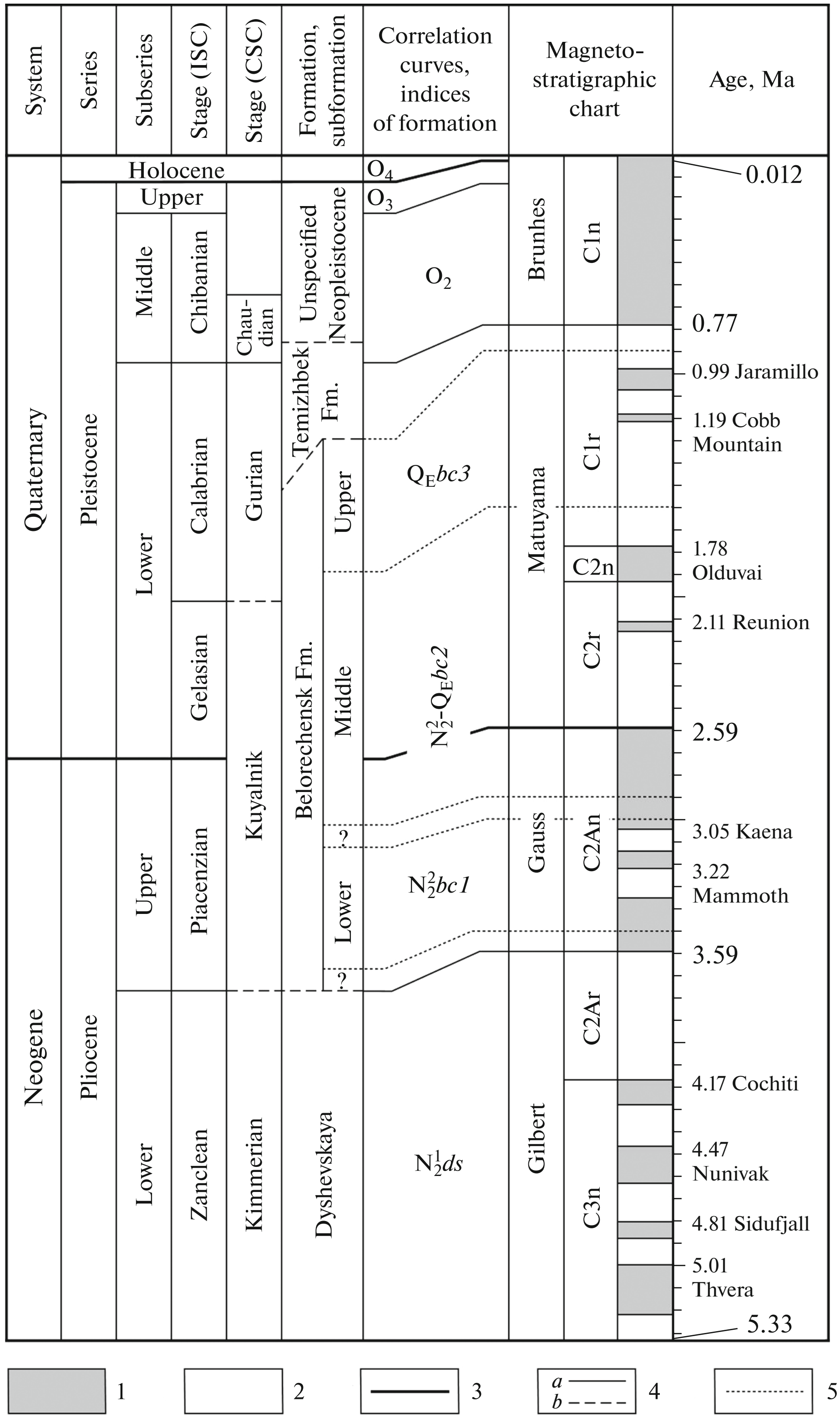

Fig. 11. Schematic correlation of the Pliocene–Quaternary deposits of the Western Kuban Foredeep and Adygean Ledge with the International Stratigraphic Chart (ISC), Common Stratigraphic Chart (CSC), and magnetostratigraphic chart. (1) Normal polarity; (2) reversed polarity; (3) boundaries of series; (4) boundaries of subseries, stages, and formations: (*a*) proven; (*b*) inferred; (5) boundaries of subformations.

