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Pleistocene palaeoenvironments in the Lower Volga region (Russia): Insights from a comprehensive biostratigraphical study of the Seroglazovka locality

Andrey Zastrozhnov [a,*], Guzel Danukalova [b], Mikhail Golovachev [c], Eugenija Osipova [b], Ravil Kurmanov [b], Maria Zenina [g], Dmitry Zastrozhnov [a,d], Oleksandr Kovalchuk [h,i], Anatoly Yakovlev [b], Vadim Titov [e], Tatyana Yakovleva [f], Dmitry Gimranov [j]

[a] A.P. Karpinsky Russian Geological Research Institute (VSEGEI), St. Petersburg, Russian Federation
[b] Institute of Geology, Ufa Federal Research Centre, Russian Academy of Sciences (RAS), Ufa, Russian Federation
[c] Astrakhan Museum-Reserve, Astrakhan, Russian Federation
[d] Volcanic Basin Petroleum Research AS (VBPR), Oslo, Norway
[e] Southern Scientific Centre RAS, Rostov-on-Don, Russian Federation
[f] Bashkir State Pedagogical University n.a. M. Akmulla, Ufa, Russian Federation
[g] Shirshov Institute of Oceanology, RAS, Moscow, Russian Federation
[h] Department of Palaeontology, National Museum of Natural History, National Academy of Sciences of Ukraine, Kyiv, Ukraine
[i] Department of Palaeozoology, Institute of Environmental Biology, University of Wroclaw, Wroclaw, Poland
[j] Institute of Plant and Animal Ecology, Ural Branch, Ekaterinburg, Russian Federation

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ABSTRACT

There are many Middle-Upper Pleistocene outcrop sections in the Lower Volga region (Caspian Lowland, Russia) in between cities of Volgograd and Astrakhan. The present study focuses on the Seroglazovka locality, which is among the most famous key sites within the Lower Volga region. The Seroglazovka locality is of great regional interest, because of its clear exposure of genetically variable Middle and Upper Pleistocene deposits containing diverse complexes of fauna and flora. Even though the Seroglazovka locality was studied by many researchers, the diversity and along-strike variability of the depositional facies often makes the stratigraphic interpretation challenging. In this study, we performed an extensive and integrated study of the Seroglazovka locality including detailed outcrop mapping with lithological description, as well as diverse biostratigraphy analysis and OSL-dating. In addition to outcrop data, we used recently obtained borehole data near the Seroglazovka locality, which cover almost the entire Quaternary interval. This multidisciplinary approach permitted us to confidently stratify the Quaternary interval of the Seroglazovka locality into a series of regional horizons and subhorizons including the Akchagyl, Apsheron, Tyurkyan, Baku, Khazar and Khvalyn. Furthermore, we correlated the interpreted section to the adjacent parts of the Caspian Lowland and the Regional Stratigraphic Scale. Our results allowed us to determine the main Pleistocene palaeoenvironments and their evolution within the study area. Our findings are important to understand the processes, which led to the modern faunistic composition of the Lower Volga region, and to clarify the role of glacial refugia in the settlement of certain species and further colonization of water basins and land areas with habitable environments. Finally, we suggest the Seroglazovka locality as the key reference Pleistocene section for the Lower Volga region.

1. Introduction

Middle-Upper Pleistocene (Neopleistocene) deposits are widespread within the Lower Volga region (North Caspian Lowland, Russia) in between cities of Volgograd and Astrakhan. They are easily accessible and nicely exposed at the Volga riverside cliffs along ca. 350 km. The Lower Volga riverside outcrops record the Middle Pleistocene to Holocene development of the northern Caspian Sea, while extensive regional

* Corresponding author.
E-mail address: Andrey_Zastrozhnov@vsegei.ru (A. Zastrozhnov).

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borehole data enable to study the entire Quaternary interval.

This paper presents the results of a comprehensive study of the Seroglazovka locality, which is among the most well-known geological sites in the Lower Volga region. The locality is regionally significant due to clear exposure of the sedimentologically variable Middle to Upper Pleistocene deposits, which contain numerous and diverse fauna and flora remains. However, though previously well-studied by many researchers (Kroonenberg et al., 2005; Popov, 1983; Sedaikin et al., 1973; Sedaikin, 1988; Shkatova, 1974, 2010; Svitoch et al., 1995; Svitoch and Yanina, 1997; Svitoch and Makshaev, 2020; Vasiliev and Fedorov, 1965; Yanina, 2005), the stratigraphic interpretation of the Seroglazovka locality has remained ambiguous mainly due to the diversity and variability of depositional facies which are present there.

During several field seasons we were able to visit the Seroglazovka locality and study in detail the lower part of the riverside cliff, which was usually covered by slope detritus in previous years. In addition, we used an UAV (unmanned aerial vehicle) to build-up a detailed three-dimensional model of the whole outcrop. This approach allowed us to trace the main mappable units and constrain their inter-relationships not only locally, but along the entire length of the outcrop. In addition to outcrop data, we used recently obtained borehole data near the Seroglazovka locality, which allowed us to extend the studied stratigraphic interval for almost the entire Quaternary and enabled better understanding of sedimentary sequence of the adjacent outcrop section. We extensively examined biostratigraphy data including molluscs, which are traditionally used for the stratification of the Pleistocene of the

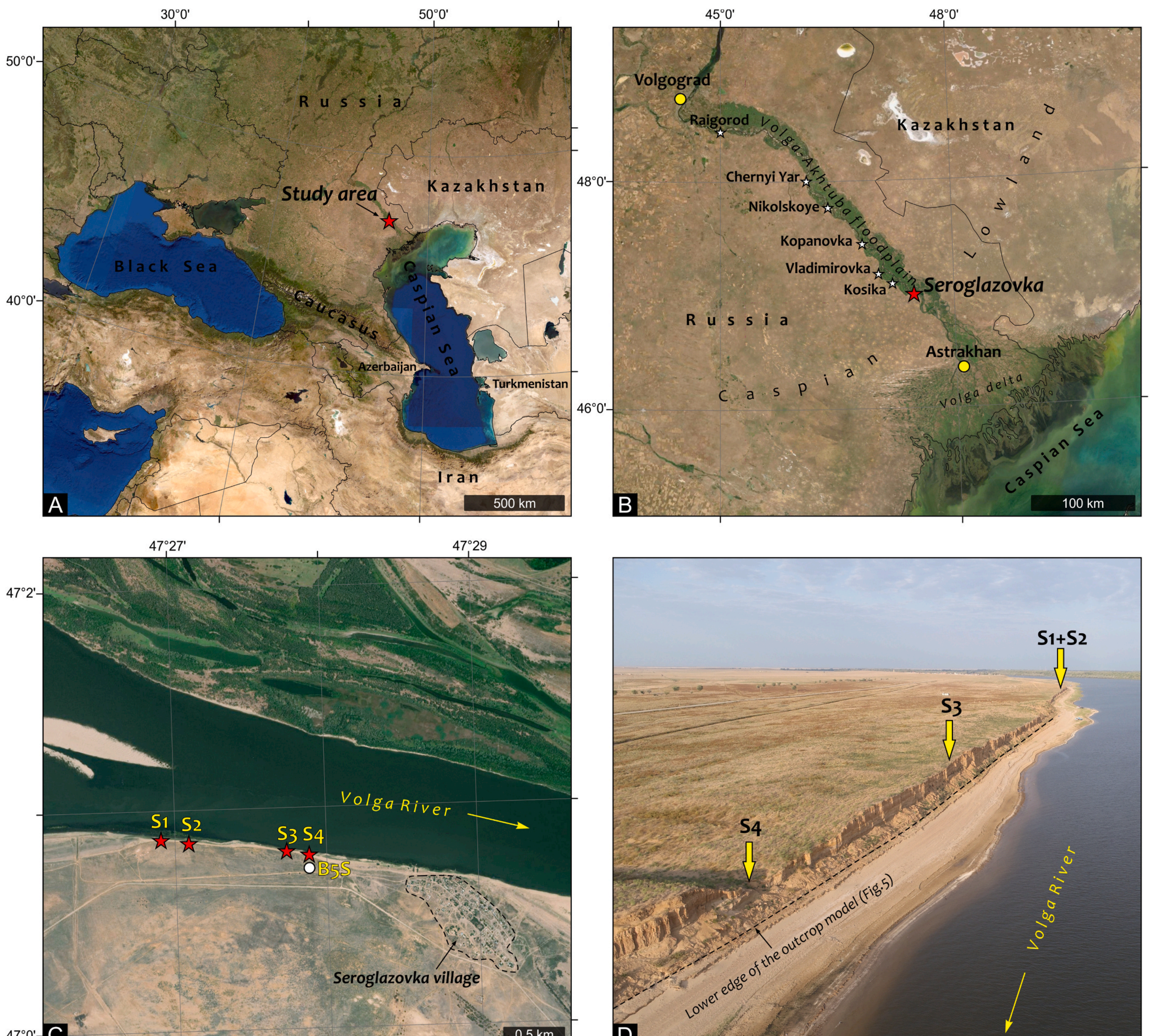


Fig. 1. (A) Regional setting of the study area within the Ponto-Caspian framework; (B) Regional setting of the study area within the Lower Volga region; (C) Detailed image showing the locations of the studied Seroglazovka outcrop sections (S1-4) and borehole (BS5). Image source: ArcGIS World Imagery (arcgis.com). State boundaries are from EUROSTAT (© EuroGeographics for the administrative boundaries). (D) Drone view of the Seroglazovka outcrop (as for September 2017) with main sections (S1-4) highlighted by thick yellow arrows. Direction of the river flow is indicated by a thin yellow arrow. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

Caspian Sea, as well as flora, large and small mammals, fishes, amphibians and reptiles. The main stratigraphic units were also dated using the optically stimulated luminescence method (OSL).

Our results allowed to stratify the Quaternary interval of the Seroglazovka section into a series of regional horizons and sub-horizons such as the Akchagyl, Apsheron, Tyurkyan, Baku, Khazar and Khvalyn. We were further able to determine main palaeoenvironments and their evolution within the study area and to compare our results with the adjacent Kosika section, which was recently studied by our research group (Zastrozhnov et al., 2020). Finally, we believe that our results provide a solid basis for considering the Seroglazovka locality as the reference section for the Pleistocene of the Lower Volga region.

2. Regional setting

The study area globally belongs to the Ponto-Caspian region and is located in the southeast of the East European Plain in the southwestern part of the Caspian Lowland (Fig. 1a-b). The Caspian Lowland adjoins to the northwestern coast of the Caspian Sea and represents a gently sloping plain, which is dominantly below global sea-level. The Seroglazovka locality is situated at the right bank of the Volga River near the village of Seroglazovka, ca. 90 km northwest of the city of Astrakhan (Fig. 1b-c), at an altitude of 24 m below global sea level.

Tectonically, the study area belongs to the southwestern part of the Caspian Depression (or Syncline), a large negative structure, the depth of the crystalline basement of which is more than 8–10 km in the area. The Caspian Depression shows a prolonged and complex basin development since the Late Proterozoic up to the Quaternary (e.g. Lavrishchev et al., 2011 and references therein).

During the Quaternary, the study area experienced multiple phases of transgression and regression of the Caspian Sea, where it was respectively connected and isolated from the Black Sea (e.g. Krijgsman et al., 2019; and references therein). Such a complex and periodic change in Quaternary depositional environments in the study area resulted in the accumulation of a thick pile of marine, fluvial and eolian sediments. The maximum thickness of Quaternary sediments in the Caspian Depression is up to 1000 m as documented by many exploration boreholes and can be even more in some local troughs. In the riverside cliffs of the Volga River a thickness of exposed Quaternary sediments usually does not exceed 25 m.

3. Material and methods

The studied material was obtained during field seasons in 2009–2019 within the frame of state mapping projects carried out by Russian Geological Research Institute (VSEGEI) in the Lower Volga region. Our work consisted in the study of the entire length of the Seroglazovka locality (ca. 1.5 km), which we divided into four most representative sections (Seroglazovka 1–4, or S1-4; Fig. 1c-d, Table 1), where the detailed lithological description and sampling of the main units were done. In addition, our study was accompanied by a drilling campaign in 2013 near the village of Seroglazovka, as a result of which we got 503 m of core material from a single borehole 5 Seroglazovka. 53 beds were defined and described for the borehole (Fig. 2), and 14 beds for the outcrop (Fig. 3). The main photographic documentation was done in 2014, when the lower part of the riverside cliff was less covered

Table 1
Studied sections of the Seroglazovka locality.

N	Section and its number	Latitude	Longitude
1	Seroglazovka 1	N 47°00′51.74″	E 47°26′60.00″
2	Seroglazovka 2	N 47°00′50.91″	E 47°27′10.13″
3	Seroglazovka 3	N 47°00′47.73″	E 47°27′48.82″
4	Seroglazovka 4	N 47°00′47.37″	E 47°27′50.66″
5	Borehole 5 Seroglazovka	N 47°00′43.7″	E 47°27′47.9″

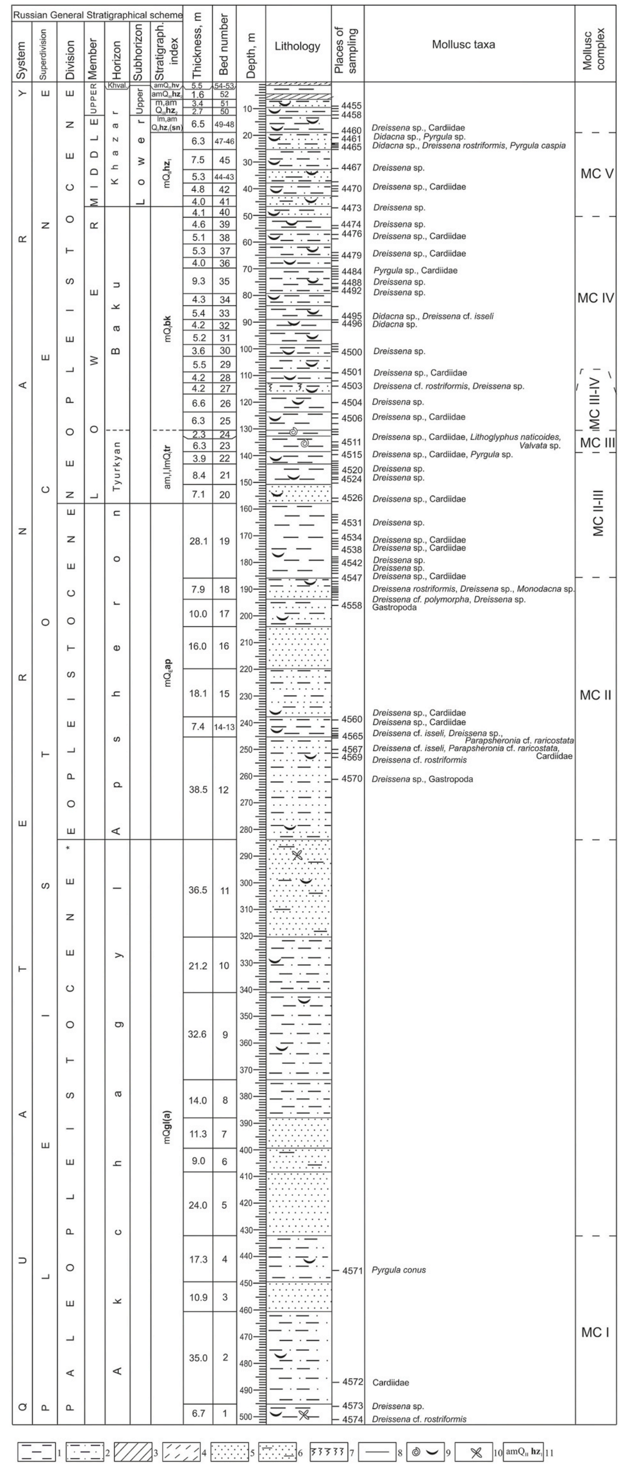


Fig. 2. Borehole 5 Seroglazovka section with malacological data. Legend: MCI-V-malacological complexes (see explanation in Chapter 4.2.3); lithologies (1–7) denoted by 1-clay; 2-sandy clay and aleuritic (silty) clay; 3-loam; 4-sandy loam; 5-sand; 6-clayey sand; 7-paleosol horizon; 8-boundaries between stratigraphical divisions; 9-freshwater and brackish water mollusc shells; 10-macroplant remains; 11-stratigraphical index (from left to right) with symbols of deposit genesis: a-alluvial facies, m-marine, am-alluvial-marine, l-lacustrine; lm-liman (=lagoon); symbols of general stratigraphic subdivision: Q (Quaternary): Qgl-Gelasian (Palaeopleistocene), Q_E-Eopleistocene, $Q_{I,II,III}$-Lower, Middle and Upper Neopleistocene; symbols of regional or local stratigraphical subdivision, with **a**-Akchagyl, **ap**-Apsheron, **b**-Baku, **sn**-Singil, **hz**-Khazar, **hv**-Khvalyn deposits, and $hz_{1\ (2)}$-lower (upper) parts of a stratigraphical subdivision. 4455-IG UFRC RAS sample registration number.

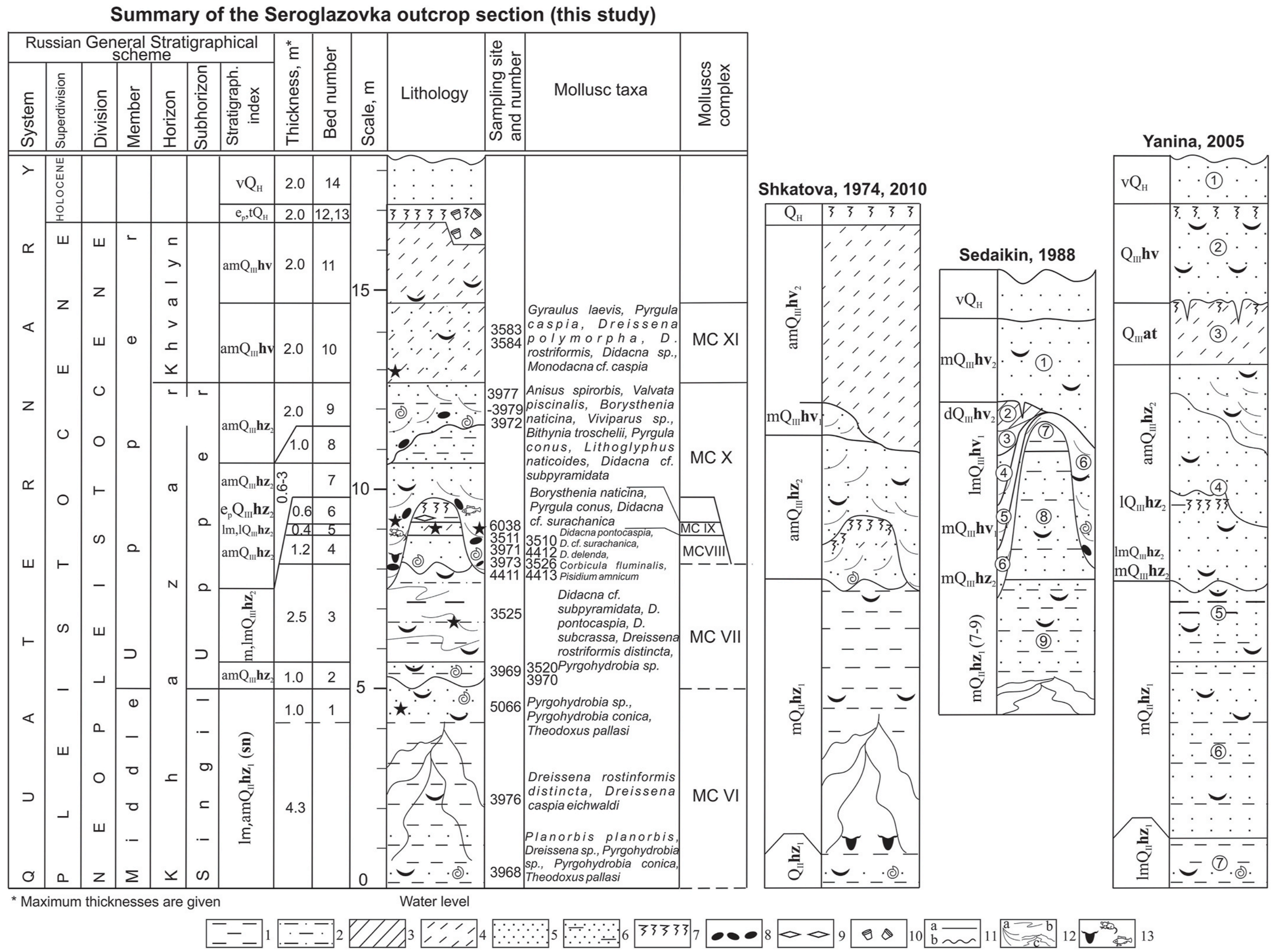


Fig. 3. Summary of the Seroglazovka 1–4 sections with malacological data and its stratification according to different authors. The vertical Legend: MCVI-XI-malacological complexes (see explanation in Chapter 4.2.3); lithologies (1–7) the same as for Fig. 2; 8-gravel and pebbles; 9-anhydrite; 10-anthropogenic deposits; 11-boundaries between stratigraphical units (a-conformity; b-unconformity); 12-sedimentary structures: a-cross-bedding, b-syn-depositional deformations (convolute bedding); c-slump/slope detritus; 13-vertebrate animal finds: large mammals, small mammals, fishes. Stratigraphical indices are the same as for Fig. 2 including **at** – Atel unit and additional symbols of deposit genesis: d-deluvial, e_p-eluvial (paleosol), v-eolian, t-anthropogenic deposits.

by slope detritus and water level of the Volga River was relatively low. Later in 2017, we were able to perform a detailed UAV-mapping of the outcrop (Figs. 1d and 5); however, its lower part was more covered compare to 2014.

The main part of our study comprised of an extensive biostratigraphical analysis of the outcrop and borehole data including spore and pollen data, ostracods, molluscs, fishes, small vertebrates (amphibians, reptiles, small mammals) and large mammals. Analyses of spore, pollen and ostracod data were done only for the borehole 5 Seroglazovka, while molluscs were studied both for the borehole and outcrop sections. Fishes, small vertebrates as wells as large mammals were studied only for the outcrop section.

We used the general stratigraphic subdivision of the Russian Stratigraphic Scale (Zhamoida et al., 2019) with our slight modifications, while regional stratigraphic subdivisions for the Lower Volga region are presented according to Zastrozhnov (in Postanovleniya, 1999) (Fig. 4). From the borehole and outcrop data we studied continental and marine deposits ranging in age from the Lower Pleistocene (Akchagyl and Apsheron horizons), the Middle Pleistocene (Tyurkyan, Baku, Lower Khazar horizons and Singil beds) to the Upper Pleistocene (Upper Khazar and Khvalyn horizons). A new stratigraphical position of the Singil beds in this paper is adopted according to Zastrozhnov et al. (2018b). We also prefer to use the term "marine" for the characterization of deposits of the Quaternary Caspian basins, while the term "brackish water" is used for the characterization of reservoirs and fauna.

3.1. Spore and pollen data

In total, 210 palynological samples were examined. Among them, 48 representative spore and pollen spectra were obtained and united into 11 palynological complexes (PC). Palynological analysis was performed according to the standard methods described by Grichuk and Zaklinskaya (1948) with some additions. Samples weighing 100 g were in sequence treated by 10% solution of HCl and KOH in order to remove carbonates and organic matter. Obtained mixtures were boiled during 20 and 10 min respectively. Then a heavy liquid with specific weight 2.25 (solution of potassium-cadmium iodide) were added to samples. Additionally, palynological samples were treated with sodium pyrophosphate and hydrofluoric acid.

The percentages of various taxa distribution were calculated based on the total number of pollen grains and spores found in each sample. The studied samples were characterized by diverse palynoflora and very low concentration of palynomorphs. In this regard the minimum amount of pollen and spores, which is required to calculate the percentages, was 50.