Molasse Deposits and Tectonic Activity of the Caucasus

The time of the beginning of the formation of the Caucasus Island described in many paleoreconstructions (Milanovsky, 1968; Safronov, 1972; Beluzhenko, 2006; Popov et al., 2010) is a matter of debate. Our studies show that Western and probably Central Caucasus landmass (as a provenance of clastic material) already existed in the Middle Miocene. In the middle and late Sarmatian, the Caucasus Island included only the Central, Western, and Northwestern Caucasus. This is evident, first, from the findings of the representatives of on-land malacofauna (Steklov, 1966) and the leaf flora imprints in the Middle and Late Miocene deposits of Western Ciscaucasia (Korsakov et al., 2013); second, from the occurrence of pebble and, locally, boulder conglomerates in the Western and Eastern Kuban foredeeps; and third, from the absence of Sarmatian marine deposits in both the axial zone and within the flanks of these segments of the mountain system. In the Eastern and Southeastern Caucasus, the upper Sarmatian marine deposits are described in the axial zone at elevations of up to 3600 m (Budagov, 1973; Trikhunkov et al., 2021).

The character of coarse-clastic deposits, their composition, and sporadic occurrence in the sedimentary section of the foredeep indicate the absence of high or even middle mountains, which could serve as a permanent source of coarse molasses over the Miocene and Kimmerian (Zanclean). They include only basal conglomerates, which are composed of clasts of exclusively sedimentary rocks eroded close to their deposition area. Even rather thick (up to 10 m) upper Sarmatian coarse-pebble sequences in the eastern part of the Eastern Kuban Foredeep at the boundary with Stavropol Arch include only fragments of sedimentary rocks. It is likely that the latter are indicators of late Sarmatian pulse of collision and orogenesis, which is described by many authors (Milanovsky et al., 1968; Khain et al., 2006; *Tektonika*..., 2009; Kangarli et al., 2018) and related to enhanced press of the Arabian indenter on the entire Arabian–Caucasus region. We think, however, that this pulse did not lead to the formation of highlands with dissected relief. If we suppose the alluvial genesis of basal conglomerates, then their composition indicates that the crystalline basement of the Caucasus Orogen was exposed even in the Central Caucasus during that period, which argues for the absence of the dissected high-mountainous relief within the Caucasus Island.

The presence of large pebbles, as well as boulders, which could have come only from the hitherto low-mountain Northwestern Caucasus and were composed only of sedimentary rocks, in the Mid-Late Miocene basal conglomerates of the Western Kuban Foredeep casts doubt on their alluvial genesis. First, the typical sandy–pebble alluvial facies of the Upper Belorechensk Subformation and the Middle Pleistocene pebblestones, which were formed already during the reliable presence of high-mountainous areas, include only medium and less commonly coarse pebble. Second, the latter have polymictic composition, which indicates a wide area and strong erosion of their sources upon strongly divided mountainous relief. The facies of the Middle–Upper Miocene coarse-clastic deposits in structure of marine formations of the Eastern Kuban and Western Kuban foredeeps mostly consist of basal conglomerates, which accumulated close to the coastlines of shallow seas. They are initial elements of transgressive series of deposits registering the change of the denudation evolution stages of the Caucasus Island by stable sedimentation during transgression epochs. The pebble and, locally, boulder size of these deposits, as well as the concentration in frontal basins and the absence in the northernmost regions of the Scythian Plate (*Geologiya*..., 1968), exclude their transportation from the Russian Plate. It is impossible, however, to imagine the presence of a river with high erosion ability within the relatively small and lowland Caucasus Island that could be sufficient to transport large pebble and boulders for tens and hundreds of kilometers, even if the present-day rivers of the region deliver no boulders to the frontal basins. All these facts (pebble and even boulder dimension of molasses and the presence of clasts of exclusively sedimentary rocks) force us to exclude their distant transportation by rivers and to consider that the basal conglomerates of the lower molasses of the Western Kuban Foredeep, Adygean Ledge, and Eastern Kuban Foredeep have abrasion origin. The first formation of typical subcontinental deposits (Gaverdovsky) consists only of sandy–clayey fractions of alluvium of the pra-Belaya and pra-Pshekha rivers (Beluzhenko, 2006). All facts indicate that the Caucasus Island was characterized by flatland or, at least, lowland relief up to the Kimmerian (Zanclean) epoch.