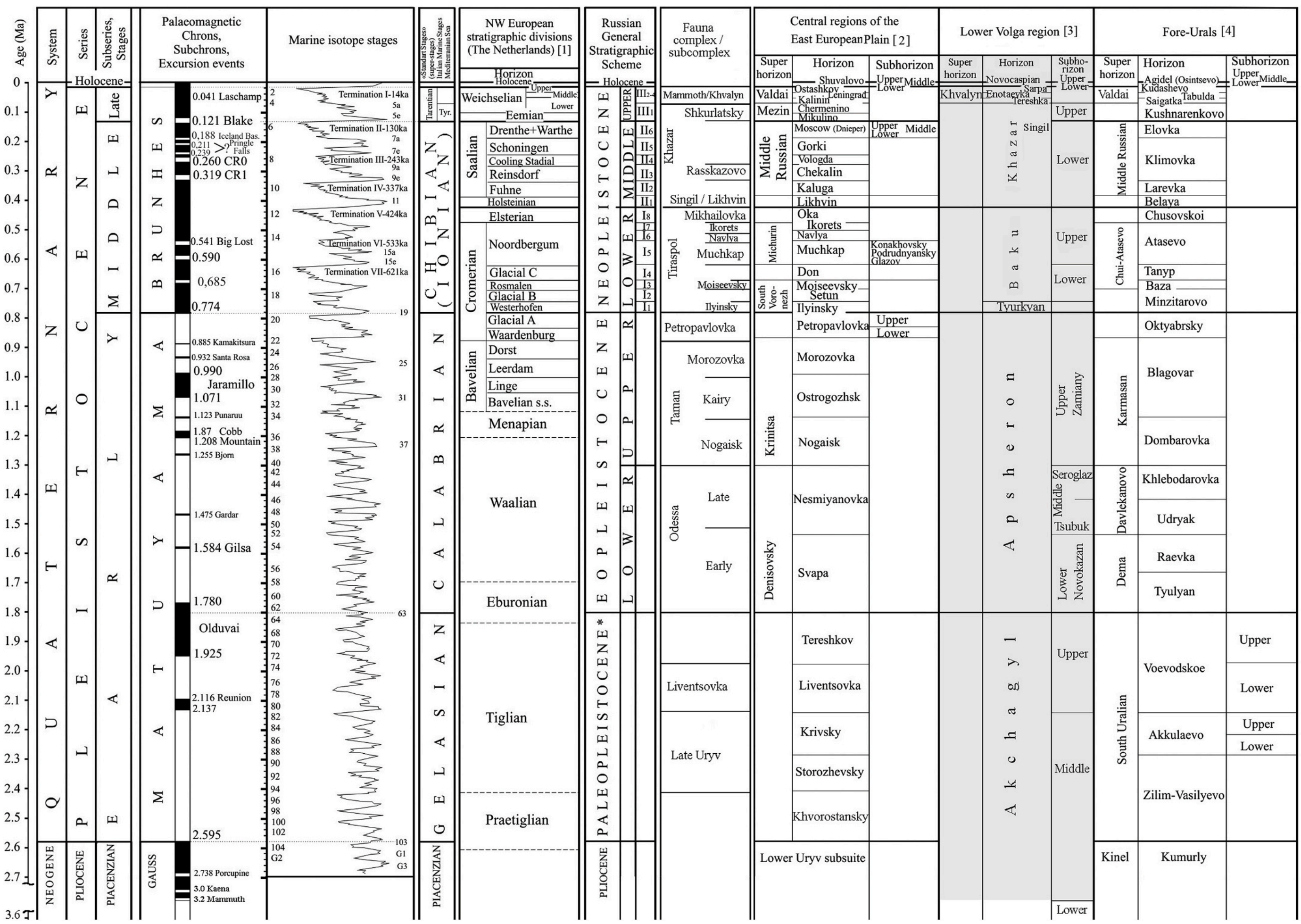


Fig. 4. Correlation between the Pleistocene subdivisions of the Lower Volga, Central European part of Russia, Fore-Urals and Western Europe with the General Stratigraphic Scale of Russia and the International Chart (Zastrozhnov et al., 2018a, modified).
Legend: Sampled interval in Seroglazovka sections is indicated in grey. Tyr.-Tyrrenian; Seroglaz-Seroglazovka. [1] Urban (1995); Zagwijn (1996); Turner (1998); [2] Shick et al. (2015a,b); [3] Zastrozhnov in Postanovleniya (1999) with additions; [4] Danukalova in Postanovleniya (2008). International Chart, Palaeomagnetic Chart, Marine Isotope Stages, and Italian marine stages are given according to Cohen and Gibbard (2016). Faunal complexes/subcomplexes are given according to Agadjanian (2009) and Markova (2014).

In some instances, a similar technique was already used by other researchers, who performed palynological studies of the Pleistocene deposits of the Lower Volga region (e.g. Grichuk, 1954; Moskvitin, 1962).

Taxa determination based on spores and pollen spectra was done according to Kupriyanova and Aleshina (1972, 1978), Bobrov et al. (1983), as well as by comparison with the recent spore and pollen collection of the Institute of Geology UFRC RAS (Ufa). Redeposited pollen were recognized by the degree of fossilization, exine preservation, and colour as methodologically described by Ananova (1960).

3.2. Ostracods

Ostracods were picked from a grain size fraction of 0.1–2 mm which was obtained by a wet seiving of 200–250 g of a dry core (ø10 cm) through a nylon sieve (ø100 μm). In total, 228 samples were examined, and ostracods were found in 65 of them. Species and genera identifications were made by comparisons of faunal descriptions with the available taxonomic literature (e.g. Livental, 1929; Suzin, 1956; Agalarova et al., 1961; Mandelstam et al., 1962; Mandelstam and Schneider, 1963; Stancheva, 1989; Gliozzi et al., 2005). We also compared our samples with the collection of SEM (scanning electronic microscope) images of the reference ostracod material stored in All-Russian Petroleum Research Exploration Institute (VNIGRI).

A large number of ostracod species of the Caspian region were described in 1950–1970s (e.g., Suzin, 1956; Agalarova et al., 1961; Mandelstam et al., 1962; Karmishina, 1975), however their further revision was not carried out. So, in this paper there are many species listed in the open nomenclature as well as some generic names have a question mark sign.

3.3. Molluscs

The mollusc-bearing sediments were wet sieved through a sieve with a mesh size of 1 mm in the field (for samples from the outcrop) and of 0.5 mm in the laboratory (for samples obtained from the borehole). The volume of a typical sample taken from the outcrop was 10 dm^3 and for the borehole it was 0.2 dm^3. Species identification was accomplished according to 1) Nevesskaja (2007) and Nevesskaja et al. (2013) for Cardiidae and the genus *Didacna*; 2) Bogutskaya et al. (2013) for the genera *Adacna* and *Hypanis*; 3) Logvinenko and Starobogatov (1968) for Pyrgulidae; 4) Sokolov (1994) for the genus *Dreissena* and 5) Glöer (2002), Zhadin (1952), and Gittenberg and Janssen (1998) for freshwater gastropods and bivalves. In total, more than 19 400 Bivalvia and Gastropoda shells and their fragments were determined.

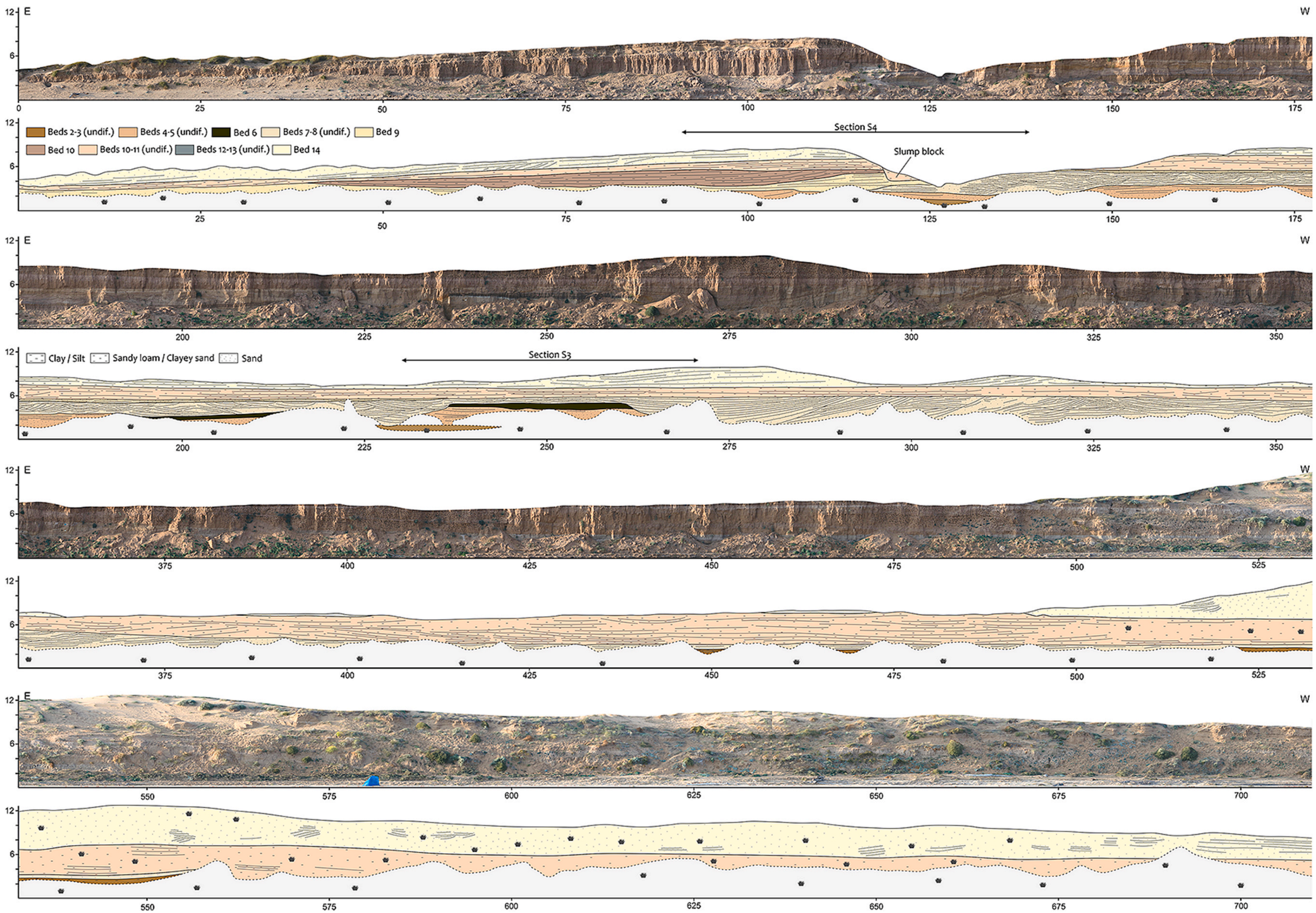


Fig. 5. General view and interpreted section of the entire Seroglazovka locality extracted from the 3D outcrop model (no vertical exaggeration). Note, that only dominant lithologies are shown.

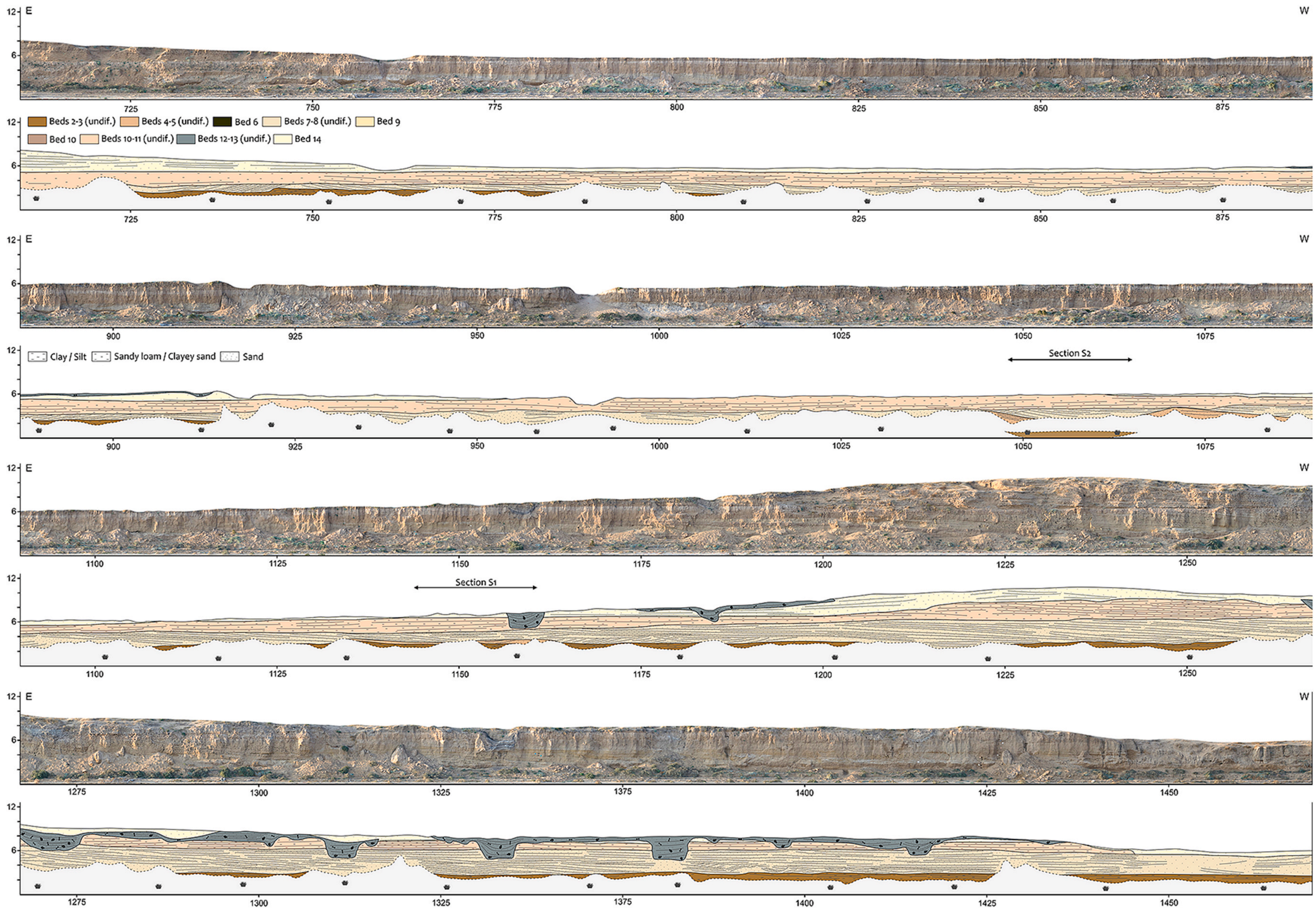


Fig. 5. (*continued*).

3.4. Fishes

The total number of processed fish remains is 37 specimens, of which 15 (40.5%) are determined to species, 3 (8.1%) to genus, and 9 (24.3%) to the family level. The remaining 10 specimens (27.1%) are represented by elements of the postcranial skeleton (e.g. rib fragments, vertebrae and other bone fragments) without diagnostic features. Statistically, vertebrae predominate among the fish remains in the collections, while epihyal, articular and opercular bones, cleithra, fragments of pharyngeal bones, isolated pharyngeal teeth, fin rays, as well as scales were also found. The bone remains were collected by wet sieving with a mesh size of 0.5–1 mm. The systematic affiliation was determined under the generally accepted methodology using the comparative osteological collection of the Department of Palaeontology, National Museum of Natural History of the National Academy of Sciences of Ukraine (Kyiv), osteological database (Tarcerie et al., 2016) and literature sources (Galkin, 1958; Sytchevskaya, 1976, 1989; Cumbaa et al., 1981). In this paper we adopted the modern ichthyological taxonomy of Nelson et al. (2016). The names of skeletal elements are consistent with the nomenclature proposed by Lepiksaar (1994) and Radu (2005).

3.5. Small vertebrates (amphibians, reptiles, small mammals)

In total, 12 bones of small vertebrates were investigated. The bone remains were wet sieved through a sieve with a mesh size of 1 mm. The volume of each sample was ca. 0.1 m^3. The bones were identified according to Agadjanian (2009), Gromov and Erbaeva (1995) and Ratnikov (2002), as well as by comparison with the osteological collection of extant species of the Institute of Geology UFRC RAS (Ufa).

3.6. Large mammals

Large mammalian material was collected during palaeontological excavations from the trenches or directly from the outcrop surface. During 2009–2019, several fossils and undetermined small fragments of thick-walled bones with a high degree of rounding were collected. Materials from the collection of the Astrakhan State United Historical and Architectural Museum-Reserve and Azov Historical Archaeological and Palaeontological Museum-Reserve were used for comparison.

3.7. OSL dating

Optically stimulated luminescence (OSL) dating of six samples from the main outcrop units (beds 1, 3, 5, 7 and 9) was performed in the Nordic Laboratory for Luminescence Dating (Department of Geoscience, Aarhus University, Prof. A. Murray). It was done using quartz grains (SAR-protocol) and feldspar grains (protocols IR50 and pIRIR290) (see details in Murray and Wintle, 2000; Thiel et al., 2011).

3.8. The 3D outcrop modelling and interpretation

In order to perform a detailed stratigraphic mapping along the Seroglazovka outcrop, we used DJI Phantom 4 Pro + drone to obtain over 400 high-resolution images of the outcrop. These images were photogrammetrically processed in Agisoft PhotoScan software (www.agisoft.com) in order to build up a 3D photo-textured digital model of the entire outcrop. The digital outcrop model was further interpreted in LIME software (Buckley et al., 2019) developed by the VOG Group (NORCE Norwegian Research Centre AS and University of Aberdeen). Such approach provided a unique opportunity to digitally revise and update our field mapping interpretations depending on obtained analytical results and new insights into sedimentary sequence of the outcrop. The principles and applications of the photogrammetric technology in Earth Sciences are described in detail by Buckley et al. (2006, 2008), Bemis et al. (2014), Nesbit et al. (2018) and references therein.

Table 2

The detailed lithological description of the borehole 5 Seroglazovka section. The description starts from the lowermost bed. The numbers of the beds are shown in the left column. At the end of each bed description the first numbers in brackets correspond to a depth interval and the second number is a thickness of a unit (both in meters).

Akchagyl Horizon (Qgl a)	
1	Dark grey clay with silty powder on the bedding surfaces, with interlayers of greenish silty clay (1 cm thick) giving platy parting to clay. The fragments of *Dreissena* shells occur at the depths of 501 and 502 m. Rare plant detritus occur at the depth of 496 m (503–496.3; 6.7).
2	Dark grey silty micaceous clay with rare shell fragments of Cardiidae (496.3–461.3; 35).
3	Grey sands (461.3–450.4; 10.9).
4	Dark grey silty micaceous clay with single shell of *Pyrgula conus* and rare fragments of other mollusc shells (450.4–433.1; 17.3).
5	Grey sands (433.1–409.1; 24).
6	Grey quartz sands, slightly clayey, fine-grained, interlayered with grey micaceous silty clays (up to 0.7 m thick) (409.1–400.1; 9).
7	Grey sand (400.1–388.8; 11.3).
8	Dark grey sandy clay with fine platy parting (388.8–374.8; 14).
9	Dark grey sandy clay with fragments of mollusc shells (374.8–342.2; 32.6).
10	Dark grey sandy clay with rare fragments of mollusc shells (342.2–321; 21.2).
11	Grey glauconite sand, slightly clayey, fine-grained, with interlayers (up to 20 cm thick) of dark grey sandy clays, with rare fragments of mollusc shells and plant detritus (321–284.5; 36.5).
Apsheron Horizon (Q_E**ap**)	
12	Alternation of dark grey and grey sandy micaceous clays, grey silty clays with fine platy parting and grey clayey medium- and fine-grained sands with marine mollusc shells and their fragments (284.5–246; 38.5).
13	Grey clay with fine platy parting due to silty powder on the bedding surfaces, with molluscs of Apsheron age (246.0–240.8; 5.2).
14	Dark grey slightly sandy micaceous clay with platy parting due to silty powder on the bedding surfaces, with rare fragments of mollusc shells (at the depth of 239 m) (240.8–238.6; 2.2).
15	Alternation of grey clayey fine-grained sands (0.2–0.3 m thick) and grey sandy micaceous clays (0.7–1 m thick) with platy parting due to silty powder on the bedding surfaces. Rare fragments of mollusc shells occur at the depth of 238 m (238.6–220.5; 18.1).
16	Grey sand (220.5–204.5; 16).
17	Alternation of grey clays and grey clayey fine-grained sands with a single gastropod shell (204.5–194.5; 10).
18	Dark grey clay with a silty powder and fine sand on the bedding surfaces, as well as rare mollusc shell fragments. There are clayey medium- to fine-grained, slightly cemented sands in the lower part of the bed (194.5–186.6; 7.9).
19	Dark grey clay with platy parting due to silty powder on the bedding surfaces, rare nodules of silts and manganese oxide grains, and very few fragments of mollusc shells (186.6–158.5; 28.1).
Tyurkyan Horizon (Q_1**tr**)	
20	Grey quartz sand, medium- to fine-grained, with glauconite and rare fragments of mollusc shells (158.5–151.4; 7.1).
21	Grey clay with fine platy parting, marcasite nodules (1–3 mm in diameter) and rare fragments of mollusc shells (151.4–143.0; 8.4).
22	Grey clay with a conchoidal fracture, marcasite nodules (1–3 mm in diameter) and rare mollusc shell fragments (143.0–139.1; 3.9).
23	Bluish-grey micaceous clay with a conchoidal fracture, silty powder on the bedding surfaces and rare fragments of mollusc shells (139.1–132.8; 6.3).
24	Mottled clay with greenish-grey, greenish-yellow, light-brown and blue spots, fine platy parting, rare gastropods and shell fragments of Cardiidae (132.8–130.5; 2.3).
Baku Horizon (Q_1**bk**)	
25	Grey clay with fine platy parting due to silty powder on the bedding surfaces, ferrum oxide spots containing rare fragments of mollusc shells (130.5–124.2; 6.3).
26	Light grey sandy clay with sideritic nodules in the upper part of the bed and rare fragments of mollusc shells (124.2–117.6; 6.6).
27	Alternation of grey, brownish-grey sandy clays (0.7–0.9 m thick) and turquoise clayey, fine-grained, slightly cemented sands (up to 0.3 m thick), black clays (paleosol?) (up to 2 m thick) with aggregate structure in the upper part of the bed and rare fragments of mollusc shells (117.6–113.4; 4.2).
28	Grey sandy clay with rare fragments of mollusc shells (113.4–109.2; 4.2).
29	Dark grey sandy and lumpy clays (109.2–103.7; 5.5).
30	Dark grey, partly light-brownish clays with sideritic intercalations (at depth 100.5–100.75 m). The clays become sandier from the depth of 102 m, with rare *Dreissena* sp. shell fragments (103.7–99.1; 3.6).
31	

(*continued on next page*)

Table 2 (*continued*)

	Dark grey, almost black clay interlayered with 5 cm-thick greenish-bluish silty clays at the depth 97.2 m, with rare shell fragments of Cardiidae (99.1–93.9; 5.2).
32	Dark grey, almost black viscous clay with a conchoidal fracture, silty powder on the bedding surfaces, and rare mollusc shell fragments (93.9–89.7; 4.2).
33	Light-brownish-grey and grey clays with black grains and rare mollusc shell fragments (89.7–84.3; 5.4).
34	Grey pliant clay with light-brown colour at the depth interval of 84.4–83.5 m, conchoidal fracture, silty powder on the bedding surfaces and rare shell fragments of Cardiidae (84.3–80.0; 4.3).
35	Grey clay with a conchoidal fracture, rare fragments of mollusc shells and fine platy parting due to silty powder on the bedding surfaces (80.0–70.7; 9.3).
36	Light-brownish and grey clays with horizontal lamination due to silty powder on the surface of the bedding surfaces, and with rare mollusc shell fragments (70.7–66.7; 4.0).
37	Grey clay with horizontal lamination due to silty powder on the bedding surfaces, with rare fragments of mollusc shells (66.7–61.4; 5.3).
38	Grey sandy clay with horizontal lamination due to silty powder on the bedding surfaces, with rare mollusc shell fragments (61.4–56.3; 5.1).
39	Grey, partly sandy, lumpy clay with interlayers of sands, rare fragments of mollusc shells (56.3–51.7; 4.6).
40	Alternation of grey sandy clays with siderite grains and grey, slightly clayey fine-grained sands, and fragments of mollusc shells (51.7–47.6; 4.1).
Khazar Horizon, Lower Subhorizon (Q_{II}**hz**$_1$)	
41	Grey clayey, fine-grained sand with mollusc shells (47.6–43.6; 4.0).
42	Light-brownish and grey sandy clays with black spots (organic remains?) and very few fragments of mollusc shells (43.6–38.8; 4.8).
43	Grey clay with micro-lenses and silt powder, rare fragments of mollusc shells (38.8–37.5; 1.3).
44	Grey clayey fine-grained sand with *Didacna* sp. fragments (at depth of 37.5 m) (37.5–33.5; 4.0).
45	Grey pliant clay with silt powder and micro-lenses, rare fragments of *Dreissena* sp. shells (33.5–26.0; 7.5).
46	Bluish-grey clayey fine-grained sand with rare fragments of mollusc shells (23.8–26.0; 2.2).
47	Bluish-grey clay with intercalations of fine-grained sands and silts in the lower part of the bed, and greenish-grey sandy pliant clays with interlayers (10 cm) of clayey fine-grained sands and with rare fragments of mollusc shells in the upper part (23.8–19.7; 4.1).
Khazar Horizon, Lower Subhorizon, Singil beds (Q_{II}**hz**$_1$ (**sn**).	
48	Dark grey clay with light brown interlayers (ferruginization) with black spots, silt micro-lenses and rare fragments of mollusc shells (19.7–15.5; 4.2).
49	Greenish-grey pliant sandy clays interlayered with grey fine-grained sands (up to 10 cm thick) and shell detritus (15.5–13.2; 2.3).
Khazar Horizon, Upper Subhorizon (Q_{III}**hz**$_2$)	
50	Light-brown sandy clay with the spots of ferrum oxide and rare fragments of mollusc shells (13.2–10.5; 2.7).
51	Light-brown sandy clay intercalated with yellow sands, with poorly preserved mollusc shells (10.5–7.1; 3.4).
52	Light- brown horizontally bedded loam with fine-grained sand interlayers and fragments of mollusc shells (7.1–5.5; 1.6).
Khvalyn Horizon (Q_{III}**hv**)	
53	Light brown clay (5.5–2; 3.5).
54	Sandy loam (2–0; 2).