During the Kimmerian, the territory of the Eastern Kuban Foredeep and Adygean Ledge underwent inversion of the tectonic regime and was involved in the uplifts of the Western Caucasus homocline. This is evident from the hiatus and a significant angular unconformity between the deposits of the Gaverdosky and Belorechensk formations. The change in lithologic-petrographic composition of pebble indicates the exposure of the crystalline basement of Western Caucasus in Kimmerian time. The segments of the foredeep, which were divided by transverse faults, were uplifted stage-by-stage. In particular, the Pshekha Block of the Adygean Ledge in the Pshekha–Belaya interfluve underwent inversion of its evolution later (only in the Calabrian) (Fig. 2). The strike-slip displacements along the transverse faults of the Pshekha–Adler Zone, which divided the Western and Northwestern Caucasus and contour the Adygean Ledge, were replaced by vertical movements.

The Kimmerian uplifts are also described in other parts of the orogen and are mostly suggested from strongly coarse molasses. As shown by (Trikhunkov et al., 2021), however, the appearance of the Kimmerian coarse molasses (the continental analogs of a productive sequence in Eastern Ciscaucasia and the Kusar–Divichi Foredeep) are first of all a result of increasing river energy at a sharp drop of erosion basis during the Balakhanian regression of the Caspian to –750 m (Svitoch, 2014) rather than the uplifts of the orogen. In contrast to the Caspian, the Black Sea erosion basis was unaffected by strong and deep submergence over the Pliocene (Nevesskaya et al., 2004; Svitoch, 2014). In particular, the Kimmerian marine deposits occur in the Western Kuban Foredeep in the basins of the Psekups, Pshish, and even Pshekha rivers (Fig. 2). It can therefore be stated that the deposits of the Belorechensk Formation accumulated as a result of increasing surface slope and river energy owing to activation of orogenic uplifts. We cannot judge, however, a significant amplitude of the Kimmerian uplifts also in the Western Caucasus, because the related increase in river energy became insignificant. In fact, only the thin member 1 of the Lower Belorechensk Subformation with small-sized pebblestones, gravel, and sands is a result of erosion of orogenic structures of that period. The subcontinental overlying deposits of the Lower and Middle Belorechensk subformations with fine-clastic liman–deltaic deposits of members 2, 5, and 6 indicate extremely weak energy of the pra-Laba, pra-Belaya, and pra-Pshekha rivers. Their valleys were poorly developed and rivers were meandering (Safronov, 1957). It is obvious that this partly affected the uplift of the erosion basis during Kuyalnik transgression. Generally, these facts indicate that the Kimmerian and further uplifts of the Western Caucasus and especially the Northwestern Caucasus were insignificant and were compensated by the denudation up to the beginning of the Calabrian.

Starved orogenic uplifts of Western Caucasus began only in the Gurian (Calabrian). They resulted in the formation of mostly medium-sized pebblestones of the Upper Belorechensk Subformation. In contrast to the underlying lacustrine deposits, which are abundant on vast areas, they represent typical alluvium of mountain rivers and occur in the upper part of the basement of the Belaya River upper terraces. This indicates the intensification of river energy as a result of accelerating uplifts and the beginning of the formation of shallow valleys.

The uplifts intensified in the Middle Pleistocene, which led to the formation of cover pebble–boulder stones, which occur in all studied sections of the territory of the Adygean Ledge and Western Kuban Foredeep. They form an accumulative cover of high terraces of the Belaya, Pshekha, Pshish, and Psekups rivers. The normal polarity, as well as the exterior of the Acheulian tools (Shchelinsky et al., 2021), forces us to ascribe them to the Bakinian time or later stages of the Middle Pleistocene. These deposits overlie with erosion unconformity the various elements of the combined section of the Belorechensk Formation and, in addition to the dimensions, they have an oxidized brown color (Fig. 7). It is likely that they are fluvioglacial and were delivered to the foredeep by strong rivers, the energy of which additionally intensified during deglaciation epochs in conditions of orogenic uplifts. The present-day river valleys of the region already originated in these pebble–boulder sequences in the Middle–Late Pleistocene (Fig. 2).

The deposits of the Upper Belorechensk Subformation and the Middle Pleistocene boulder–pebble sequence are similar to the molasses of the frontal aprons of the Eastern and Southeastern Caucasus (Milanovsky, 1968; Trikhunkov et al., 2021). Successive enlargement of their granulometric composition occurred during the acceleration of orogenic movements.

The main part of the Western Kuban Foredeep, which adjoins the Northwestern Caucasus, was unaffected by orogenic processes and has evolved as a foredeep to this day. This is likely related to the fact that Northwestern Caucasus adjacent to the foredeep underwent no significant newest ascending movements in contrast to the Western Caucasus. Within the Western Kuban Foredeep, no Gurian coarse molasses are observed in the Ignatenkov Kutok section (Fig. 10). The small- to medium-sized pebblestones appear only in the Middle Pleistocene. The section is located in the valley of the Psekups River in a similar geomorphological position and at an equal distance from frontal parts of the orogen with the Krugozor or Belorechensk sections. The sources of the Psekups River flow from the drainage divides of the Northwestern Caucasus, which are no higher than 1 km now (Mt. Agoy of 994 m). Taking into account the general orogenic trends of the region, the uplifts of the Northwestern Caucasus during the formation of pebblestones could not have been higher than a half of a kilometer. The energy of water streams flowing from the hills of the Northwestern Caucasus was thus sufficient for the formation of small- to medium-sized fractions of upper molasses. Under the assumption that the climate and thus the rate of erosion at the Northwestern and Western Caucasus are similar now and could not have been different in past, it can be concluded that the axial zone of Western Caucasus in the upper reaches of the Belaya River before the formation of the alluvial pebblestones in the basement of the Belorechensk Formation was low-mountainous, not exceeding 500–1000 m at the Kimmerian–Kuyalnikian boundary.

Collision deformations have continued to this day. The predominance of longitudinal compression within the orogen is ubiquitous (Marinin and Rastsvetaev, 2008). In particular, we described numerous active fold and fault deformations in both the axial zone of the Western and Northwestern Caucasus and the zone of the Taman Pericline (Trikhunkov, 2016; Trikhunkov et al., 2018, 2019a, 2019b). The amplitude of the uplifts of these segments of the Great Caucasus, which started synchronously in the Middle Miocene, however, differs now by at least a factor of two. Taking into consideration similar climate conditions and the rate of denudation, the minimum difference in the value of uplifts of the Western and Northwestern Caucasus over the last 3.6 mln years from the beginning of the accumulation of coarse molasses is 2200–2300 m (ignoring the erosion). Only collision therefore cannot explain the origin of the uplifts. The evolution of linear folding of the Northwestern Caucasus led only to the formation of its low- to medium-mountainous relief. Collision of the Western Caucasus started earlier, was more intense, and has now been replaced by mostly late-collision uplifts, the nature of which is described in detail by Trifonov et al. (2012). Exactly this can explain the attenuation of the activity of strike-slip displacements along the faults of the Pshekha–Adler Zone and their change by vertical movements.

New Issues of the Pliocene–Quaternary Dynamics of Climate and Landscapes of Ciscaucasia

The climate and landscapes of the time of sedimentation of the Belorechensk Formation in the Late Pliocene and Early Pleistocene are interpreted on the basis of biotic and, partly, geochemical data. The palynological spectrum of samples from the lower part of the Lower Belorechensk Subformation (3.5–3.0 Ma) at the contact of members 1 and 2 shows the predominance of coniferous forests and reflects a cool and wet climate, which was typical of the Western Caucasus in the Kimmerian–the beginning of the Kuyalnikian to the Pliocene climate optimum. This, in turn, explains the absence of carbonate cement in this horizon of the subformation. Mesophytic communities corresponding to the Late Pliocene optimal climate conditions were dominant in the region during the accumulation of the main liman–deltaic part of the subformation (member 2). This is evident from rich and diverse vertebrate fauna with Neogene thermophile forms and the predominance of animals that inhabited the forest and subaquatic biotopes. It is possible that warming and some aridization upsection in the sequence of lacustrine–liman clayey–silty deposits of member 2 are responsible for the increasing carbonate content of deposits.