4. Results

In the subchapter 4.1 we first provide a lithological description of all the studied units both in the borehole 5 Seroglazovka and outcrop sections. Further in the subchapter 4.2 we provide factual material on groups of fauna and vegetation, as well as OSL dating, which forms a basis for the stratification of the studied sections.

4.1. Stratigraphy

The Akchagyl and Apsheron deposits (= Lower Pleistocene of the International Chronostratigraphic Chart (ICC), Tyurkyan, Baku and Lower Khazar deposits (= Middle Pleistocene, ICC) were described only in the borehole 5 Seroglazovka, while Singil, Upper Khazar, Khvalyn deposits (= Upper Pleistocene, ICC) were described both in the borehole 5 Seroglazovka and along the outcrop of the Seroglazovka locality (Figs. 2 and 3). The total thickness of the investigated section is 503 m.

4.1.1. Borehole 5 Seroglazovka

The generalized description of the borehole section starts from the lowermost bed. Considering rather monotonous sandy-clayey deposits, for further correlations of deposits we provide a detailed description of the section in Table 2.

4.1.1.1. Upper Pliocene and Lower Pleistocene. The Upper Pliocene corresponds to the Piacenzian Stage and the Lower Pleistocene corresponds to the Gelasian and Calabrian stages, which are respective equivalents of the Palaeopleistocene and Eopleistocene of the Russian General Stratigraphic Scheme (Fig. 4). In the Lower Volga region stratigraphic scheme, the Piacenzian and the Gelasian corresponds to the Akchagyl Horizon and the Calabrian corresponds to the Apsheron Horizon (Fig. 4).

The Akchagyl Horizon (Q**gl(a)**) (beds 1–11, depth range of interval is 503–284.5 m, total thickness is more than 218.5 m) is represented by irregular interbedding of clayey and sandy deposits with rare mollusc shells and plant detritus. **The Apsheron Horizon** (Q_E**ap**) (beds 12–19; depth range of interval is 284.5–158.5 m; total thickness is 126 m) consists of interbedding of dark-grey and grey sandy-mica clays, grey silty clays and grey clayey medium-to small-grained sands with mollusc shells and their fragments.

4.1.1.2. Middle Pleistocene. The Middle Pleistocene subseries corresponds to the Ionian (Chibanian) Stage (Neopleistocene in the Russian General Stratigraphic Scheme). It includes the Tyurkyan and Baku horizons as well as the Lower Khazar Subhorizon and Singil beds of the Lower Volga region stratigraphic scheme (Fig. 4).

The Tyurkyan Horizon (Q_1**tr**) (MIS 19) (beds 20–24; depth range of interval is 158.5–130.5 m; total thickness is 28 m) is represented by grey, bluish-grey clay with a sandy layer at the bottom with rare fragments of mollusc shells. **The Baku Horizon** (Q_1**bk**) (MIS 18–12) (beds 25–40; depth range of interval is 130.5–47.6 m; total thickness is 82.7 m) is dominantly clayey interval with rare fragments of mollusc shells. The distinctive feature of this clayey interval is thin horizontal lamination of dark-grey and grey clays.

The Lower Subhorizon of the **Khazar Horizon** (Q_{II}**hz**$_1$) (MIS 11–7) (beds 41–47; depth range of interval is 47.6–19.7 m; total thickness is 27.9 m) is a clayey-sandy interval, a distinctive feature of which is lighter colour of deposits. The upper part of the Lower Subhorizon is represented by **Singil beds** (MIS 6) (Q_{II}**hz**$_1$ (**sn**) (beds 48–49; depth range of interval is 19.7–13.2 m; total thickness is 6.5 m) which consists of dark-grey to greenish-grey clay with sandy layers and rare fragments of mollusc shells.

4.1.1.3. Upper Pleistocene. The Upper Pleistocene subseries corresponds to the Tarentian Stage (Upper Neopleistocene in the Russian General Stratigraphic Scheme). It includes the Upper Khazar and Khvalyn horizons of the Lower Volga region stratigraphic scheme (Fig. 4).

The Upper Subhorizon of the **Khazar Horizon** (Q_{III}**hz**$_2$) (MIS 5) (beds 50–52; depth range of interval is 13.2–5.5 m; total thickness is 7.8 m) is represented by light-brown sandy-clayey deposits with mollusc shells. **The Khvalyn Horizon (**Q_{III}**hv**) (MIS 3–2) (beds 53–54; depth range of interval is 5.5–0 m, thickness is 5.5 m) consists of light-brown clays and loams.

4.1.2. Seroglazovka sections 1-4

Deposits of the upper part of the borehole down to a depth of 15.7 m are described in more detail along the riverside cliff (Seroglazovka 1–4 sections (S1–4)) (Figs. 3–9). The entire length of the riverside cliff is about 1.5 km with the height of the cliff free of slope detritus is about 12 m (as for the year 2017) (Fig. 5). The main outcrop units are most fully represented in the S3 and S4 sections. However, due to visual and lithological similarities of several units and their complex inter-relations (thinning, pinch-outs, etc.) we had to combine them into thicker mappable units in order to facilitate more confident tracing along the entire outcrop (Fig. 5). The detailed stratification within the sections is given in Figs. 6–9.

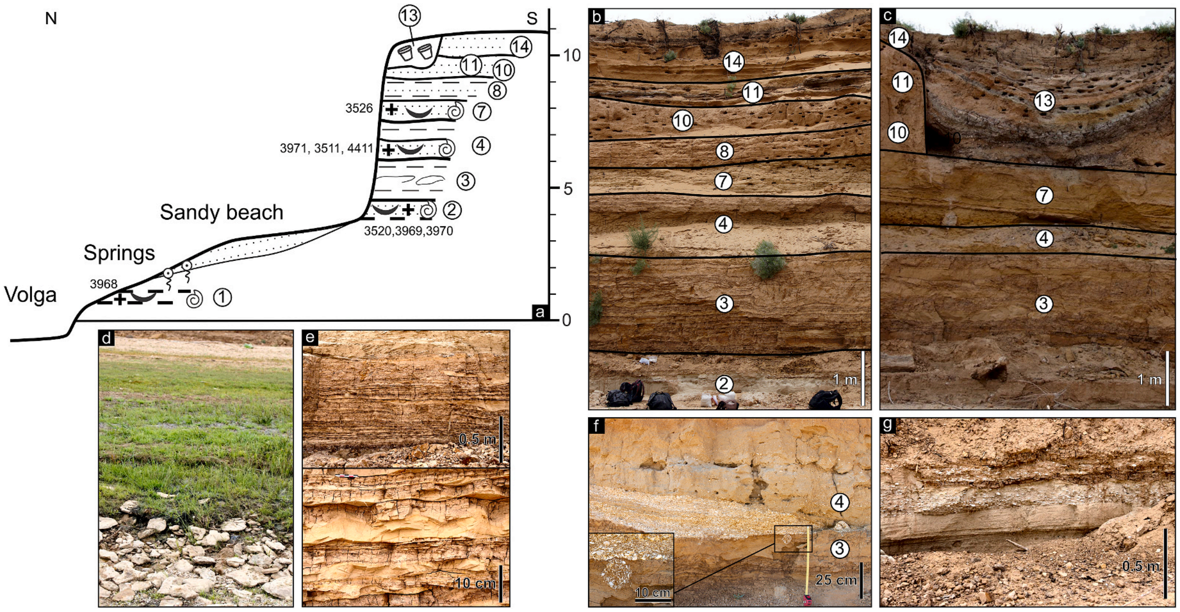


Fig. 6. Seroglazovka 1 section (S1). (a)-drawing of the section; (b)-general view of the outcrop in the riverside cliff; (c)-"cultural" deposits filling the rectangular depressions (bed 13); (d)-rocks plates with gastropods (bed 1) at the river beach; (e)-features of the bed 3; (f)-contact between the beds 3 and 4: accumulation of the mollusc shells on the erosional surface; (g)-construction of the lower part of the river side cliff – sandy bed 2 (Photos taken by G. Danukalova).

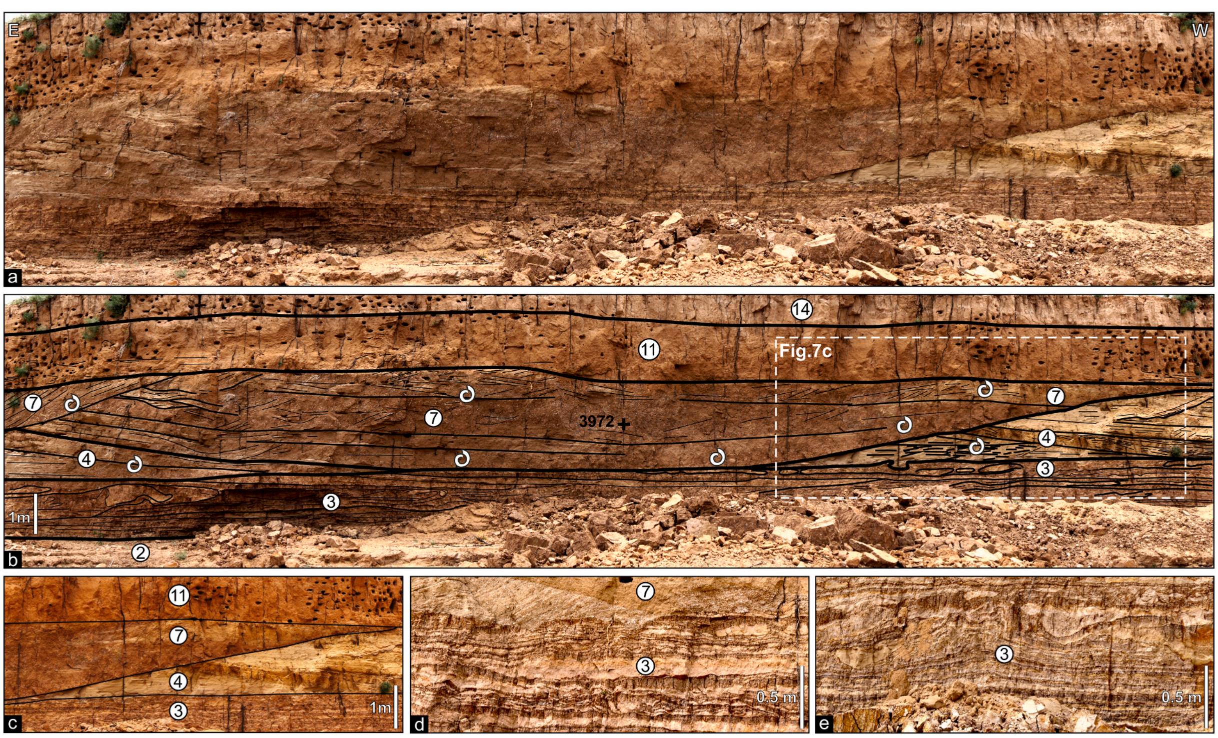


Fig. 7. Seroglazovka 2 section (S2). (a)-general view of the outcrop section; (b)-interpreted section; (c)-structural features of the beds 3, 4, 7 and 11; (c)-structural features of the beds 3 and 7; (d)-syn-depositional deformations (convolute bedding) of the bed 3. (Photos taken by G. Danukalova).

4.1.2.1. Middle Pleistocene. **Singil deposits** (MIS 6) (Q_{II}**hz**$_1$ (**sn**)) overlay Lower Khazar marine deposits are represented by the **bed 1** with total thickness up 4.3 m. This is dark grey clay (visible thickness starting from the water level of the Volga River is 4.3 m) with small Pyrgulidae and bivalve shells. The upper part of the bed 1 is represented by light-grey and yellowish fine-grained sands (thickness is 0.3 m) with numerous gastropods. This unit is covered by grass along the entire outcrop and is hard to study and map out along the entire outcrop. However, local clearances allowed us to study its lithology and biostratigraphy (e.g. S1 section; Fig. 6a, d). OSL data at the top of the bed indicates an age of 109 ± 9 ka BP (OSL Volga–4–2015, S3 section).

4.1.2.2. Upper Pleistocene. **The Upper Subhorizon** of the **Khazar Horizon** (MIS 5) (Q_{III}**hz**$_2$) consists of the **beds 2–9** with total thickness up to 10.2 m. **The bed 2** is an alternation of grey cross-bedded fine-grained silty sands (30 cm) and brown dense viscous horizontally laminated

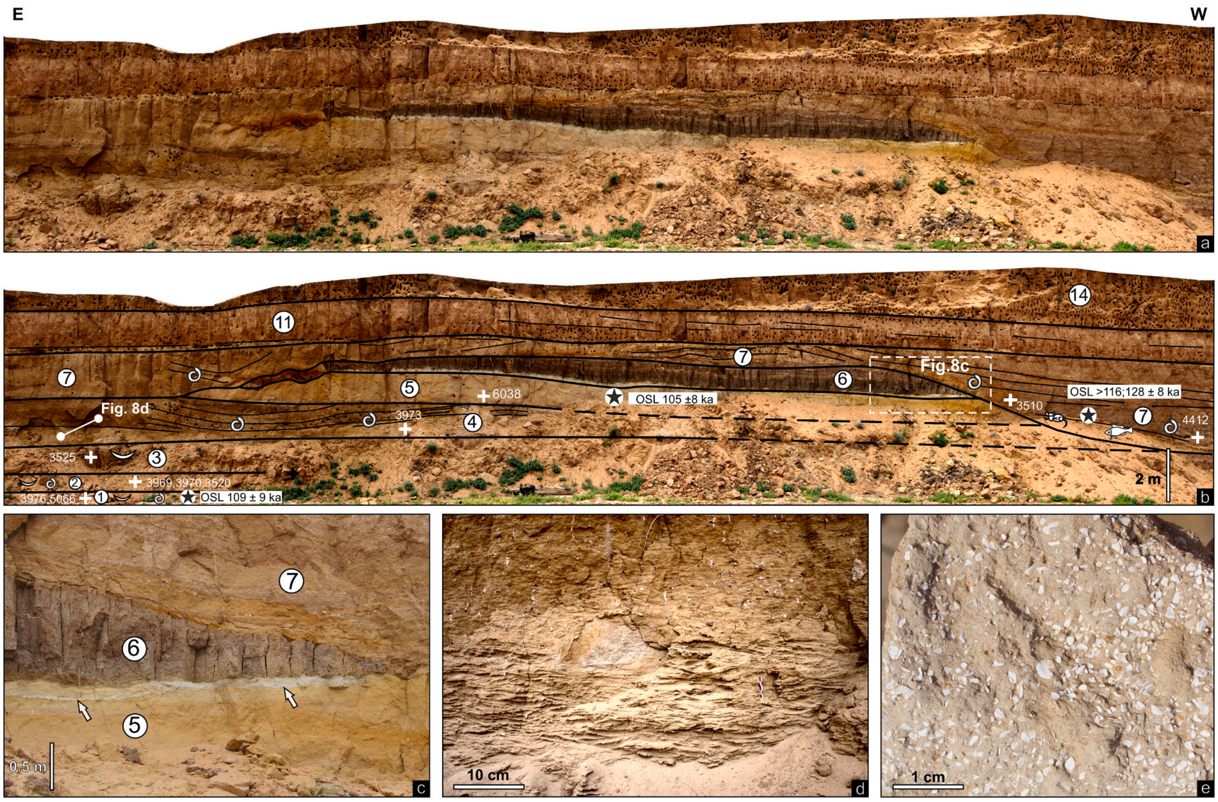


Fig. 8. Seroglazovka 3 section (S3). (a)-general view of the section; (b)-interpreted section; (c)-structural inter-relationships of the beds 5, 6 and 7. White layer below (pointed by white arrows) is anhydride; (d)-bedding pattern of the bed 4; (e) – sand of the bed 1 with mollusc shell detritus.

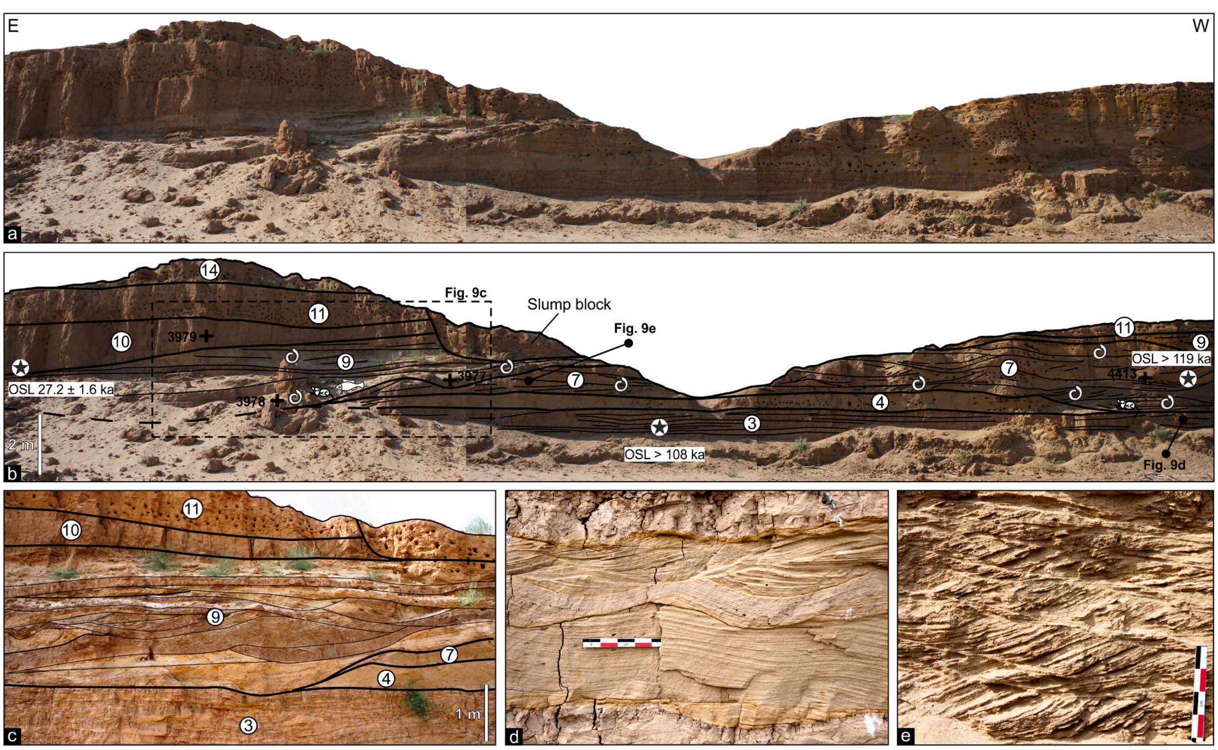


Fig. 9. Seroglazovka 4 section (S4). (a)-general view of the section; (b)-interpreted section; (c)-structural features of the beds 3, 4, 7, 9, 10 and 11; (d)-bedding pattern of the bed 3; (e)-bedding pattern of the bed 7 (Photos taken by G. Danukalova).

clays (20 cm) (S1 section, Fig. 6b, g). Lenses of mollusc shells also occur (2–20 cm thick, up to 5 m in length). The lower contact of the bed is rough. Thickness is 0.5 m.

The bed 3 consists of an alternation of brown clays and yellowish- and greyish-brown silt interlayers (0.5–10 cm each) with a clear wavy lamination, which is locally disturbed by syn-sedimentary deformations (S2 section, Fig. 7d and e). Rare poorly preserved *Didacna* shells occur in the lower part of the bed. Thickness is 2.5 m. OSL data indicates an age of more than 108 ka BP (OSL Volga–2014–16, S4 section). Notably, beds 2 and 3 with a characteristic "stripy" structure (Figs. 6e, 7d and 7e) are distinctively recognizable in the lower part of almost all sections along the left and right banks of the Volga River from the Tsagan-Aman locality down to the Seroglazovka and Selitrennoye localities.

The bed 4 comprises grey and brownish-grey fine-grained sands (Fig. 8d) with *Didacna* shells. The lower boundary of the bed is clearly eroded. The erosion surface is highlighted by a crust of ferrum oxide and depressions ("pockets") filled by gravels and numerous shells of freshwater and brackish water molluscs (Fig. 6f). The bed is partly truncated by the deposits of the bed 7 (S2 section, Fig. 7b and c). Thickness is up to 1.3 m.

The bed 5 is represented by light yellow and brownish-grey clayey fine-grained sands (Fig. 8b and c), slightly ferruginated, with lenses of brown clays in the lower part of the bed. Thickness is up to 0.4 m. OSL data indicates an age of 105±8 ka BP (OSL Volga–2014–19, S3 section).