The lacustrine–alluvial Middle Belorechensk Subformation of the Early Pleistocene mostly accumulated in warm semiarid conditions, which is evident from the higher carbonate content of its main volume up to member 6. It can be suggested that the carbonatization is secondary and is related to the gain of calcium carbonate from pebble sequences with clasts of limestones, dolomites, and marls, which are plentiful in both the Laba–Malka Zone and the axial zone of the Western and Northwestern Caucasus in the upper reaches of the valley of the Belaya River. The pebblestones of similar lithological–petrographic composition, however, are contained in higher horizons of the subformation (member 6), as well as in the Upper Belorechensk Subformation totally devoid of carbonate cementation. We therefore consider that the carbonatization is primarily related to arid sedimentogenesis of this epoch. These conclusions are confirmed by the presence of animals of the Early Pleistocene Psekups assemblage of Eastern Europe, which includes inhabitants of open and semi-open biotopes of savanna-like landscapes such as the southern elephant *Archidiskodon meridionalis meridionalis*, in the HPP section. The strong change in the composition of the deposits, including the degree of carbonization at the boundary of the formation of members 5 and 6 (Fig. 7), can indicate the climate change toward cooling, humidification, or both.

The Upper Belorechensk Subformation (Gurian/Calabrian), as well as overlying coarse carbonate-free deposits, accumulated during the colder period of the upper part of the Lower Pleistocene–Middle Pleistocene. These molasse sequences formed at the beginning of the origination of wide valleys of current rivers during strong intensification of their erosion compared to active uplift of the Western Caucasus. The orogenic uplifts could have been one of the main factors of the climate change in Ciscaucasia, complicating the advection of tropical air masses from Transcaucasia.

CONCLUSIONS

(1) The Belorechensk Formation is dated at 3.5–0.9 Ma and is the first and the thickest element of coarse molasses of the western part of the Ciscaucasian Foredeep, which formed as a result of increasing surface slope and energy of rivers owing to activation of orogenic uplifts. The formation is divided into the Lower, Middle, and Upper Belorechensk subformations, which correspond to erosion-accumulative cycles of accumulation of molasses. The lower and middle subformations are transitional from the lower to upper molasses and include subcontinental mostly carbonatized sandy–clayey deposits of the basin, which are related to the erosion basis of the Kuyalnik sea–lake, with the presence of the alluvial–deltaic pebblestones and sands of the Caucasus paleorivers and are dated at 3.5–3.0 and 2.9–1.6 Ma, respectively. The Upper Belorechensk Subformation consists of pebble alluvial deposits without carbonate cementation, which are typical of the upper molasse. It formed at the beginning of the origination of wide valleys of current rivers during intensification of their erosion effect against the background of the active uplift of the Western Caucasus in the Gurian (Calabrian).

(2) The subformations of the Belorechensk Formation successively acquire all the more coarse-clastic character, indicating the acceleration of uplifts of the Western Caucasus. Their maximum intensity is observed in the Calabrian and, later, in the Middle Pleistocene. This is reflected in the coarse character of

the deposits of the Upper Belorechensk Subformation, as well as in the involvement of the territory of the Adygean Ledge in uplifts of that epoch and the formation of primary dissected relief. No similar acceleration of the uplifts is observed in the basin of the Psekups River: the Early Pleistocene deposits here include sandy–clayey fractions, the Middle Pleistocene ones are small- to medium-pebble, and the Western Kuban Foredeep is unaffected by the newest uplifts, has lowland undissected relief, and evolves as a zone of molasse accumulation.