The bed 6 is brown clay with traces of hydromorphic pedogenesis,

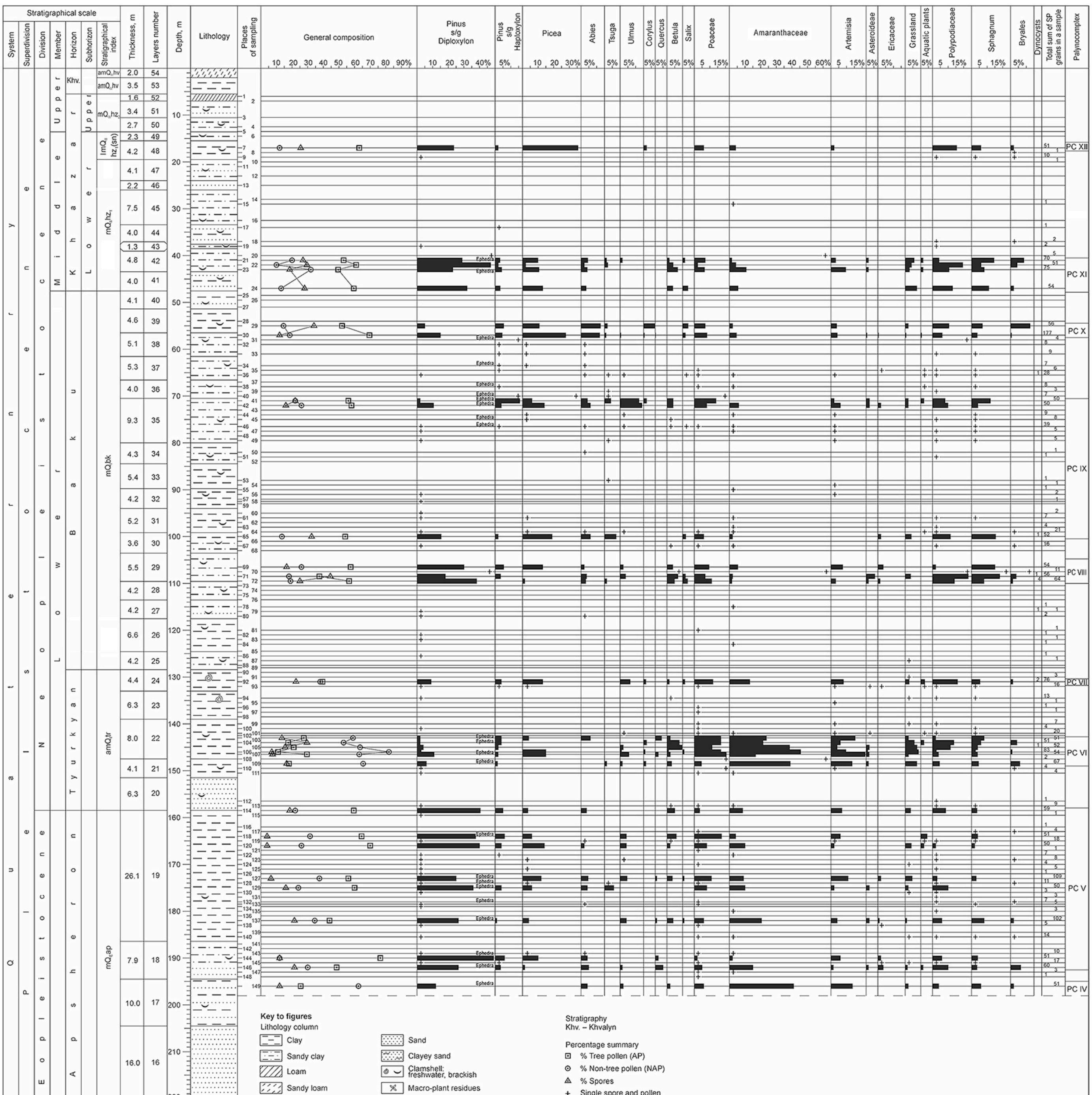


Fig. 10. Borehole 5 Seroglazovka core and pollen diagram. Explanation for stratigraphical indices and facies genetic symbols is given in Fig. 2 caption.

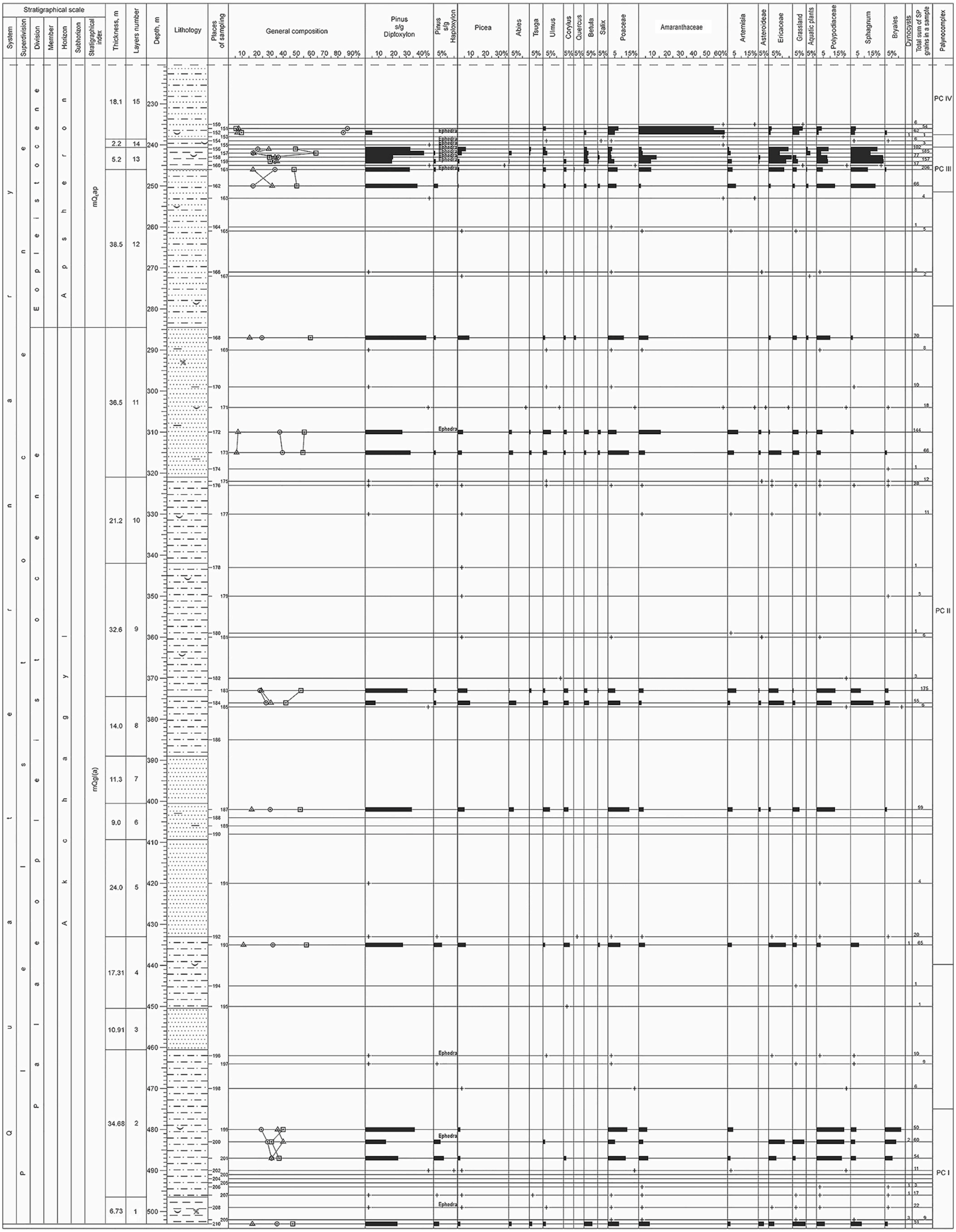


Fig. 10. (*continued*).

greenish-grey silt interlayers (up to 15 cm thick) and very thin anhydride interlayer (1–2 mm thick) in the lower part of the bed. (Fig. 8b and c). Thickness is up to 0.6 m.

The full sequence of the beds 4–6 are present only within the downstream part of the locality, where it is observed in the outlier, which was preserved from erosion (Fig. 5, 235–265 m). The beds 4–6 represent a common regressive cycle, which resulted in the abandonment of the sea basin from the region and subsequent formation of alluvial-floodland and lacustrine-chemogenic deposits. Overlying beds 7, 8 and 9 represent several generations of alluvial incisions which have variable thicknesses and areal extent and cut the underlying deposits sometimes down to the beds 3 and 2 (Figs. 5–9). These beds are most recognizable in the downstream part of the locality, while within the upstream part they are hardly distinguishable (Fig. 5). Based on the fossils and lithological features of these beds, we suggest alluvial-deltaic environment for their formation.

The bed 7 is distributed along almost the entire length of the outcrop (Fig. 5). It is represented by uneven-grained sand with distinct cross-bedding (Fig. 9e) highlighted by clay interlayers (5–10 cm thick), gravel, pebbles at the bottom of the bed, elongated lenses filled by clay pellets, numerous shells of fresh-water and brackish water molluscs (Fig. 6b–d). OSL data indicate the following ages for two samples: 1) OSL Volga–2014–18: >116 ka (quartz), 128±8 ka (feldspar) and 2) OSL Volga–2014–17: >119 ka (quartz) and 111±13 ka (feldspar). Thickness of the bed is in the range of 0.6–3 m. The lower contact of the bed 7 is erosional.

The bed 8 is an alternation of brownish-grey clays and fine-grained sands. The lower contact is erosional. These deposits are locally truncated by the bed 9. Thickness is up to 1 m.

The bed 9 is represented by an alternation of brownish-grey medium-to fine-grained sands with brown clays (Fig. 9). Deposits contain clayey gravels with freshwater and brackish water mollusc shells. Thickness is 2 m.

The Khvalyn Horizon (MIS 3–2) (Q_{III}**hv**) consists of **beds 10–11** with total thickness up to 4 m. **The bed 10** comprises brownish clay and sandy loam which are alternating along the strike of the bed. They have subtle horizontal bedding at the bottom of the bed and traces of pedogenesis at the top. OSL data indicates an age of 27.2 ± 1.6 ka (OSL Volga–2014–15). Thickness is up to 2 m.

The bed 11 is represented by light-brown clayey sand (Baer Knoll suite) with fragments of mollusc shells (Figs. 7 and 9). Thickness is up to 2 m.

4.1.2.3. Holocene. **The Novocaspian Horizon** (MIS 1) is represented by **beds 12–14** with total thickness up to 4.2 m. **The bed 12** is brownish-grey loam with traces of pedogenesis and roots of extant plants. Thickness is 0.2 m.

The bed 13 Is anthropogenic (residential) deposits – household wastes, fragments of ceramics, glass, coal, which fill in the pits and cellars preserved from the old, abandoned part of the Seroglazovka village (Figs. 5 and 6). Thickness is up to 2 m.

The bed 14 is yellowish fine-grained modern eolian sand (Figs. 5, 6b and 6e). The deposits form dunes as a result of wind-blowing of underlying strata. Thickness is up to 2 m.

4.2. Results of the biostratigraphical investigations

4.2.1. Palynological investigations

Eleven palynological complexes (PC) were established in the borehole 5 Seroglazovka section (Fig. 10). These complexes characterize floristic composition of the Akchagyl, Apsheron, Tyurkyan, Baku and Lower Khazar deposits. In total, 78 taxa of pollen and spores as well as remains of *Pediastrum* algae and dinocysts were recognized in the studied samples. Almost all samples contain redeposited Mesozoic and Palaeozoic pollen and spores. Identified palynological complexes are described in detail below.

Akchagyl Horizon. Two PC came from these deposits. Their spore and pollen composition indicate the development of forest-steppe vegetation.

PC I (depth interval of 502.9–475 m). Spore and pollen spectra characterize the development of *Pinus* forests with *Picea, Abies, Tsuga* as well as broad-leaved (*Ulmus, Zelkova, Corylus, Juglans, Acer*) and small-leaved (*Betula*) trees admixture. Polypodiaceae, *Selaginella, Osmunda, Lycopodium* and *Botrychium lunaria* grew on forest edges. *Sphagnum*, Bryales, Ericaceae, *Calluna vulgaris*, and *Carex* occurred in small, wet and swampy areas. Open spaces were occupied by Poaceae-grassland and *Artemisia*-Amaranthaceae groups. Dinoflagellate cysts were also detected.

PC II (depth interval of 440–287 m). There was a gradual increase of the forest area. The part of the coniferous species (*Picea* and *Abies*) increased in the composition of pine forests. More termophillic representatives of broad-leaved trees (*Carya, Pterocarya, Castanea, Quercus,* and *Tilia*) appeared. *Salix* and *Alnus* grow in river floodplains; *Typha* and *Sparganium* gradually occupied the coastal areas. Among herbaceous plants, the diversity of meadow vegetation was increasing. Wetlands were declining and the climate became more humid and warmer.

Apsheron Horizon. Three PC (PC III, PC IV and PC V) characterize the vegetation of this time. PC III (depth interval of 251–240.5 m). Pollen and spore spectra characterize the development of forest and forest-steppe landscapes at the beginning of this interval. Pines dominated in the structure of coniferous forests. The proportion and variety of broad-leaved trees in the forests decreased, while the role of xerophytes (*Ephedra*, Amaranthaceae and *Artemisia*) increased, as wetland area was covered by *Sphagnum* and Ericaceae. The climate became drier and probably cooler.

PC IV (depth interval of 237.5–195 m). Because of aridization, there is a sharp increase in open areas with semi-desert vegetation (mainly Amaranthaceae).

PC V (depth interval of 192–158.5 m). The afforestation of the territory increased again. Pine and pine-spruce forests with an admixture of *Keteleeria, Larix, Tsuga*, broad-leaved (*Ulmus*, *Quercus*, *Castanea*, *Tilia*, *Carpinus*, and *Juglans*) and small-leaved species (*Betula, Alnus* and *Salix*) were widespread at that time. The areas occupied by *Artemisia*-Amaranthaceae associations were decreased and the role of Poaceae was increasing. Areas of wetlands were not significant, and the representatives of the coastal-aquatic vegetation (*Typha, Alisma*) were rare.

The Tyurkyan Horizon is characterized by the presence of two PC (PC VI and PC VII). PC VI (depth interval of 149–142.5 m) indicates the development of open landscapes covered by *Artemisia*-Amaranthaceae and Poaceae-grassland associations existed in the dry climate. Small mixed forests with increased role of *Betula* trees also existed at that time. PC VII (depth interval of 132–130.5 m) characterizes a typical forest-steppe with *Picea–Pinus* forests with a small admixture of *Larix, Keteleeria, Ulmus, Corylus* and *Betula*. The climate became more humid and cooler at that time.

The Baku Horizon is represented by three PC (PC VIII, PC IX, and PC X). The composition of conifers in mixed forests changed in the following direction: *Pinus* (PC VIII, depth interval of 109–105 m) – *Pinus* and *Picea* (PC IX, depth interval of 100–70.9 m) – *Picea* and *Abies* (PC X, depth interval of 57.5–54.5 m). Such transformation reveals a gradual increase in humidity. *Tsuga* was common in the forest composition. Grasses were represented mainly by Poaceae, Amaranthaceae and *Artemisia*. The wetlands were occupied mainly by *Sphagnum*. Dinocysts were also present. The climate during the accumulation of the Baku deposits was cool. The appearance and gradual increase in the pollen spectra of *Ephedra* sp. probably indicate an increase of aridization by the end of the Baku time.

The Lower Khazar Horizon is characterized by two PC (PC XI and PC XII). PC XI (depth interval of 47.5–40.0 m): at that time, pine and pine-spruce forests dominated. *Abies, Tsuga* and *Betula* occurred in forests as an admixture. In the composition of grasses, at first, a significant role was played by Amaranthaceae and *Artemisia*, later – by Poaceae and herbs. *Sphagnum* and Bryales indicate the existence of wet and marshy areas. *Pediastrum* remains indicate the existence of freshwater reservoirs. Floodplain and coastal-aquatic plants *Salix*, *Sparganium*, and *Typha* are sporadically recorded in the spectra. The climate of the Early Khazar was cool and moderately humid.

PC XII (depth 17.0 m): *Picea-Pinus* forests with broad-leaved tree

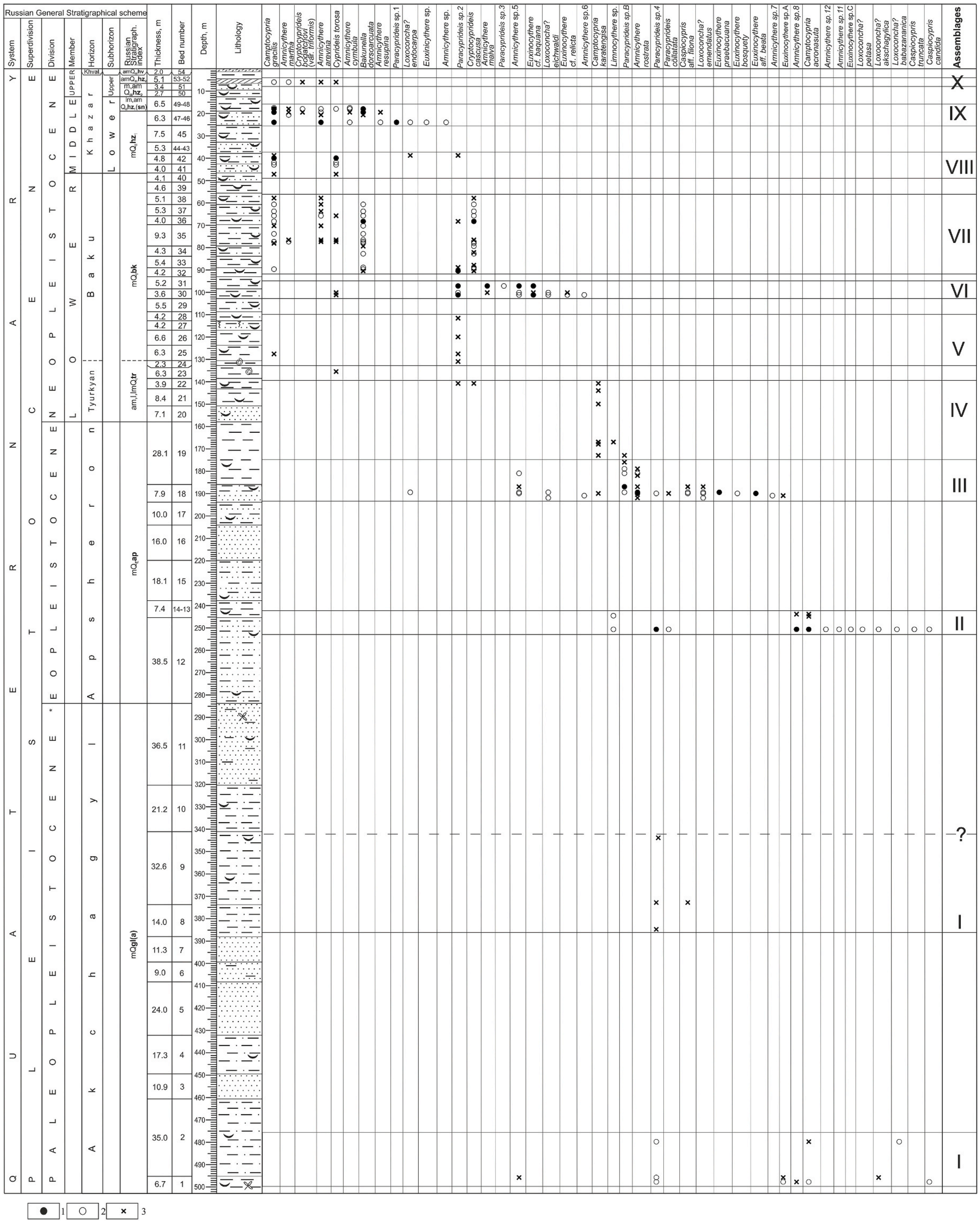


Fig. 11. Borehole 5 Seroglazovka section with ostracod data. Legend: O I - O X-ostracod assemblages. Species abundance: 1-abundant (more than 50 valves), 2-common (more than 5 valves); 3-rare (less than 5 valves). Explanation for lithological symbols, stratigraphical indices and facies genetic symbols is given in Fig. 2 caption.

admixture (*Corylus*) were widespread during the first half of the Singil. Small open areas were occupied by *Artemisia*–Amaranthaceae and Poaceae associations. In wet areas and marches, *Sphagnum,* Bryales, and *Selaginella* grew. The climate at the beginning of the Singil was cool and humid.

4.2.2. Ostracods

In total, 4050 ostracod valves belonging to 71 taxa were identified in the borehole 5 Seroglazovka core samples. Ten ostracod assemblages (O I-X) with different species composition were distinguished. The distribution of stratigraphically important ostracod species is illustrated in Fig. 11. Depth intervals with ostracod fauna, all species composition and abundance are shown in Table 3. One carapace was considered as two valves.

The Akchagyl Horizon is confined to the assemblage I (O I) (beds 1–2, 8–9; depth interval 498–343 m). Depth interval 498–480 m contains abundant ostracods and is represented by 215 valves, which are partially poorly preserved. Most species belong to the endemic Caspian

Table 3
The stratigraphical distribution of the ostracods in the borehole 5 Seroglazovka core.

	Stratigraphic Unit	Akchagyl	Apsheron	Apsheron	Apsheron-Tyurkyan	Baku-Tyurkyan	Baku	Baku	Lower Khazar	Lower Khazar	Upper Khazar	Upper Khazar
	Index	mQ**gl(a)**	mQ$_E$**ap**	mQ$_E$**ap**	mQ$_E$**ap**-am,l, lmQ$_1$**tr**	am,l, lmQ$_1$**tr** -mQ$_I$**bk**	mQ$_I$**bk**	mQ$_I$**bk**	mQ$_{II}$**hz**$_1$	mQ$_{II}$**hz**$_1$**(sn)**	m, amQ$_{II}$**hz**$_2$	amQ$_{II}$**hz**$_2$
	Complex	O I	O II	O III	O IV	O V	O VI	O VII	O VIII	O IX		O X
	Bed №	1,2,8?,9?	12-13	18-19	19-22	24-28	30-31	32-38	40-42	46-49	50	52-53
	Depth, m Taxa	343-498	244-250.8	176-193.0	140.8-173.0	111.6-131.0	97.3-101.2	57.9-90.5	38.8-47.2	17.5-24.0	11.0	6.0
1	2	3	4	5	6	7	8	9	10	11	12	13
	Loxoconcha? spp.	5v										
	Camptocypria sp.	2vAd, 5vjv										
	Candona sp.	1vfrAd 11vjv										
	Caspiocypris sp.	6vAd, 9vjv										
	Ilyocypris gibba	1vjv										
	Paracyprideis? sp. 4	64vAd, 21vjv										
	Amnicythere spp.	13v										
	Caspiocypris candida (Livental, 1929)	1vAd, 24vjv	108v									
	Caspiocypris truncana Markova in Mandelstam et al., 1962		4vAd									
	Amnicythere multituberculcata (Livental, 1929)		2vAd									
	Loxoconcha? babazananica (Livental, 1929)		46vAd, 7vjv									
	Loxoconcha? sp. C		8vAd, 8jv									
	Loxoconcha? sp. B		11vAd, 15vjv									
	Loxoconcha? sp. A		2vAd									
	Amnicythere sp. 10		1vAd									
	Amnicythere sp. 12		14vAd, 1vjv									
	Amnicythere sp. 11		11vAd									
	Paracyprideis? (Livental, 1929)		24vAd, 55 vjv									
	Cryptocyprideis sp. 3		1vjw									
	Euxinocythere sp. A	34vAd, 1vjv	1vAd									
	Amnicuthere sp. 8	1vAd, 1vjv	70vAd									
	Camptocypria acronasuta (Livental, 1929)	6vAd, 3vjv	41vAd									
	Loxoconcha? sp. H			15vAd, 11vjv								
	Amnicythere sp.G			56vAd								
	Paracyprideis? collatäta (Markova, 1959)		23vAd, 11vjv	2vAd								
	Euxinocythere sp. D	1vAd		46vAd								
	Loxoconcha? endocarpa (Sharapova in litt., 1940 sensu Schweyer, 1949)			17vAd, 2jv								
	Euxinocythere aff. beata (Stepanaitys in Mandelstam et al., 1962)			117vAd								
	Euxinocythere sp. E			16vAd								
	Euxinocythere sp. B			247vAd	-							
	Amnicythere sp.4			2vAd								
	Loxoconcha? emendatis (Markova, 1957)			24vAd, 6vA-1								

(*continued on next page*)

Table 3 (*continued*)

Stratigraphic Unit	Akchagyl	Apsheron	Apsheron	Apsheron-Tyurkyan	Baku-Tyurkyan	Baku	Baku	Lower Khazar	Lower Khazar	Upper Khazar	Upper Khazar
Index	mQ**gl(a)**	mQ$_E$**ap**	mQ$_E$**ap**	mQ$_E$**ap**-am,l, lmQ$_1$**tr**	am,l, lmQ$_1$**tr** -mQ$_I$**bk**	mQ$_I$**bk**	mQ$_I$**bk**	mQ$_{II}$**hz**$_1$	mQ$_{II}$**hz**$_1$**(sn)**	m, amQ$_{II}$**hz**$_2$	amQ$_{II}$**hz**$_2$
Complex	O I	O II	O III	O IV	O V	O VI	O VII	O VIII	O IX		O X
Bed N°	1,2,8?,9?	12-13	18-19	19-22	24-28	30-31	32-38	40-42	46-49	50	52-53
Depth, m Taxa	343-498	244-250.8	176-193.0	140.8-173.0	111.6-131.0	97.3-101.2	57.9-90.5	38.8-47.2	17.5-24.0	11.0	6.0
Caspiocypris cf. *filona* (Livental in Suzin, 1956)			12vAd, 1vjv								
Amnicythere rostrata (Evlachova, 1940)			299vAd, 29vjv								
Loxoconcha? sp. E				1vAd							
Limnocythere sp.		21vAd		1vjv							
Amnicythere sp. 11				1vAd							
Camptocypria karatengisa (Mandelstam in Mandelstam et al., 1962)			5vAd	4vAd, 4vjv							
Amnicythere caspia (Livental, 1938)					2vAd						
Amnicythere sp. 6						34vAd					
Amnicythere cf. *beata* (Stepanaitys in Mandelstam et al., 1962)						24vAd					
Loxoconcha? *eichwaldi* (Livental, 1929)						19vAd; 24vjv					
Euxinocythere cf. *baquana* (Livental, 1938)						49vAd, 12vjv					
Amnicythere sp. 5	2vAd		33vAd			19vAd, 23vjv					
Amnicythere sp. 3						42vAd, 17vjv					
Paracyprideis? sp. 3						13vAd, 1vjv					
Amnicythere sp. B							1vAd				
Amnicythere sp.							9vAd, 1vjv				
Hemicytheria? sp.							1vAd				
Loxoconcha? sp,							2vjv				
Amnicythere sp. 4							2vAd				
Cryptocyprideis cascusa (Mandelstam in Mandelstam et al., 1962)				1vAd			100vAd, 115vjv				
Paracyprideis? sp. 2			73vAd, 12vjv	1vAd	9vAd	252vAd, 175vjv	3vAd	1vAd			
Euxinocythere sp.									22vAd, 2vjv		
Amnicythere sp.									5vAd		
Loxoconcha? petasa (Livental, 1929)								1vAd	5vAd, 24vjv		
Euxinocythere virgata (Schneider in Mandelstam et al., 1962)									2vAd		
Paracyprideis? sp. 1									108vAd, 24vjv		
Amnicythere beata (Stepanaitys in Mandelstam et al., 1962)							1vAd		1vAd		
Euxinocythere baquana (Livental, 1938)									1vAd		
Limnocythere inopinata (Baird, 1850)									1vAd		
									1vAd		

(*continued on next page*)

Table 3 (*continued*)

Stratigraphic Unit	Akchagyl	Apsheron	Apsheron	Apsheron-Tyurkyan	Baku-Tyurkyan	Baku	Baku	Lower Khazar	Lower Khazar	Upper Khazar	Upper Khazar
Index	mQ**gl(a)**	mQ_E**ap**	mQ_E**ap**	mQ_E**ap**-am,l, lmQ_1**tr**	am,l, lmQ_1**tr** -mQ_I**bk**	mQ_I**bk**	mQ_I**bk**	mQ_{II}**hz**$_1$	mQ_{II}**hz**$_1$(**sn**)	m, amQ_{II}**hz**$_2$	amQ_{II}**hz**$_2$
Complex	O I	O II	O III	O IV	O V	O VI	O VII	O VIII	O IX		O X
Bed N°	1,2,8?,9?	12-13	18-19	19-22	24-28	30-31	32-38	40-42	46-49	50	52-53
Depth, m Taxa	343-498	244-250.8	176-193.0	140.8-173.0	111.6-131.0	97.3-101.2	57.9-90.5	38.8-47.2	17.5-24.0	11.0	6.0
Amnicythere resupina (Stepanaitys in Mandelstam et al., 1962)											
Bacunella dorsoarcuata (Zalányi, 1929)							61vAd, 224vjv		23vAd, 128jv		
Amnicythere cymbula (Livental, 1929)									7vAd		
Baturinella cf. *kubanica* (Schneider, 1956)										1vjv	
Cyprideis torosa (Jones, 1850)						4vjv	6vAd	19vAd, 103vjv			1jv
Amnicythere arevina (Livental in Agalarova et al., 1940)							81vAd		82vAd		1vAd
Cryptocyprideis bogatchovi (Livental, 1929) *(var. triformis)*									7vjv		1vjv
Amnicythere? quinqutuberculeata (Schweyer, 1949)			10vAd	1vAd	1vjv						1jv
Amnicythere martha (Livental in Agalarova et al., 1940)									6vAd		4vAd
Camptocypria gracilis (Livental, 1938)		3vAd			1vjv		27vAd, 25vjv	42vAd, 11vjv	92vAd, 133vjv		55vAd
Total number of ostracod valves	212v	488v	1035v	14v	13v	708v	659v	183v	674v	1v	63v
Total ostracod valves in borehole	4050 v										

Legend: O1-OX-ostracod assemblages. v – valve, Ad – adult specimens, jv - juvenile specimens. Explanation for stratigraphical indices and facies genetic symbols are given in Fig. 2 captions.

brackish water fauna. Genera *Amnicythere* and *Euxinocythere* are among the most diverse. Typical species are *Camptocypria acronasuta* (Livental, 1929) and *Caspiocypris candida* (Livental, 1929). The regular occurrence of juvenile ostracod instars of freshwater species belonging to Candoninae and the genus *Ilyocypris* indicates some decrease in salinity of the basin. The ostracod fauna at depths of 385, 373 and 343 m was represented only by five valves which have no stratigraphic significance, so they were tentatively referred to this assemblage and their distribution is shown in Table 3.

The Apsheron Horizon is represented by two different assemblages (O II and O III). In O II (beds 12 and 13; depth interval of 250.8–244 m), common species are *Paracyprideis*? *naphtatscholana* (Livental, 1929), *Paracyprideis*? *collatäta* (Markova, 1959), *Loxoconcha*? *babazananica* (Livental, 1929), *Amnicythere rostrata* (Evlachova). Also, species *Caspiocypris candida* and *Camptocypria acronasuta* (Livental, 1929) were identified, which are typical both for the Akchagyl and Apsheron. In most samples, brackish water fauna dominates, but at certain depth intervals (depth 244.7 m) ostracods of genus *Limnocythere* prevail indicating a periodic decrease in salinity down to slightly saline conditions.

O III (beds 18 and 19, the lowest part; depth interval of 193–176 m) is typical for environments with higher salinity compare to O II. It is distinguished by relatively high diversity and abundance of the brackish water ostracod fauna. Species indicating low saline condition of the basin are absent. *A. rostrata*, *Paracyprideis* sp. B, *Loxoconcha*? *emendatis* (Markova, 1959), *Euxinocythere* cf. *praebacuana* (Livental in Agalarova et al., 1940), *Euxinocythere* aff. *beata* (Stepanaitys in Mandelstam et al., 1962) are typical for this assemblage. From a depth of 182 m and upper in the section (bed 19), a gradual decrease in species diversity is observed. This is most likely due to a decrease in salinity and shallowing of the basin, which is also confirmed by the appearance of representatives of the genus *Limnocythere*.

The Apsheron-Tyurkyan boundary is confined to the assemblage O IV (beds 19, upper part and 20–22; depth interval of 173–140.8 m). It is low abundant (only 14 valves) with regular occurrence of *Camptocypria karatengisa* (Mandelstam et al., 1962).

The Baku Horizon consists of three assemblages (O V, O VI and O VII). O V (beds 24–28, depth interval of 131–111.6 m) is confined to the lower part of the Baku deposits. It contains single specimens of *Cyprideis torosa* and valves of *Paracyprideis* sp. B indicating shallow conditions during sedimentation.

O VI (beds 30 and 31, depth interval of 101.2–97.3 m) is represented by various species of family Leptocytheridae, *Loxoconcha*? *eichwaldi* (Livental, 1929), *C. torosa* and *Paracyprideis* sp. 2, which are typical for relatively shallow environments. This complex existed for a short time and is replaced by the deeper (cold-water) Baku assemblage O VII (beds 32–38; depth interval 90.5–57.9 m). The common species of O VII are

Camptocypria gracilis (Livental, 1938), *Bakunella dorsoarcuata* (Zalanyi, 1929), *Cryptocyprideis cascusa* (Mandelshtam in Mandelstam et al., 1962) and *Amnicythere arevina* (Livental, 1940).

The Khazar Horizon in the borehole is represented by three different assemblages (O VIII, O IX, O X). The assemblage O VIII (beds 40–42; depth intervals of 47.2–38.8 m) corresponds to the Lower Khazar. It is impoverished and represented by only two ostracod species such as *C. torosa* and *C. gracilis*.

O IX (beds 46–49; depth interval of 24.0–17.5m) correlates with the Lower Khazar (Singil) deposits and is distinguished by a diverse ostracod species composition: *C. gracilis* (Livental, 1938), *B. dorsoarcuata*, *A. arevina*, *Amnicythere cymbula* (Livental, 1929), *Amnicythere martha* (Livental in Agalarova et al., 1940), *Cryptocyprideis bogatchovi* (Livental, 1929). According to species composition, it is similar to the Baku assemblage O VII due to the presence of *C. gracilis* (Livental, 1929), *Bakunella dorsoarcuata*, and *A. arevina*, but species typical for shallower environments and Khazar age appear in these deposits: *A. cymbula*, *Amnicythere resupina* (Stepanaitys in Mandelstam et al., 1962), *A. martha*, *Loxoconcha*? *petasa* (Livental, 1929). This assemblage indicates shallow water conditions and relatively low water temperature.

At a depth of 11 m (bed 50), a single valve of *Baturinella* cf. *kubanica* (Schneider, 1956) was found; it is common for the lake-alluvial and liman-alluvial Khazar deposits of the Northern Caspian area. It usuallyoccurs in combination with diverse freshwater ostracods (Karmishina and Sedaikin, 1978), and indicates the existence of small freshwater or slightly saline water bodies. However, considering only a single valve found at this level, a separate assemblage was not assigned there.

The assemblage O X (bed 52; depth 6 m) of the Upper Khazar is relatively similar to O IX but is represented by a poorer species composition. Its main component (83%) is ostracods *Camptocypria gracilis*.

The ostracod species composition in the outcrop section is well described by Sedaikin (1988), where he studied in detail what we define here as the S3 outcrop section. In the Upper Khazar deposits of the bed 3 (our nomenclature is adapted here and further on), ostracod species are represented by a diverse assemblage of brackish water Caspian species belonging to the genera *Cryptocyprideis*, *Amnicythere*, *Euxinocythere*, *Xestoleberis* and family Loxoconchidae, as well as the euryhaline *C. torosa* and single representatives of freshwater fauna. In the overlying deposits of the Upper Khazar beds 7 and 8, ostracod assemblage is represented by a brackish-water species *C. bogatchovi*, *C. gracilis*, *A. arevina*, and *Loxoconcha*? *goibboides*, euryhaline *C. torosa* and representatives of the freshwater genera *Limnocythere*, *Candona*, *Ilyocypris*, *Cyclocypris* and *Cypria* (Sedaikin, 1988; Karmishina and Sedaikin, 1978).

The Khvalyn Horizon is represented by two different assemblages (Karmishina and Sedaikin, 1978; Sedaikin, 1988). The first assemblage corresponds to the bed 10 and is represented by euryhaline ostracods *C. torosa*, freshwater species *Limnocythere fontinalis* and juvenile instars of *Candona*. The second assemblage corresponds to the bed 11 and is distinguished by relatively high diversity and abundance of the brackish water ostracod fauna of genera *Paracyprideis*, *Cryptocyprideis*, *Loxoconcha*?, *Euxinocythere*, *Amnicythere*. In addition, freshwater ostracods of the genus *Limnocythere* are present in the bed 11 (Karmishina and Sedaikin, 1978; Sedaikin, 1988).

4.2.3. Molluscs

In total, 19 400 mollusc shells were found and identified in the deposits of the borehole and outcrop sections. Molluscs are represented by freshwater, brackish water (marine) and single terrestrial species. Two classes (Gastropoda and Bivalvia), 15 families (Succineidae, Lymnaeidae, Planorbidae, Valvatidae, Viviparidae, Bithyniidae, Pyrgulidae, Hydrobiidae, Lithoglyphidae, Neritidae, Dreissenidae, Sphaeriidae, Unionidae, Corbiculidae, and Cardiidae), 25 genera and 55 species were recognized. Collection analysis as well as genesis of the facies and stratigraphical distribution of the mollusc shells permitted to define ten malacocomplexes (MC I-X). Malacocomplexes I–V were defined for the

Table 4
The stratigraphical distribution and number of mollusc shell remains in the borehole 5 Seroglazovka section.

	Stratigraphic Unit	Akchagyl	Apsheron		Tyurkyan		Baku	Lower Khazar
	Index	mQ**gl(a)**	mQ_E**ap**	mQ_E**ap**-lmQ_1**tr**?	lm,lQ_I**tr**	lm,lQ_I**tr**-Q_I**bk**?	mQ_I**bk**	mQ_{II}**hz**$_1$
	Complex	MCI	MCII	MCII-III?	MCIII	MCIII-IV?	MCIV	MCV
	Bed	1, 2, 4	12-15, 17-18	19-22	23-24	25-26	27-39	40-48
	Taxa / Depth, m	501, 496, 445	261-238, 194-187	185.5-139.8	138.5-130	128-120	114-113.6, 109.6, 101.2-98.3, 91, 90.5-87.9, 79.4-54	50.7, 47.2-21.4
1	*Valvata* sp.				3*			
2	?*Viviparus* sp.				1			
3	*Lithoglyphus naticoides* (Pfeiffer, 1828)				1			
4	*Pyrgula* cf. *conus* (Eichwald, 1838)	1						
5	*Pyrgula variabilis* (Eichwald, 1841)		1					
6	*Pyrgula* cf. *caspia* (Eichwaid, 1838)		fr					
7	*Pyrgula* sp.		fr	1			5	
8	Gastropoda		5	2	1		2	
9	*Dreissena* cf. *polymorpha* (Pallas, 1771)		1					
11	*Dreissena* cf. *caspia isseli* (Andrussow, 1923)		fr				1	
12	*Dreissena rostriformis distincta* (Andrussov, 1903)	fr	fr				1	
11	*Dreissena* sp.	fr	fr	fr	4+fr	fr	fr	26
12	*Didacna* sp.						fr	fr
13	*Monodacna caspia* (Eichwald, 1829)		ps					
14	*Parapsheronia* cf. *raricostata* (Sjoegren) (Andrussov, 1923)		ps					
15	*Parapsheronia* sp.		fr					
16	Cardiidae	+	+	+	+	+	+	+
17	Detritus	+	+	+	+	+	+	+
	Palaeoenvironment	M	M	M/B	F	F / B	M	M

Legend: *-number of shells, fr-fragments of shells, ps-shell imprints, +-fragments were not calculated. Palaeoenvironment: M-marine; B-brackish water; F-freshwater. Explanation for stratigraphical indices and facies genetic symbols are given in Fig. 2 captions.

Table 5
The stratigraphical distribution and number of mollusc shell remains in the Middle-Upper Neopleistocene deposits of the Seroglazovka locality.

N	Stratigraphic Unit	Lower Khazar	Lower Khazar	Upper Khazar	Upper Khazar	Upper Khazar	Upper Khazar	Upper Khazar	Upper Khazar	Upper Khazar	Upper Khazar	Upper Khazar	Upper Khazar	Khvalyn
	Index	l,lm$Q_{II}\mathbf{hz}_1$ (**sn**)	l,lm $Q_{II}\mathbf{hz}_1$(**sn**)	am$Q_{III}\mathbf{hz}_2$	m, lm$Q_{III}\mathbf{hz}_2$	am$Q_{III}\mathbf{hz}_2$	am$Q_{III}\mathbf{hz}_2$	l,lm, $a_pQ_{III}\mathbf{hz}_2$	am$Q_{III}\mathbf{hz}_2$	am$Q_{III}\mathbf{hz}_2$	am$Q_{III}\mathbf{hz}_2$	am$Q_{III}\mathbf{hz}_2$	am$Q_{III}\mathbf{hz}_2$	am$Q_{III}\mathbf{hv}$
	Complex	MCVI	MCVI	MCVII	MCVII	MCVIII	MCVIII	MCIX	MCX	MCX	MCX	MCX	MCX	MCXI
	Section/Bed N	S1 / 1	S3 / 1	S1 / 2	S3 / 3	S1 / 4	S3 / 4	S3 / 5	S1 / 7	S3 / 7	S4 / 7	S2 / 7	S4 / 9	S4 / 10
	Taxa / Sample N	3968	3976, 5066	3969, 3970, 3520	3525	3511, 3971, 4411	3973	6038	3526	3510, 4412	4413	3972	3977, 3978	3979, 3583, 3584
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	*Succinella oblonga* (Draparnaud, 1801)										1			
2	Lymnaeidae			1 juv.										
3	*Planorbis planorbis* (Linné, 1758)	2*				11				1	1		4	
4	*Anisus spirorbis* (Linné, 1758)			5						3	3			
5	*Anisus eichwaldi* (Grimm, 1888)			14										
6	*Gyraulus laevis* (Alder, 1838)			23							17	1		1
7	*Gyraulus gredleri* (Gredler, 1853)												9	
8	*Gyraulus* sp.									3 juv.				
9	*Gyraulus riparius* (Westerlund, 1865)			1										
10	*Valvata piscinalis* (Müller, 1774)			69		20	5			19	25	17	35	
11	*Valvata* cf. *antiqua* (Sowerby, 1832)			6									2	
12	*Valvata* cf. *pulchella* (Studer, 1820)										5			
13	*Borysthenia naticina* (Menke, 1845)							10		44	22			
14	*Viviparus diluvianus* (Kunth, 1865)					19+2 fr.						1+2 fr	24+fr	
15	*Viviparus* sp.			3 fr.			2 fr.			3 fr	2 juv. + 2 fr.		5 juv.+1 fr	
16	*Bithynia troschelii* (Paasch, 1842)									3 juv. + 3 fr	1 juv.			
17	Operculum (*Bithynia tentaculata* (Linné, 1758))			14				1						
18	*Pyrgula dimidiata* (Eichwald, 1838)			10		3+6 fr				1	3		4	
19	*Pyrgula conus* (Eichwald, 1838)			133		485	250	122		60	181	20	169	
20	*Pyrgula* cf. *conus* (Eichwald, 1838) (high shell)					72								
21	*Pyrgula spica* (Eichwald, 1838)							1		1	6 fr.			
22	*Pyrgula* cf. *variabilis* (Eichwald, 1838)			48		238	10					19	180	
23	*Pyrgula caspia* (Eichwaid, 1838)			>970+100 juv.	1	397	39	16		109+183 fr	125	62	637	1
24	*Pyrgula* sp. fr. + juv.							4		12	140		10	
25	*Pyrgohydrobia* sp., *Pyrgohydrobia conica* (Logvinenko et Starobogatov, 1968) ? *Ecrobia ventrosa* (Montagu, 1803)	Num.			>300						19			
26	*Lithoglyphus naticoides* (Pfeiffer, 1828)			286		17	2			327+25 fr	21	34	44	
27	*Theodoxus (Theodoxus) pallasi* (Lindholm, 1924)	4		14		71	5	1		7	20	3	55	
28	*Dreissena polymorpha* (Pallas, 1771)			13	3	36			7	20+2 juv.	35	10	39	12
29	*Dreissena rostriformis distincta* (Andrussov, 1903)		Num.	602+>500 juv.	26	149	84	72	15	52+2 juv.	118 + 167 fr	28	55	21
30	*Dreissena caspia crassa* (Eichwald, 1855)								1					
31	*Dreissena caspia eichwaldi* (Issel, 1886)		Num.	>300		236	49	56	15	161	356 + 583 fr	173	159	

(*continued on next page*)

Table 5 (*continued*)

N	Stratigraphic Unit	Lower Khazar	Lower Khazar	Upper Khazar	Upper Khazar	Upper Khazar	Upper Khazar	Upper Khazar	Upper Khazar	Upper Khazar	Upper Khazar	Upper Khazar	Upper Khazar	Khvalyn
	Index	l,lmQ_{II}**hz_1** **(sn)**	l,lm Q_{II}**hz_1(sn)**	amQ_{III}**hz_2**	m, lmQ_{III}**hz_2**	amQ_{III}**hz_2**	amQ_{III}**hz_2**	l,lm, $a_p Q_{III}$**hz_2**	amQ_{III}**hz_2**	amQ_{III}**hz_2**	amQ_{III}**hz_2**	amQ_{III}**hz_2**	amQ_{III}**hz_2**	amQ_{III}**hv**
	Complex	MCVI	MCVI	MCVII	MCVII	MCVIII	MCVIII	MCIX	MCX	MCX	MCX	MCX	MCX	MCXI
	Section/Bed N	S1 / 1	S3 / 1	S1 / 2	S3 / 3	S1 / 4	S3 / 4	S3 / 5	S1 / 7	S3 / 7	S4 / 7	S2 / 7	S4 / 9	S4 / 10
	Taxa / Sample N	3968	3976, 5066	3969, 3970, 3520	3525	3511, 3971, 4411	3973	6038	3526	3510, 4412	4413	3972	3977, 3978	3979, 3583, 3584
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
32	*Dreissena* sp.	2 fr		Num.		Num.				>500	Num.		Num.	
33	*Didacna protracta* (Eichwald, 1841) + *D.* cf. *protracta*			27 +40 juv.	49								1	
34	*Didacna* ex gr. *parallela - protracta*										24			
35	*Didacna ebersini* (Fedorov, 1953) + *D.* cf. *ebersini*			37					42	41	22		83	
36	*Didacna* cf. *praetrigonoides* (Nalivkin et Anissimov, 1915)												31	
37	*Didacna* cf. *subpyramidata* (Pravoslavlev, 1939) (short shells)			29		13	15	6	2	26	11	17		1 juv.
38	*Didacna* cf. *catillus volgensis* (Svitotsch, 1967)			71										
39	*Didacna delenda* (Bogatschev, 1932), *Didacna delenda emendata* (Popov, 1983)			63		77								
40	*Didacna* cf. *surachanica* (Andrussov, 1910)			6		51	16	12	9 + 25 juv.				20	
41	*Didacna subcrassa* (Pravoslavlev, 1939)			22	20	25			25					
42	*Didacna hospes* (Vekilov, 1969)					1								
43	*Didacna nalivkini* (Wassoevitsch, 1929)			17				37				23	97	11
44	*Didacna pontocaspia* (Pavlov, 1926)			9	21	85	63		8				3	
45	*Didacna* sp. (juv. fr.)			Num.		195		177		75	Num.	Num.		9
46	*Monodacna* cf. *caspia* (Eichwald, 1829)			140+11 juv.	17	151	7	14	25	60 + 5 juv.	29	16	146 + 96 juv.	1
47	*Hypanis plicata* (Eichwald, 1829)			34 +8 juv.+ 29 fr	5	2		5 fr.	1	1	3 fr	1	34	
48	*Adacna angusticostata polymorpha* (Logvinenko & Starobogatov, 1967)					4								
49	*Adacna vitrea* (Eichwald, 1831)									29			13	
50	*Adacna* cf. *laeviscula* (Eichwald, 1829)									3 + 2 juv.			7 + 16 fr	
51	*Adacna* sp. juv.+fr			Num.		9				Num.		1		
52	Cardiidae (fr.+juv.)		Num.	Num.		Num.	Num.	Num.		Num.	Num.	Num.	Num.	14
53	*Corbicula fluminalis* (Müller, 1774)			8		5	2	3	+	4	16	1	50	
54	*Sphaerium rivicola* (Lamarck, 1818)			6		4	1			183+13 fr	27	1	141 + 46 juv.	
55	*Pisidium amnicum* (Müller, 1774)			22		9	1 juv.	1r		13	35	1	37	
56	*Pisidium supinum* (A. Schmidt, 1850)												68	
57	Unionidae			6 fr			3 fr.	2 fr		2 fr	4 fr		Num. fr	14 fr
58	*Unio pictorum* (Linnaeus, 1758)												2 r+3 l	
59	Detritus + juvenile shells			Num.			Num.			Num.	Num.	Num.	Num.	+
	Palaeoenvironment	F	F	F / B	F	F / B	F / B	F / B	F	F / B	F / B	F	F / B	F / B

Legend: *-number of shells, fr-fragments of shells, juv.-juvenile shells, Num.-numerous not calculated remains, l-left valve, r-right valve. Explanation for stratigraphical indices and facies genetic symbols is given in Fig. 2 captions.