(3) The minimum averaged rate of uplifts of Western Caucasus in the basin of the Belaya River (Mt. Chugush, 3228 m) is 0.8 mm/year over last 4 mln years From the beginning of uncompensated uplifts in the Calabrian (~1.6 Ma), however, it increased to 1.7 mm/year. These values are significantly underestimated, because the calculations ignore the volume of eroded material, whereas the rate of erosion in the wet climate of the Western Caucasus significantly exceeds that of more eastern segments of the orogen. The minimum estimated rate of the Northwestern Caucasus uplifts in the valley of the Psekups River (Mt. Agoy, 994 m) is 0.64 mm/year over last 780000 years from the beginning of the Middle Pleistocene. Taking into account similar climatic conditions and the rate of denudation within the Western and Northwestern Caucasus, the minimum difference in the newest uplifts is 2200–2300 m (ignoring erosion). The lithofacies analysis and the age of the deposits of the Belorechensk Formation allow us to state that this difference accumulated mostly from the beginning of the Calabrian.

(4) The newest uplifts of Western Caucasus began no later than the Chokrakian (Langhian) with the acceleration in the late Sarmatian (Tortonian) and Kimmerian (Zanclean). The uplifts were concentrated in the axial zone of the orogen, not exceeding the flatland–lowland values. The northern flank and frontal foredeeps were located at low elevations and were repeatedly flooded by seas up to the Kuyalnikian inclusive. The Calabrian–Middle Pleistocene acceleration of orogenic uplifts of the Western Caucasus at 8 Ma lags the Sarmatian peak of maximum compression and collision. Deformations of that epoch led only to the formation of lowlands similar to those of the Northwestern Caucasus. The uplift of the Western Caucasus by 2500–2800 m over 1.7 mln years was mainly initiated by a general uplift of the Caucasus Orogen rather than by differentiated fold-fault movements. Collision of the Western Caucasus began prior to that of the Northwestern Caucasus, was more intense, and has now been replaced by mostly late collision uplifts. Exactly this can explain the Pliocene–Quaternary attenuation of strike-slip displacements along the faults of the Pshekha–Adler Zone and their change by vertical movements. The Northwestern Caucasus, which is divided by this fault zone, is still at the collision stage of the evolution and, in spite of the formation of linear folding, has mostly lowland topography.

(5) The climate and landscapes of the sedimentation period of the Belorechensk Formation in the Late Pliocene and Early Pleistocene are interpreted from biotic data. The Lower Belorechensk Subformation accumulated in lacustrine–alluvial reservoirs, the coasts of which were covered by forests of the Late Pliocene optimal phase. The forest-steppe stations are interpreted for the Early Pleistocene Middle Belorechensk Subformation. The Upper Belorechensk Subformation, as well as the overlying coarse carbonate-free deposits, accumulated during the colder period of the end of the Early, Middle, and Late Pleistocene. The orogenic uplifts could have been one of the main factors of climate change in Ciscaucasia, complicating the advection of tropical air masses from Transcaucasia.

ACKNOWLEDGMENTS

We are grateful to V.G. Trifonov (Geological Institute, Russian Academy of Sciences, Moscow, Russia) for valuable consultations, help in organization of field works, and preparation of the manuscript. We also thank the participants of field and laboratory studies S.V. Kurshakov, M.V. Sotnikova, M.A. Vasil'eva, I.A. Nadutkin, L.N. Gavrilov, A.Kh. Medvedev, and A.G. Panasyuk.

FUNDING

Remote geological–geomorphological and magnetostratigraphic studies were supported by state contracts of the Geological Institute, Russian Academy of Sciences (Moscow, Russia), no. FMMG-2023-0006, and the Schmidt Institute of Physics of Earth, Russian Academy of Sciences (Moscow, Russia), respectively. The field works, paleontological, and stratigraphic studies and the preparation of the manuscript were supported by the Russian Science Foundation, project no. 22-17-00249, “Pliocene–Early Pleistocene Reconstruction of Structure of the Aravian–Caucasus Region and Its Influence on Paleogeographical Conditions, Dynamics of Biota, and Moving Environment of Ancient Man.”

CONFLICT OF INTEREST

The authors of this work declare that they have no conflicts of interest.

Reviewers L.A. Golovina, M.G. Leonov, and V.G. Trifonov

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Translated by I. Melekestseva