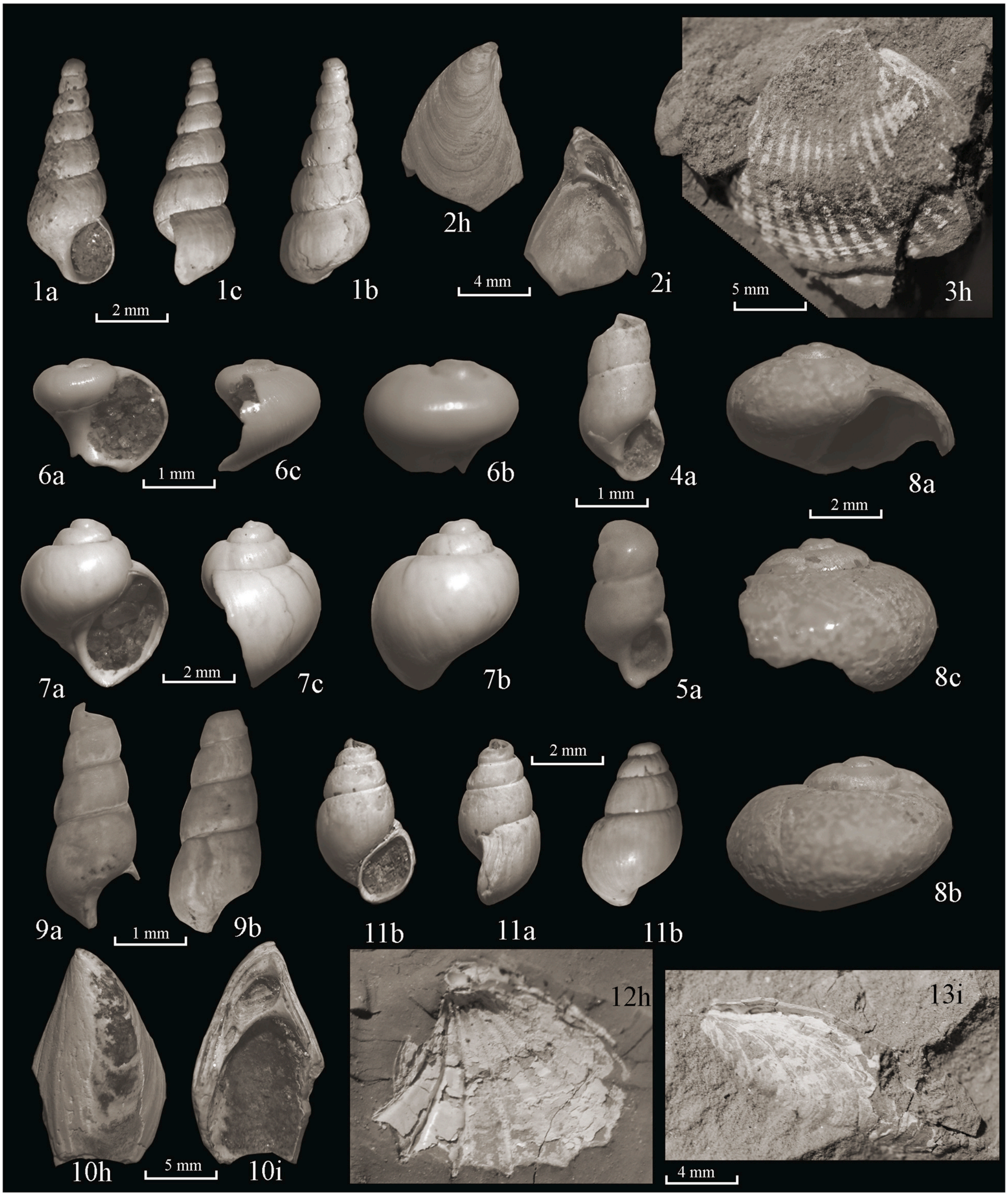


Fig. 12. Mollusc shells from the Akchagyl – Middle Neopleistocene deposits of the borehole 5 Seroglazovka.
Legend: Lower Khazar, Middle Neopleistocene (MCV): 1-*Pyrgula caspia* (Eichwaid), IG 243/4463/10, depth 23.4 m; 2-*Dreissena rostriformis distincta* (Andrusov), right valve, IG 252/4465/12, depth 24.0 m; Baku, Lower Neopleistocene (MCIV): 3-*Didacna* ex gr. *crassa*, right valve, IG 252/4496a, depth 90.5 m; 4-*Pyrgula* sp., IG 252/4485/18, depth 72.0 m; 5-*Pyrgula* sp., IG 252/4483/17, depth 70.3 m; Tyurkyan, Lower Neopleistocene (MCIII): 6-*Valvata* sp., IG 252/4511/21, depth 130.0 m; 7-*Lithoglyphus naticoides* (Pfeiffer), IG 252/4511/20, depth 134.5 m; 8-*Viviparus* sp., IG 252/4508/19, depth 130.0 m; Apsheron, Eopleistocene (MCII): 9-*Pyrgula caspia* (Eichwald), IG 252/4551/27, depth 189.5 m; 10-*Dreissena rostriformis distincta* (Andrusov), left valve, IG 252/4569/33, depth 253.0 m; 11-*Pyrgula conus* Eichwald, IG 252/4571/34, depth 445.0 m; 12-*Parapsheronia* cf. *raricostata* (Sjoegren) (Andrusov, 1923), imprint, IG 252/4567c, depth 251.0 m; Akchagyl, Palaeopleistocene (MCI); 13-*Dreissena rostriformis distincta* (Deshayes), imprint, IG 252/4574/36, depth 501.0 m; a-apertural view; b-abapertural view (view from the opposite side of the aperture); c-lateral view (top right); h-external view; i-internal view; j-top view; (MC)-mollusc complexes; IG 243/4463/10-registration number.

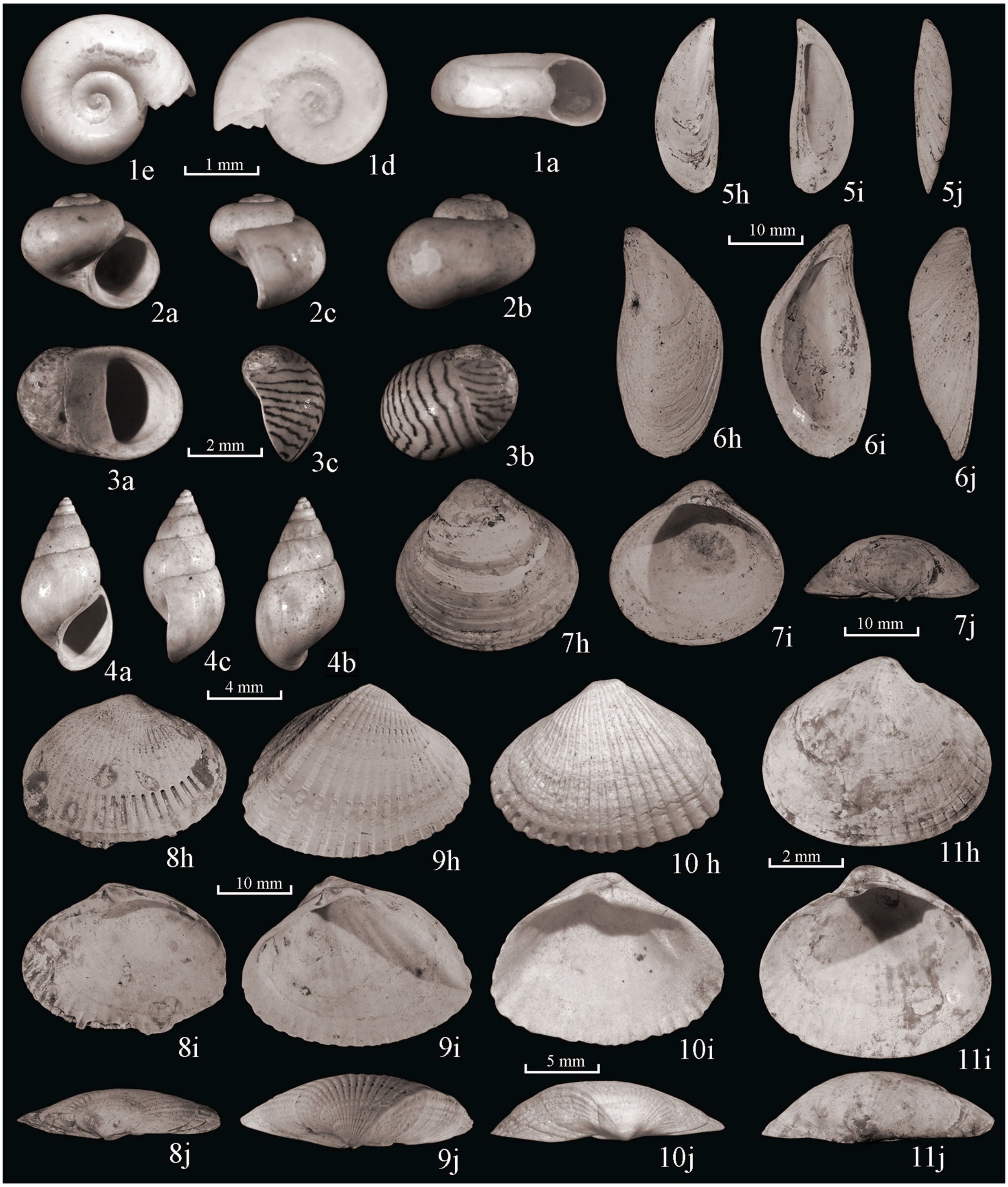


Fig. 13. Mollusc shells from the Middle–Upper Neopleistocene deposits of the Seroglazovka locality.
Legend: Lower Khazar, Middle Neopleistocene (MC VI): 1-*Planorbis planorbis* (Linnaeus), IG 239/3968/1, Seroglazovka 1; Upper Khazar, Upper Neopleistocene (MC VII–X): 2-*Valvata piscinalis* (Müller), IG 283/4411/2, Seroglazovka 1; 3-*Theodoxus pallasi* Lindholm, IG 283/4411/5, Seroglazovka 1; 4-*Pyrgula conus* Eichwald, IG 283/4411/7, Seroglazovka 1; 5-*Dreissena caspia crassa* (Andrussov), right valve, IG 232/3978/7, Seroglazovka 4; 6-*Dreissena polymorpha* (Pallas), left valve, IG 232/3978/20, Seroglazovka 4; 7-*Corbicula fluminea* (Müller), right valve, IG 232/3978/3, Seroglazovka 4; 8-*Didacna surachanica* (Andrusov), right valve, IG 312/6038/10, Seroglazovka 3; 9-*Didacna subpyramidata* (Pravoslavlev), right valve, IG 310/4412/119, Seroglazovka 3; 10-*Didacna ebersini* (Fedorov), left valve, IG 310/4412/106, Seroglazovka 3; 11-*Monodacna caspia* (Eichwald), right valve, IG 39/4413/10, Seroglazovka 4; a-apertural view; b-abapertural view (view from the opposite side of the aperture); c-lateral view (top right); d-umbo view; e-top view; h-external view; i-internal view; j-top view; g-side view; IG 236/3948/1-IG UFRC RAS registration number.

borehole section (Fig. 2) and other complexes were interpreted for the outcrop section (Fig. 3). The species composition of different malacocomplexes is represented in Tables 4 and 5.

The Akchagyl Horizon represents MC I, which was confined to the deposits of the lower part of the section (borehole 5 Seroglazovka; beds 1, 2, 4, at depths of 501, 496, and 445 m) and is characterized by a poor species composition. Only a single shell of *Pyrgula* cf. *conus* (Eichwald, 1838), as well as *Dreissena rostriformis distincta* (Andrusov, 1897), *Dreissena* sp., and shell fragments of Cardiidae were found there (Table 4, Fig. 12). This complex is tentatively correlated to the Akchagyl, based on its occurrence under the Apsheron deposits.

The Apsheron Horizon corresponds to MC II which was derived from the beds 12–15, 17–18 (borehole 5 Seroglazovka; depth intervals of 261–238 and 194–187 m) and is represented by six complete shells as well as numerous fragments of brackish water mollusc shells (eight species and five genera) (Table 4, Fig. 12). Key species *Parapsheronia* cf. *raricostata* (Sjoegren) (Andrusov, 1923) indicate Apsheron age of these deposits (Kolesnikov, 1950).

Apsheron-Tyurkyan transition. Transitional MC II–III (borehole 5 Seroglazovka; beds 19–22; depth interval of 185.5–139.8 m) contains rare shells of brackish water gastropods, namely *Dreissena* and Cardiidae (Table 4, Fig. 12). Because of poor preservation and small number of the studied specimens, the complex of molluscs is difficult to compare with Apsheron or Tyurkyan complexes. We suggest that the sediments containing this complex could have been accumulated at the end of the Apsheron transgression/beginning of the Tyurkyan regression.

The Tyurkyan Horizon corresponds to MC III (borehole 5 Seroglazovka, beds 23–24; depth interval of 138.5–130 m) which is represented by rare freshwater gastropods, as well as *Dreissena* and Cardiidae shell fragments (Table 4, Fig. 12). In total, 10 shells and their fragments were determined. Freshwater molluscs belong to four species of four genera. Brackish water molluscs belong to one species within the genus *Didacna* (Table 4, Fig. 12). MC III can be correlated to the Tyurkyan regression based on the presence of freshwater taxa.

Tyurkyan-Baku transition. Transitional MC III–IV (borehole 5 Seroglazovka; beds 25–26; depth interval of 128–120 m) is allocated according to its position in between the underlying deposits containing freshwater molluscs and overlaying grey clays with *Didacna* ex gr. *crassa*. Therefore, we suggest that the sediments containing this complex could have been accumulated at the end of the Tyurkyan regression/beginning of the Baku transgression.

The Baku Horizon is characterized by MC IV (borehole 5 Seroglazovka; beds 27–39; depth intervals of 114–113.6, 109.6, 101.2–98.3, 91, 90.5–87.9, and 79.4–54 m) which contains 12 complete shells and the fragments of only brackish water molluscs which were assigned to four species and three genera (Table 4, Fig. 12). The shell imprints of *Didacna* belong to *Didacna* ex gr. *crassa* group. The presence of imprints of large *crassa*-like *Didacna* and peculiar lithological features of the deposits (dark grey loam and clay) allow us to attribute this complex to the Baku period.

The Lower Khazar Subhorizon corresponds to MC V (borehole 5 Seroglazovka; beds 40–48; depth of 50.7, 47.2–21.4 m) and MC VI (Seroglazovka outcrop section, bed 1). MC V is represented by 30 shells and their fragments belonging to three species of three genera (Table 4, Fig. 12). Key Khazar mollusc species were not found there, but the lithology of the deposits permits correlating this MC to the Early Khazar

Table 6
Fish, amphibian, reptilian and small mammalian finds in the Upper Khazar deposits of the Seroglazovka locality.

N	Stratigraphic Unit	Upper Khazar	Upper Khazar	Upper Khazar	Upper Khazar	Upper Khazar	Total number
	Index	$amQ_{III}\mathbf{hz}_2$	$amQ_{III}\mathbf{hz}_2$	$amQ_{III}\mathbf{hz}_2$	$amQ_{III}\mathbf{hz}_2$	$amQ_{III}\mathbf{hz}_2$	
	Section/Bed N	S1 / 2	S3 / 7	S4 / 7	S4 / 9	S4 / 9	
	Taxa / Sample N	3970	4412	4413	3977	3978	
1	**Pisces**						
1.1	*Rutilus rutilus* (L., 1758)		1/1 (pharyngeal bone)	3/3 (pharyngeal tooth)			4
1.2	*Abramis brama* (L., 1758)			1/1 (pharyngeal bone)			1
1.3	*Carassius carassius* (L., 1758)			2/2 (pharyngeal tooth)			2
1.4	*Stenodus leucichthys* (Gueldenstaedt, 1772)				1/1 (vertebra)		1
1.5	*Esox* sp.		1/1 (vertebra)	1/1 (vertebra)			2
1.6	*Lota lota* (L., 1758)		2/2 (vertebra)			1/1 (vertebra)	3
1.7	*Perca fluviatilis* (L., 1758)			23/3 (opercular, articular, cleithra)	1/1 epihyal		4
1.8	*Perca* sp.			1/1 (ctenoid scale)			1
1.9	Percidae gen. et sp. indet.		1/1 (fin ray)	7/7 (fin ray (3), vertebra (4))		2/2 (vertebra)	10
1.10	Teleostei indet.	1/1 (vertebra)	2/2 (vertebra, rib)	3/3 (vertebra(1), bone fragments (2))		4/4 (rib (3)), bone fragments (1))	10
	Total number	1	7	20	3	7	38
2	**Amphibia**						
2.1	Anura indet.			1/1* (antebrachium)			1
3	**Reptilia**						
3.1	*Eremias arguta* (Pallas, 1773)			1/1* (trunk vertebra)			1
3.2	Sauria indet.			1/1(caudal vertebra)			1
4	**Mammalia**						
4.1	*Spermophilus pygmaeus* (Pallas, 1778)		3/1* (1p4, 1m1 fr., 1m2 fr.)				3
4.2	*Eolagurus luteus* (Eversmann, 1840)			1/1 (1M1 fr.)		1/1 (1m2)	2
4.3	*Arvicola* sp.		2/1(1M1,1M2)	1/1(1m2 fr.)			3
4.4	*Microtus* sp.			1(1M1)			1
	Total number		5/2	6/6		1/1	12
	Palaeoenvironment		Semi-desert	Semi-desert and near water species		Semi-desert	

Legend: *-number of bone remains / number of individuals; fr.-fragment; p-premolar of the lower jaw; m-molar of the lower jaw (p4-fourth premolar; m1-first molar; m2-second molar); M-molar of the upper jaw (M1-first molar; M2-second molar). Explanation for stratigraphical indices and facies genetic symbols is given in Fig. 2 captions.

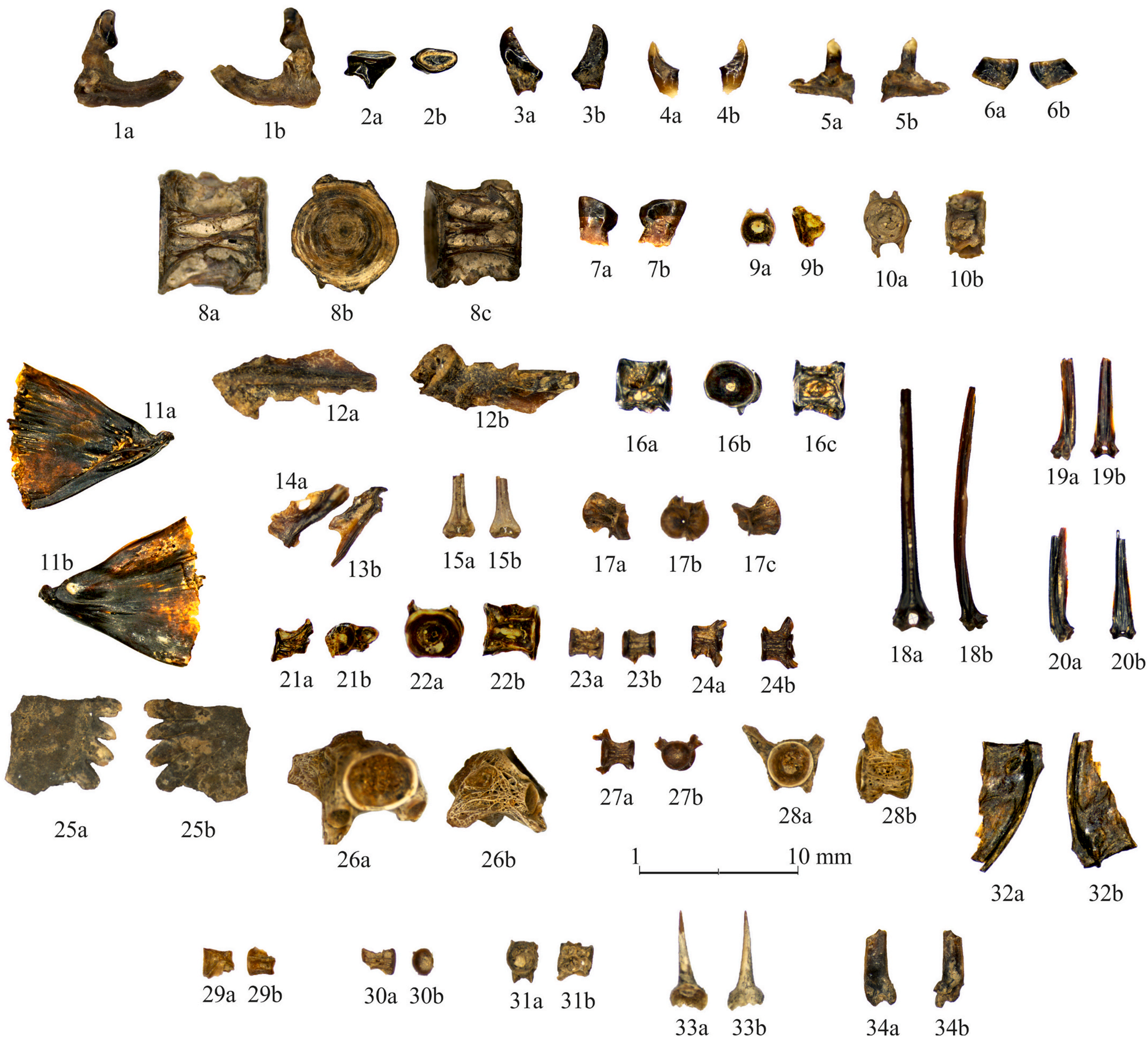


Fig. 14. Fish remains from the Upper Khazarian deposits of the Seroglazovka locality.
Legend: *Rutilus rutilus*: 1a–b-pharyngeal bone fragment in medial (1a) and lateral view (1b) (4412); 2a–b-pharyngeal tooth in lateral (2a) and dorsal view (2b) (4413); 3a–b-pharyngeal tooth in medial (3a) and lateral views (3b) (4413); 4a–b-pharyngeal tooth in medial (4a) and lateral view (4b) (4413). *Abramis brama*: 5a–b-pharyngeal bone fragment in medial (5a) and lateral view (5b) (4413). *Carassius carassius*: 6a–b-pharyngeal tooth in lateral (6a) and medial view (6b) (4413); 7a–b-pharyngeal tooth in lateral (7a) and medial view (7b) (4413). *Stenodus leucichthys*: 8a–c-abdominal vertebra centrum in ventral (8a), anterior (8b) and lateral view (8c) (3977). *Esox* sp.: 9a–b-centrum fragment in anterior (9a) and dorsal view (9b) (4412), 10a–b-abdominal centrum in anterior (10a) and lateral view (10b) (4413). *Perca fluviatilis*: 11a–b-epihyal in medial view (11a) and lateral view (11b) (3977), 12a–b-opercular fragment in medial (12a) and external view (12b) (4413); 13-cleithra fragment in lateral view, 13b-articular in lateral view (4413). Percidae gen. et sp. indet.: 14a–b – fin ray base in posterior (14a) and anterior view (14b) (4412), 15a–c-vertebra centrum in different views (3978), 16a–c-vertebra fragment indifferent views (3978); 17a–b-fin ray in posterior (17a) and lateral view (17b) (4413), 18–19a–b-fin ray fragment in lateral (18a, 19a) and anterior view (18b, 19b) (4413), 20a–b-vertebra fragment in different views (4413), 21a–b-vertebra centrum in anterior (21a) and ventral view (21b) (4413), 22a–b-vertebra centrum in ventral (22a) and dorsal view (22b) (4413), 23a–b-vertebra centrum in ventral (23a) and dorsal view (23b) (4413). *Perca* sp.: 24a–b-ctenoid scale fragment in internal (24a) and eternal view (24b) (4413). *Lota lota*: 25a–b-vertebra centrum in posterior (25a) and lateral view (25b) (4412), 26a–b-vertebra centrum in dorsal (26a) and posterior view (26b) (3978), 27a–b-vertebra centrum in posterior (27a) and dorsal view (27b) (4412). Teleostei indet.: 28 a–b (4412), 29 a–b (3970), 30 a–b (4413)-vertebrae fragments in different views, 31 a–b (3978), 32 a–b (4413), 33 a–b (4413)-bone fragments in different views. IG UFRC RAS registration numbers: 3970-Seroglazovka 1, bed 2; 4412-Seroglazovka 3, bed 7; 3978-Seroglazovka 4, bed 7; 4413-Seroglazovka 4, bed 7; 3977-Seroglazovka 4, bed 9.

period.

MC VI comes from the bed 1 of the Seroglazovka outcrop section. More than 300 shells of three species and genera of freshwater molluscs accompanied with two species and three genera of brackish water molluscs were identified (Table 4, Fig. 13). The presence of freshwater species and the occurrence of the fossil-bearing bed between two marine (brackish water) formations suggest a regressive stage at the end of the Early Khazar transgression, which is referred as the Singil.

The Upper Khazar Subhorizon. *Didacna* species in the MC VII–X indicate Late Khazar age of the deposits. The allocation of molluscs into complexes was done due to the different genesis of the fossil-bearing deposits. The presence of numerous brackish water taxa in fluvial deposits with forms typical for the Khazar and their satisfactory preservation indicate erosion of marine Khazar sediments, short-term transportation and redeposition of the shells.

MC VII was found in the beds 2–3 of the Seroglazovka outcrop section represented by the alternation of grey sands, brown clays and greyish-brown silts (am,lmQ_{III}hz$_2$). 740 shells of freshwater molluscs belonging to 21 species and 16 genera as well as 3057 shells of brackish water molluscs assigned to 24 species within 7 genera were recognized in MC VII (Tables 4 and 5, Fig. 13).

MC VIII corresponds to the bed 4 which consists of grey sands (amQ_{III}hz$_2$). 209 shells of freshwater molluscs belonging to 9 species and 10 genera as well as 2531 shells of brackish water molluscs assigned to 15 species within 6 genera were recognized in MC VIII (Tables 4 and 5, Fig. 13). *Didacna subcrassa* (Pravoslavlev, 1939), *D.* cf. *surachanica* (Andrusov, 1902), *D.* cf. *subpyramidata* (Pravoslavlev, 1939), *D.* cf. *catillus volgensis* (Svitoch et al., 1995), *D. delenda emendata* (Popov, 1983) and other species indicate Khazar age of the fossil-bearing deposits.

MC IX belongs to the bed 5 of the Seroglazovka section and contains *Didacna subpyramidata* (Pravoslavlev, 1939), *D.* cf. *surachanica* (Andrusov, 1902), *D. nalivkini* (Wassoevitch, 1930) and some other taxa indicating Khazar age of deposits. 15 specimens represent 5 freshwater species of 5 genera, while 519 others were assigned to 11 brackish water species within 5 genera (Table 5, Fig. 13).

MC X was allocated in the deposits of the beds 7 and 9 of the Seroglazovka outcrop section. In total, 2280 shells representing 15 freshwater species of 13 genera, 6518 shells of 21 brackish water species within six genera, as well as one terrestrial species were identified (Table 5, Fig. 13).

The Khvalyn Horizon is confined to MC XI and corresponds to the bed 10 of the Seroglazovka outcrop section. This complex contains two freshwater species and three genera represented by two complete shells and numerous fragments. In addition, 44 shells of brackish water taxa were assigned to five species and four genera (Table 5). It should be noted that key Khvalyn species are absent in this complex. *Didacna* species were identified as *Didacna nalivkini* (Wassoevitch, 1930) and *D.* cf. *subpyramidata* (Pravoslavlev, 1939) which possibly could be redeposited from the underlying Khazar deposits.

4.2.4. *Vertebrates*

The collection of vertebrates from of the outcrop section is confined to the Upper Khazar. It is represented by the bones of fishes, amphibians, reptiles, as well as small and large mammals.

4.2.4.1. Fishes. A large group of fish remains from the Seroglazovka section is nearly unidentifiable small, rounded vertebrae, as well as complete and fragmentary fin rays which were assigned to Percidae gen. et sp. indet. Nonetheless, in total, eight fish species belonging to 7 genera of 5 families Cyprinidae, Salmonidae, Esocidae, Lotidae, Percidae were identified. They were observed in the Upper Khazar interval (beds, 2, 7 and 9). (Table 6, Fig. 14).

The common roach *Rutilus rutilus* (L., 1758) is represented by a fragment of the left pharyngeal bone, as well as by three isolated pharyngeal teeth. The dorsal toothless ceratobranchial branch is curved arcuately, its width is inferior to the height of the crown of a preserved pharyngeal tooth, and the length is almost equal to the latter. The cavernous surface is rather narrow. The pharyngeal tooth is placed on a cylindrical pedicle. Its back smoothly rises to the blunt top without a hook. The tooth crown is high and laterally compressed. The grinding surface is narrow, elongated, with a slightly elevated edge, sloping down to the rounded belly, with a pronounced pinch at the neck. There are several morphotypes corresponding to different positions of individual teeth in the pharyngeal bone. They are distinguished by different crown heights, varying degrees of abrasion as well as the presence of a weak hook on the top and a wavy grinding edge.

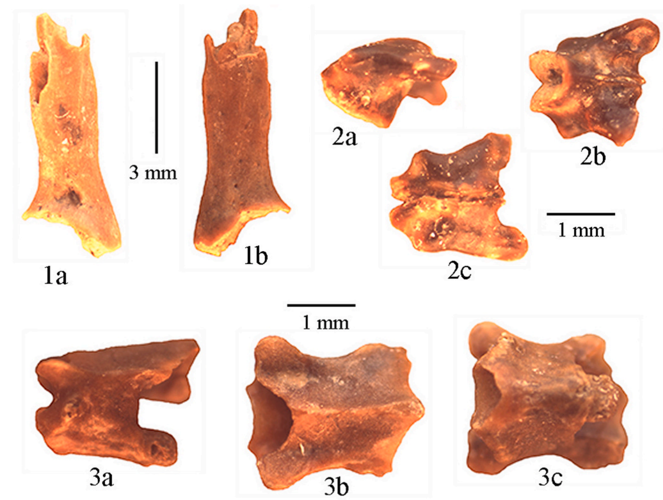


Fig. 15. Bones of amphibians and reptiles from the Upper Khazar deposits of the Seroglazovka 4 section (bed 7).
Legend: 1-Anura indet., antebrachium (a-lateral surface; b-medial surface); 2-Sauria indet., caudal vertebra (a-side view; b-top view; c-bottom view); 3-*Eremias arguta* (Pallas, 1773), trunk vertebra (a-side view; b-top view; c-bottom view).

Pharyngeal bone fragment of the common bream *Abramis brama* (L., 1758) was identified due to the presence of a preserved pharyngeal tooth. Its molariform crown is laterally compressed, and its straight back rises to the top which is elongated in a small hook. There is a longitudinal fold on the short grinding surface forming a bulge in the medial part. The grinding edge is narrow, sloping towards a rounded belly, rolling in a wide pedicle without noticeable pinch in the neck. Pharyngeal teeth of the crucian carp *Carassius carassius* (L., 1758) are characterized by low laterally compressed crowns with an arcuate back, absence of the hook, and sloping grinding surface.

The whitefish *Stenodus leucichthys* (Gueldenstaedt, 1772) vertebra is moderately elongated. The anterior and posterior surfaces of the centrum are round; the aperture of the notochord is slightly displaced dorsally. The ventral surface of the bone forms a network of narrow interlaced cords. It is worth noting the presence of an open lattice-shaped structure on the lateral surface of the vertebra, which is a common feature of members of the subfamily Coregoninae, including *Stenodus* and *Coregonus* (Böttcher, 1994). There are also two vertebrae (basioccipital and precaudal) in the collection from the Seroglazovka section, belonging to a small pike *Esox* sp., one of which is characterized by the presence of large rectangular facets with rounded edges at its ventral and lateral surfaces.

The burbot *Lota lota* (L., 1758) is represented by three isolated vertebrae, two of which have similar size, while the third one is smaller. The centra are well preserved; each of them yields two small processes at the extended anterior part. Both articular surfaces are rounded in cross section and slightly flattened dorsoventrally. The lateral surface has a spongy structure.

The most numerous fish remains in the collection from the Seroglazovka section are those assigned to the river perch *Perca fluviatilis* L., 1758. In particular, a large triangular-shaped epihyal, partially broken articular with a deep articulating facet, as well as small opercular fragments with a powerful middle ridge, and one cleithrum branch were found. A fragment of the ctenoid scale also probably belongs to this species, although, considering its fragmentarity, it is attributed to *Perca* sp. The basal core is displaced proximally, and the anterior margin is divided by scallops.

4.2.4.2. Amphibians, reptiles and small mammals. Small vertebrates

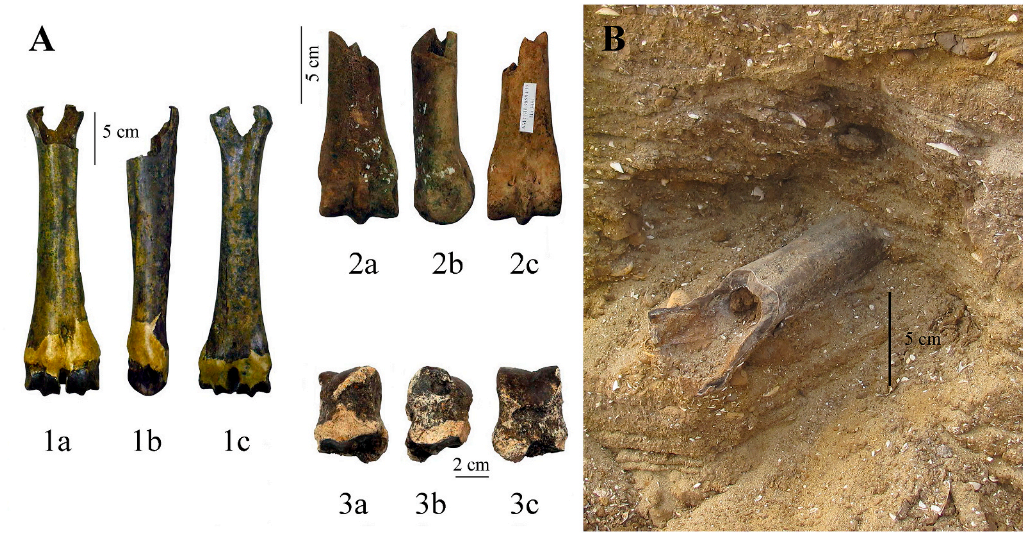


Fig. 16. Remains of large mammals from the Seroglazovka section.
Legend: A: 1-*Bison priscus,* left metatarsus, Upper Khazar horizon (*in situ*), AMZ (unnumbered); 2-*Equus caballus* ssp. (cf. *E. caballus ferus*), distal end of right metatarsus, water level, AMZ KP 48584/15 PL 3491; 3-*Bison priscus*, phalanx II, in talus, AMZ (unnumbered); a-front view; b-lateral view; c-posterior view. B: location of the *Bison priscus* metatarsus in the Upper Khazar alluvium (*in situ*) (western part of Seroglazovka 3 section).

(amphibians, reptiles, and small mammals) from the Upper Khazar beds 7 and 9 (S3 and S4) are represented by fragmented bones (Table 6; Fig. 15). The colours of the bones vary from light brown to dark brown. The bones were significantly transported before their accumulation in the fossil-bearing beds.

A single complete tooth of the water vole from the bed 7 (S3) has approximately equal enamel layer on the occlusal surface of conids. Such enamel differentiation is characteristic for the late Middle and early Late Pleistocene water voles (Agadjanian, 2009).

4.2.4.3. Large mammals. Remains of large mammals from the Seroglazovka section are quite rare. Only a few specimens were collected there such as 1) the left metatarsal bone of the steppe bison *Bison priscus* Bojanus, 1827 (Fig. 16A/1, Fig. 16B) which was collected *in situ* (Upper Khazar, bed 7); 2) the second phalanx of *B. priscus* (Fig. 16A/3) which was collected in the slope detritus, as well as 3) the distal end of the metatarsus (MT–III) of the horse *Equus caballus* ssp. (cf. *E. caballus ferus* Boddaert, 1785) (Fig. 16A/2) which was collected on the river beach. Also, several undefinable small fragments of thick-walled bones with a high degree of roundness were found on the surface of the bed 1. All these specimens were found in the central and western parts of the S3 section.

Metatarsal bone of *Bison priscus* (Fig. 16A/1, Fig. 16B, AMZ, unnumbered) has a grey-brown colour, a damaged proximal epiphysis and is characterized by a significant degree of fossilization. The maximal length of MT–III is about 270 mm, the width of the diaphysis – 36.2 mm, the width of the distal end – 68.4 mm; the massiveness/slenderness index is equal to 25.33/13.41. On the diaphysis, a pronounced thickening is observed cranially from the medial side, increasing from the middle to the proximal end of the diaphysis. There are no signs of roundness. The second phalanx of *Bison priscus* (Fig. 16A/3, AMZ, unnumbered) is characterized by the slight fossilization and friable structure. The colour of the specimen is from ash-grey to black-brown and white on the fracture. The bone is relatively small.

The distal end of the metatarsus (MT–III) of *Equus caballus* ssp. (cf. *E. caballus ferus*) (Fig. 16A/2, AMZ KP 48584/15) is slightly rounded and brown in colour. It has a significant degree of fossilization and signs of roundness.

5. Discussion. Stratigraphy and palaeoecological reconstructions

5.1. Palynological data

Comparison of the obtained results with previously published palynological materials allowed us to identify both the general similarity of palynocomplexes (PC) and their local differences. According to our interpretation, PC I and PC II possibly correspond to the Middle-Late Akchagyl (=Gelasian). According to published data (Vronsky, 1965; Kovalenko, 1971; Kurmanov and Alimbekova, 2015; Naidina and Richards, 2016), forest landscapes (coniferous forests with broad-leaved trees admixture) were widespread during the Middle Akchagyl (beginning of the Gelasian), while forest-steppe and semi-desert landscapes occurred there during the Late Akchagyl (second part of the Gelasian). Palynological analysis of the Akchagyl deposits from the east of Azerbaijan, which were dated by $^{40}Ar/^{39}Ar$ method in the range of ~2.77–2.45 Ma, allowed to identify pollen assemblage zones corresponding to 8 glacial-interglacial cycles (MIS G8 to 98). Coniferous or broad-leaved and small-leaved elements periodically dominated among arboreal plants, while among nonarboreal plants the role of Amaranthacae, *Artemisia*, Poaceae and Asteraceae were continuously changing (Hoyle et al., 2020).

Forest-steppe and steppe PC III from the borehole 5 Seroglazovka could correspond to the Early-Middle Apsheron. The forest-steppe environments were mainly widespread within the study area during the Early and Middle Apsheron (Calabrian) as described by Grichuk (1954), Vronsky (1965), Naidina and Richards (2016). Desert vegetation was established in the Late Apsheron due to gradual aridization (Chigur-yaeva, 1968 cited by Zavialov et al., 2002).

The defined Tyurkyan pollen complexes (PC VI-VII) in the borehole 5 Seroglazovka section reveal the distribution of semi-deserts and steppe areas at the beginning of this time period and forest-steppe environment at the end. Therefore, our interpretation indicates that the climate was arid at the beginning of the Tyurkyan and became more humid at the end. The pollen spectra from the Tyurkyan deposits of the borehole 5 Seroglazovka can be regionally compared with palynological data from the borehole 3 Erdnievskaya (Danukalova et al., 2018) and the borehole 2 Kosika (Zastrozhnov et al., 2020). However, the Tyurkyan complexes of the boreholes 3 Erdnievskaya and 2 Kosika were confined only for the upper part of the horizon and reflect the development of forests and distribution of wet and swampy areas. The pollen of thermophilic broad-leaved species (*Juglans* sp., Fagaceae, *Carpinus* sp.) were determined only in the spectra of the borehole 2 Kosika.

Pollen spectra from the lower part of the Baku sediments (PC VIII, PC IX, and PC X) of the borehole 5 Seroglazovka indicate distribution of mainly coniferous forests. A gradual increase of *Ephedra* sp. pollen in spectra probably indicates a gradual aridization at the end of this time period. Our results are consistent with those obtained for the lower part of the Baku Horizon of the Lower Volga region (Tyurina, 1961).

Pollen spectra from the Lower Khazar deposits (PC XI and PC XII) reflect the distribution of forest landscapes in moderately humid and cool climate. Similar spectra were obtained from the Lower Khazar deposits of the borehole 2 Kosika (Zastrozhnov et al., 2020). Also, we have to note that the Lower Khazar (pre-Singil) sediments were previously described as the Baku ones by several authors, therefore their pollen spectra were considered as corresponding to the Baku (see details in §5.7 of this paper and in Zastrozhnov et al., 2018b).

Singil deposits from the borehole 5 Seroglazovka are characterized only by single palynological spectrum which reflects the existence of *Picea-Pinus* forests. The climate was cool and humid at the beginning of this time. These data can be correlated with the spectra obtained from the lower part of the Singil deposits from the Chernyi Yar and Raigorod localities (Grichuk, 1954) and borehole 2 Kosika (Zastrozhnov et al., 2020) where pollen of conifers dominated (*Picea, Pinus*).

5.2. Ostracod data

The interpreted ostracod assemblages indicate strongly changing environmental conditions during the Quaternary. The Akchagyl ostracod assemblage O I is typical for brackish water environments. Caspian ostracod species predominate in this assemblage. However, along with them there are also young instars of the freshwater genera *Candona* and *Ilyocypris*, which indicate some freshwater influence (Table 3). Since juvenile instars of ostracods are stages of expansion and do not survive to adulthood under unfavorable conditions, it could be concluded that the salinity was slightly higher than required for the environment favorable for them and was about or just above 8 psμ.

The assemblages O II and O III correspond to the Apsheron time and are represented by the typical Apsheron species (Agalarova et al., 1961; Mandelstam et al., 1962; Karmishina, 1975; Zhidovinov et al., 1981). According to Karmishina (1975), these assemblages associate with the Middle Apsheron or lower part of the Upper Apsheron. These assemblages are typical for brackish water conditions with different salinity. The lower assemblage O II contains a large number of ostracods of genus *Caspiocypris* and *Limnocythere* sp., which are represented by both adult and juvenile stages, and indicates a lower salinity environment. In the upper assemblage O III, species of genus *Caspiocypris* are rare and there is a diverse brackish water complex of paratethyan species, which indicates a higher salinity compared to O II. The high species diversity of these assemblages is associated with shallow water conditions.

At the end of the Late Apsheron, ostracod diversity gradually decreased (Karmishina, 1975). *Camptocypria karatengisa* with single valves of other species were met in the assemblage O IV. It also existed at the beginning of the Tyurkyan. Due to the low ostracod abundance and generally poorly studied ecological preferences of *Camptocypria karatengisa*, it is hard to conclude about the environment of that time based on ostracod data.

The assemblage O V is depleted and points to the existence of shallow water environment with variable salinity. It contains rare Caspian species valves of genus *Amnicythere* and *Camptocypria gracilis* (Table 3; Fig. 11) indicating the beginning of the Baku transgression in this area.

The assemblages O VI and O VII are typical for the Baku period. They are significantly different and indicate the various environmental conditions. The assemblage O VI is shallower as indicated by a large number of ostracods belonging to genera *Paracyprideis*, *Amnicythere*, *Euxinocythere*. The assemblage O VII is apparently deeper. The main species are *Bacunella dorsoarcuata*, *Camptocypria gracilis*, and *Cryptocyprideis cascusa*. The last two species indicate Baku age of these deposits. Abundant *Bacunella dorsoarcuata* are present in Baku to recent sediments. Similar ostracod assemblage was previously described in the Baku deposits of Turkmenistan (Mandelstam et al., 1962).

The ostracods distributed in the Khazar time are mainly represented by genera and species which existed in the Baku basin. There are very few species appearing at that time (Mandelstam et al., 1962). However, during the Khazar, ostracod species formed specific assemblages which are different from the Baku ones. The Khazar deposits are represented by three ostracod assemblages (O VIII, O IX, and O X). The assemblage O VIII is poor with the predominance of *Cyprideis torosa*, that indicates relatively shallow water environment with changeable salinity. The assemblage O IX is characterized by a high species diversity (15 species) and is typical for shallow water conditions. The assemblage O X belongs to the Upper Khazar deposits and is slightly different from the lower assemblage O IX, but it is significantly depleted in the species composition.

According to Sedaikin (1988), in the Upper Khazar deposits of the S3 outcrop section two assemblages are distinguished. The first assemblage is typical for more saline brackish water basin, while the second one is usual for less saline brackish water shallow environments. In the Khvalyn deposits, the first assemblage, which is typical for less saline shallow water environments, is replaced by the second assemblage, which is common for a deeper brackish water basin (Karmishina and Sedaikin, 1978; Sedaikin, 1988).

5.3. Malacological data

The interpreted malacological complexes indicate a multiple change in the living conditions of molluscs: either decrease in salinity of the reservoir occurred in a certain time interval, and then the number of freshwater species increased, or salinity increased, and then brackish water species prevailed in the complexes.

The data on the characteristics of sedimentary environment, to which the MC I is confined, are relatively scarce. Pyrgulidae live in the brackish water reservoirs, such as the modern Caspian Sea, and the presence of shell fragments of *Dreissena rostriformis distincta* suggests a reservoir with a salinity up to 12.6‰ (Zhadin, 1952). The latter species live in shallow water at depths up to 40–260 m (Kolesnikov, 1950) and prefer silty bottom.

Even though the following MC II is represented by mollusc shells of poor preservation (imprints, fragments), it contains *Parapsheronia* cf. *raricostata*, which is a typical Middle Apsheron species indicating the presence of a brackish water sea basin at that time. In the transitional MC II–III, rare pyrgulides, *Dreissena* and Cardiidae are present, suggesting the existence of a brackish water reservoir. We assume that this interval can be correlated to the end of the Apsheron prior to the beginning of the Tyurkyan regression.

The presence of freshwater molluscs (*Valvata, Viviparus, Lithoglyphus,* and *Dreissena*) in the MC III indicates alluvial-marine sedimentation during the Tyurkyan regression. Such a change in salinity is prominent in almost all borehole sections which we previously studied in the Lower Volga region (e.g. borehole 2 Kosika - Zastrozhnov et al., 2020; borehole 3 Erdnievskaya - Danukalova et al., 2018). Later (the transitional MC III–IV), freshwater species disappeared, likely because the territory was flooded as a result of the beginning of the Baku transgression.

The MC IV contains *crassa*-type *Didacna*, indicating the presence of a brackish water basin. The peculiar lithological features of clays (e.g. thin horizontal lamination) and the presence of *crassa*-type *Didacna* (albeit found as imprints) allow to define these sediments as the Baku Horizon. Similar clays were observed in the borehole 5 Seroglazovka (this study), borehole 2 Kosika (Zastrozhnov et al., 2020), borehole 3 Erdnievskaya (Danukalova et al., 2018) and many other yet unpublished borehole results.

Mollusc shells in MC V are rare. Based on the presence of fragments of *Dreissena* and Cardiidae and varying lithology of deposits, we suggest the existence of a brackish water Early Khazar basin with frequently changing hydrological regime. Notably, the marine Lower Khazar deposits are found extensively between Volgograd and Astrakhan. They occur below water level of the Volga River and were reached by many boreholes. Popov (1983) also reported the presence of *Didacna subpyramidata* and *Dreissena rostriformis distincta* in the Lower Khazar deposits.

Up the studied section, there are deposits with freshwater and brackish water molluscs (MCVI) which we correlate to the Singil deposits. These deposits were reached by the borehole 5 Seroglazovka and their upper part is exposed along the riverside cliff near the Seroglazovka locality. The Singil interval is represented by the sediments of freshwater, sometimes swampy lakes or limans (lagoons) formed during the regression phase of the Early Khazar sea (Zastrozhnov et al., 2018b).

After the Singil regression, a new brackish water Late Khazar reservoir was formed, which was inhabitated by molluscs of MC VII. The presence of freshwater species in this complex indicates the influence of a river flow. We assign Late Khazar age for these sediments based on their stratigraphic position over the Singil deposits, which are attributed to the end of Early Khazar stage of sedimentation (Zastrozhnov et al., 2018b).

At the end of the Khazar time, the landscape resembled the modern Volga delta with numerous branches and terraces, on the surface of which hydromorphic soils were formed. The flow of the river was strong enough to transport molluscs shells and bones of large mammals and redeposit them in the basal parts of sand incisions. Such palaeo-incisions are typical for many Lower Volga sections (e.g. Kosika, Zastrozhnov et al., 2020). This redeposition may explain observed associated occurrence of two key Khazar species - *D.* cf. *subpyramidata* (Pravoslavlev, 1939) and *Didacna* cf. *surachanica* (Andrusov, 1902), which are key for the Early and Late Khazar respectively (Yanina, 2005).

The malacocomplex MC XI indicates a transgression stage of the Khvalyn basin, which contained brackish water molluscs with an admixture of freshwater molluscs. In addition, in the Seroglazovka locality Yanina (2005) collected shells of Late Khvalyn molluscs such as *Didacna praetrigonoides*, *Dreissena rostriformis distincta*, *Sphaerium* sp.

5.4. Ichthyological data

Cyprinids slightly predominate among the identified fish species from the Seroglazovka section, while other families are represented by individual species-rank taxa. All skeletal elements are morphologically identical to those in extant species. Most of them belong to the roach and perch, while the burbot takes the second place in abundance. All other identified species (bream, crucian carp, whitefish and pike) are represented by a handful number of bones.

A majority of fish species identified among osteological remains from the Seroglazovka section are common components of Pleistocene ichthyofaunal assemblages of Europe (Pawłowska, 1963; Lister et al., 1990; Böttcher, 1994; Schreve et al., 2002; Böhme, 2010; Kovalchuk, 2013, 2017; Rekovets et al., 2014; Stefaniak et al., 2020; Vasile et al., 2020). The findings of the burbot remains are relatively scarce (Costedoat and Gilles, 2009) and mentioned only among the fossils from the Novgorod-Seversky Late Palaeolithic camp (Nikolsky, 1945, 1952), Khazar floodplain deposits in the Ural River region (Lebedev, 1960), as well as Middle Pleistocene of Little Oakley, England (Lister et al., 1990) and the Late Pleistocene Hohle Fels locality near Schelklingen, Germany (Conard et al., 2013). Significant similarity of species lists has been established for the Seroglazovka and Kosika sections, which are comparable in age and located in the same region (Zastrozhnov et al., 2020). In addition, there was a certain connection between Pleistocene freshwater fish faunas of the Volga basin and water bodies of North America, manifested in the presence of whitefish, burbot, and pike (Cumbaa et al., 1981; Harington, 2011).

Based on the habitat preferences of extant fish species, it can be assumed that the Seroglazovka assemblage existed in a slow-flowing reservoir with a sandy-silt or pebbly bottom and well-developed aquatic vegetation. Further study of the Pleistocene fish remains from the Lower Volga basin is of great interest for clarification the ways of formation the current fish fauna composition (Levin et al., 2017) and dispersal of certain species in suitable water bodies (Van Houdt et al., 2003; Costedoat and Gilles, 2009; Vasile et al., 2020).

5.5. Data on small vertebrates

Several sites containing remains of small vertebrates are known in the Lower Volga region such as Nizhnee Zaimishche, Chernyi Yar, Bueraki, and Kosika. Traditionally, small mammal fauna in the previous publications were correlated with the Khazar Period of the Middle Pleistocene. Deposits of the Nizhnee Zaimishche and Chernyi Yar sections contain small mammalian fauna, among which Aleksandrova (1976) described *Arvicola chosaricus* Alexandrova, 1979, *Pitymys hintoni* Kretzoi, 1941, *Pitymys gregaloides* Hinton, 1926, *Pitymys arvaloides* Hinton, 1923, *Microtus arvalinus* Hinton, 1923, *Microtus ratticepoides* Hinton, 1923. Ratnikov (2002) also identified the remains of *Bufo* cf. *raddei* Strauch, 1876. These deposits were correlated to the end of the Early Neopleistocene – first half of the Middle Neopleistocene (Middle Pleistocene) and referred as "Chernyi Yar sands" by Aleksandrova (1976).

Kirillova (in Kirillova and Svitoch, 1994) studied small mammals (*Arvicola* cf. *sapidus* Miller, 1908; *Eolagurus* cf. *luteus*, *Lagurus* cf. *lagurus* (Pallas, 1773), *Lemmus* sp., *Microtus oeconomus* (Pallas, 1776), *Microtus arvalis* (Pallas, 1778), *Microtus (Stenocranius) gregalis* (Pallas, 1779))

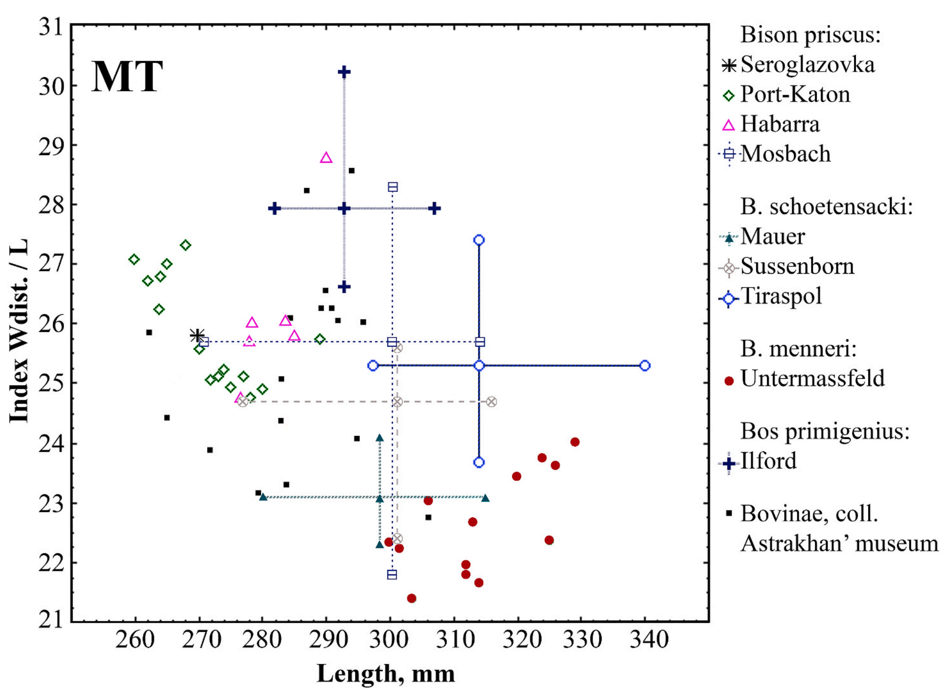


Fig. 17. The ratio of length and stoutness of some Pleistocene bovid metatarsals from various localities of Europe. Measurements from the literature (Sher, 1997; Prat et al., 2003; Baygusheva et al., 2014) supplemented by our data.
Legend: Index Wdist/L-relation of the distal width to the total length; L-the total length.

from the deposits of the Bueraki section and attributed them to the Khazar time of the second half of the Middle Pleistocene.

New data and reinterpretation of the age of fossil-bearing deposits occurring in the lower part of the riverside cliffs in the Lower Volga region allow considering fluvial deposits containing the remains of vertebrates as young as the Late Khazar of the Late Pleistocene. For example, the fluvial deposits of the Kosika section containing the fauna of amphibians, reptiles, and small mammals were attributed to the Late Khazar (Zastrozhnov et al., 2020).

The taxa of amphibians, reptiles, and small mammals established in the Seroglazovka locality (Table 6) are common for the second half of the Middle and Late Neopleistocene of the Russian Plain. Among terrestrial small vertebrates from this locality, the remains of *Eremias arguta*, *Spermophilus pygmaeus* and *Eolagurus luteus* were identified. These species are characteristic for the steppe and semi-deserts. The near-water forms are represented by Anura and *Arvicola* sp. The palaeoenvironment for the accumulation of bone remains is reconstructed as an alternation of steppe and semi-desert landscapes on the watersheds and floodplain biotopes in the palaeo-Volga valley.

5.6. *Data on large mammals*

Parameters of the metatarsal bone of *Bison priscus* from the Seroglazovka locality are similar to those of the posterior bison metapodials from the Upper Khazar alluvial sands obtained from other localities of the Lower Volga region (Chernyi Yar, Nikolskoye, Kopanovka), as well as with other *B. priscus* from the late Middle – early Late Pleistocene of Eastern and Western Europe (Sher, 1997) (Fig. 17). At the same time, the specimen from the Seroglazovka locality differs from those of the earlier Middle Pleistocene remains of *Bison schoetensacki* Freudenberg, 1910 by being shorter and more massive.

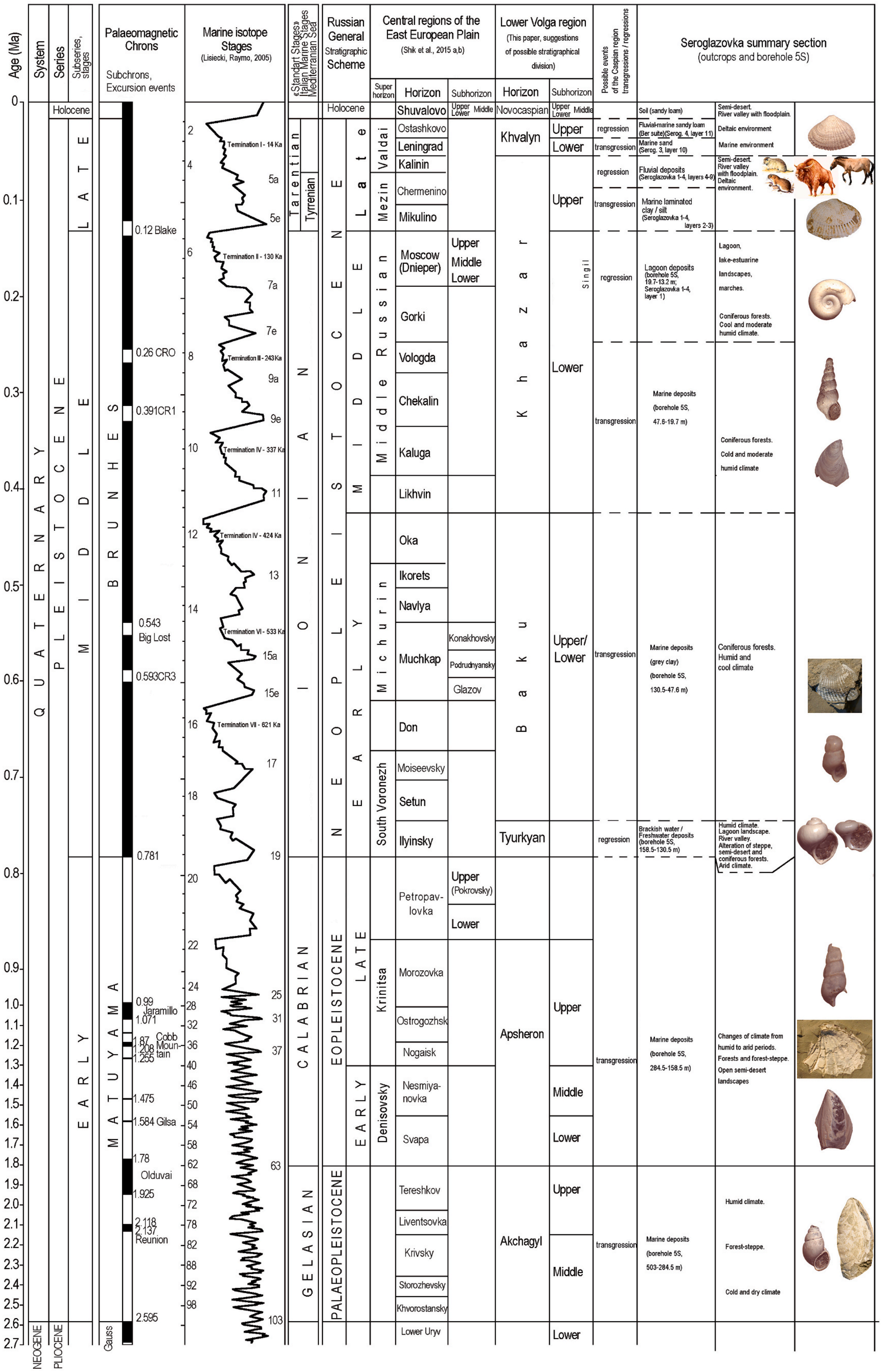
The comparison of the bison phalanx from the Seroglazovka locality with the bison phalanx from other localities of the Lower Volga region showed the absence of significant differences in size and proportions. The relatively small size of the phalanx allows us to assign it to a medium-sized individual. The degree of preservation of the bone indicates that it originates from the buried soils of the bed 6, under which it was found in the slope detritus. Fully developed epiphysis on the metatarsal bone of *Equus caballus* ssp. (cf. *E. caballus ferus*) indicates that it belonged to an adult individual. The character of fossilization of this bone is similar to those from the Upper Khazar alluvial deposits. The remains of large mammals described herein come from different bone beds. The first of them probably correlates with the upper boundary of the Singil clays, from which the findings of indeterminate bone fragments are known (beds 1–2). The second bone bed, from which the metatarsal bone of *Bison priscus* was obtained *in situ*, is associated with the Upper Khazar alluvial sands (bed 7). Another bone bed can be associated with the buried soil of the bed 6 (phalanx of *Bison priscus*).

The small number of fossil remains of large mammals does not allow carrying out a detailed palaeoecological reconstruction. Both identified species (*Bison priscus* and *Equus caballus* ssp. (cf. *E. caballus ferus*) are representatives of open and semi-open landscapes of the steppe and forest-steppe type (Zastrozhnov et al., 2018c), so we can assume these environments for the region adjacent to the Seroglazovka locality during the sedimentation period. The bones were probably subjected to some post-mortal transfer, which is supported by the burial conditions of the bison's metatarsus and the traces of rounding on the horse's metatarsal bone. The species composition and stratigraphic position of the findings allow us to correlate it to the faunistic complexes that lived in the south of Eastern Europe at the end of the Middle Pleistocene-beginning of the Late Pleistocene (MIS 7–5). Typical representatives of these complexes were *Equus* ex gr. *caballus* and *Bison priscus* (Zastrozhnov et al., 2018b).

Table 7
Estimates of the genesis of the studied deposits based on multi-proxy data.

Series, Stage [1]	Unit [2]	Horizon [3]	Subhorizon [3]	Suite	Stratigraphical index	Genesis (facies)	Beds	Depth interval, m
Borehole 5 Seroglazovka								
Lower Pleistocene	Gelasian	Akchagyl			m **Qgl(a)**	marine	1–11	503–284.5
	Palaeopleistocene							
	Eopleistocene	Apsheron			m Q_E**ap**	marine	12–19	284.5–158.5
Middle Pleistocene	Lower Neopleistocene	Tyurkyan			am,l, lm Q_I**tr**	alluvial-marine, lacustrine, lagoon (=liman)	20–24	158.5–130.5
		Baku			m Q_I**bk**	marine	25–40	130.5–47.6
	Middle Neopleistocene	Khazar	Lower		m Q_{II}**hz**$_1$	marine	41–47	47.6–19.7
				Singil	lm, am Q_{II}**hz**$_1$ **(sn)**	lagoon (=liman), alluvial-marine	48–49	19.7–13.2
Upper Pleistocene	Upper Neopleistocene		Upper		m, am Q_{II}**hz**$_2$	marine, alluvial-marine	50–52	13.2–5.5
		Khvalyn			am Q_{II}**hv**	alluvial-marine	53, 54	5.5–0
Seroglazovka outcrop section (S1-4)								
Middle Pleistocene	Middle Neopleistocene	Khazar	Lower	Singil	lm, am Q_{II}**hz**$_1$ **(sn)**	lagoon (=liman), alluvial-marine	1	
Upper Pleistocene	Upper Neopleistocene		Upper		am,lm, m Q_{III}**hz**$_2$	alluvial-marine, lagoon (=liman), marine,	2,3	
					am Q_{III}**hz**$_2$	alluvial-marine	4,5	
					l Q_{III}**hz**$_2$	lacustrine (hydromorphic paleosol)	6	
					am Q_{III}**hz**$_2$	alluvial-marine	7,8,9	
		Khvalyn			am Q_{III}**hv**	alluvial-marine	10	
					am Q_{III}**hv**	alluvial-marine eolian?	11	
Holocene	Holocene	Novocaspian			e_p Q_H	modern soil	12	
					t Q_H	anthropogenic	13	
					v Q_H	eolian	14	

Legend: [1] according to Cohen and Gibbard (2016); [2], [3] according to Zastrozhnov in Postanovleniya (1999) with additions.



(caption on next page)

Fig. 18. Stratigraphical position of the studied deposits.
Legend: International Chart, Palaeomagnetic chart, and Italian marine stages are given according to Cohen and Gibbard (2016). Marine Isotope Stages are after Lisiecki and Raymo (2005). Russian General Stratigraphic Scheme is given according to Zhamoida et al. (2019) with authors additions. Figure of Bison priscus is a courtesy of Robert Pawlicki, https://nam03.safelinks.protection.outlook.com/?url=https%3A%2F%2Fcommons.wikimedia.org%2Fw%2Findex.php%3Fcurid&data=04%7C01%7Cb.jeyapandian%40elsevier.com%7C28740622ed0348a9558d08d8d3fbf6e5%7C9274ee3f94254109a27f9fb15c10675d%7C0%7C0%7C637492426576495123%7CUnknown%7CTWFpbGZsb3d8eyJWIjoiMC4wLjAwMDAiLCJQIjoiV2luMzIiLCJBTiI6Ik1haWwiLCJXVCI6Mn0%3D%7C3000&sdata=8220pmbPgcARl6Nh9b0Za6EnGBd9D5bM7rMx0caCaZ4%3D&reserved=0 = 53569355; photo of Equus is given according to Rigelus https://nam03.safelinks.protection.outlook.com/?url=https%3A%2F%2Fupload.wikimedia.org%2Fwikipedia%2Fcommons%2F2%2F28%2FEquus_ferus_przewalskii_4.jpg%3Fuselang%3Dru&data=04%7C01%7Cb.jeyapandian%40elsevier.com%7C28740622ed0348a9558d08d8d3fbf6e5%7C9274ee3f94254109a27f9fb15c10675d%7C0%7C0%7C637492426576495123%7CUnknown%7CTWFpbGZsb3d8eyJWIjoiMC4wLjAwMDAiLCJQIjoiV2luMzIiLCJBTiI6Ik1haWwiLCJXVCI6Mn0%3D%7C3000&sdata=%2F1Cn4TJE0E8YTVEVaatsaDM5crcylXgs74NMYCOJELc%3D&reserved=0.

5.7. *Multi-proxy palaeoenvironmental reconstruction of the Seroglazovka locality and possible regional correlations*

In this subchapter we combine our biostratigraphical intepretations from each proxy discussed in §§5.1–5.6 to reconstruct in the chronological order Quaternary palaeoenvironments (from the Akchagyl to the Holocene) within the Seroglazovka locality. We also compare our reconstructions with previous studies and put them into a regional context.

The origin of the studied deposits was also estimated using multi-proxy data discussed in §§5.1–5.6. Our results indicate multiple changes in the depositional conditions during the Pleistocene and Holocene. The genesis of the studied deposits is summarized in Table 7.

5.7.1. *Akchagyl time*

Our palaeontological data from the borehole 5 Seroglazovka can only constrain middle and late parts of the Akchagyl Stage (=Gelasian). During this time there was a brackish water reservoir inhabited by ostracods, Pyrgulidae and *Dreissena*. The surrounding land was covered dominantly by forest-steppes. The climate was most likely cool and dry during sedimentation of the lower part of the studied Akchagyl deposits and more humid later (Fig. 18). Scarcity of mollusc fossils in this interval may indicate difficult environments for molluscs in the central part of the northern Akchagyl Sea.

We have to note that only a small number of regional publications devoted to the Akchagyl interval exists, because this interval can only be reached by drilling in the study area. The only base for some regional correlations exists in the geological engineering reports by Akuz et al. (1961) and Smagin et al. (1977), where results of extensive regional drilling campaigns were present. Akchagyl deposits have an average thickness of about 200 m and starting depth from 280 m in the study area. The regional drilling data confirm that the lower part of Akchagyl sediments (which are referred to the Gelasian) was formed by a maximum stage of the Akchagyl Sea transgression that covered almost the entire Lower Volga and Caspian Lowland areas and penetrated along the palaeoriver valleys further north into the Belaya and Kama River basins. Upper part of these deposits was marked by the development of a final transgressive-regressive basin phase (Kolesnikov, 1950; Karmishina, 1975; Fedkovich, 1978; Danukalova, 1996; Zastrozhnov et al., 2018a).

Forest-steppe and semi-desert during the Late Akchagyl for the northern and north-western Caspian areas were also suggested earlier by Vronsky (1965), Kovalenko (1971), Kurmanov and Alimbekova (2015), Naidina and Richards (2016). For the interval 2.77–2.45 Ma in the east of Azerbaijan Hoyle et al. (2020) documented a palynological record, which is characterized by periodical changes of the extent of forest and open landscapes (the AP/NAP ratio) due to climatically-controlled displacements of altitudinal vegetation belts in adjacent mountain ranges (Greater Caucasus, Lesser Caucasus and potentially also Talysh).

Possible reasons of the Akchagylian transgression are still hypothetical and were described extensively by Andrusov (1902), Kolesnikov (1950), Alizade (1954), Ali-Zade (1967; 1969), Danukalova (1996) and Popov et al., 2006). Recently, Krijgsman et al. (2019) discussed two ways of how vast amount of water could enter the basin: 1) a climatically controlled switch to a more positive hydrological budget or 2) connection with an adjacent waterbody. However, our data do not allow us to speculate on possible flooding drivers.

Notably, the Akchagyl sediments from the borehole 5 Seroglazovka do not contain Arctic forms of molluscs and ostracods. Furthermore, data from other Akchagyl sections in the Caspian, Volga and Fore-Urals regions also show the absence of typical Arctic species of foraminifers, ostracod and molluscs (e.g. Yakhimovich et al., 1970; 1998; Matoshko et al., 2004; Danukalova et al., 2019). Therefore, we rather support the idea about the pervasion of Akchagyl fauna from the southern and western Paratethys. This is also supported by the recent findings of Akchagyl-like dynocysts and molluscs in the South Caucasus (e.g. Büyükmeriç and Wesselingh, 2018; Trifonov et al., 2020).

5.7.2. *Apsheron time*

The data from the borehole 5 Seroglazovka allow subdivision of the Apsheron Stage (=Calabrian) into the lower, middle and upper (?) parts, where the middle part is clearly confirmed by key mollusc species. During the Apsheron time, there was a brackish water basin inhabited by typical Apsheron molluscs and ostracods. This period was characterized by the fluctuations in salinity, which led to the co-existence of two significantly different ostracod assemblages. Forests and forest-steppes were growing on the adjacent coastal plains. However, these landscapes were periodically replaced by open areas with a semi-desert vegetation during more arid periods (Fig. 18). The climate was cool and dry.

As mentioned above (see §5.1), Grichuk (1954), Vronsky (1965), Naidina and Richards (2016) also implied forest-steppe environments for the Early and Middle Apsheron, while Chiguryaeva (Zavialov et al., 2002) indicated a desert vegetation during the Late Apsheron. Similar ostracod species typical for Middle or lower part of Upper Apsheron deposits were described by Agalarova et al. (1961), Mandelstam et al. (1962), and Karmishina (1975). Similar key species of molluscs typical for the Apsheron of the Caspian area were documented by Kolesnikov (1950).

Connectivity of the Apsheron basin with the Black Sea and possibly the Mediterranean area evidenced by *Didacna* bivalve which migrated to the Caspian area from the Black Sea (Nevesskaja, 2007) and by the occurrence of the *Monodacna* bivalve recorded in the Pliocene of Turkey (Wesselingh and Alçiçek, 2010). Both genera are typical for the Apsheron basin. As stated by Andrusov (1923), Popov (1956), Ali-Zade (1973), Kolesnikov (1950) and summarized by Krijgsman et al. (2019), the Apsheron basin was characterized by saline conditions prevailed in the central parts, while in the deltaic and coastal parts of the basin salinity was lower.

5.7.3. *Tyurkyan time*

During the Tyurkyan (the earliest Middle Pleistocene of the ICC) the brackish water basin was replaced by lacustrine, lagoon reservoirs and rivers. Steppes and semi-deserts were being periodically replaced by forest-steppes consisting of dark coniferous forests (Fig. 18). Amaranthaceae were widespread and occupied the vacant spaces after the retreating brackish water basin. The climate at the beginning of the Tyurkyan was more arid than in the Apsheron and later humidity increased. At the end of the Tyurkyan, when the transgression of a new brackish water basin started, the freshwater mollusc species began to disappear, euryhaline species of ostracods started to dominate and the first occurrences of brackish water fauna appeared.

Regional palaeontological data for the Tyurkyan period of the Caspian

Lowland area are rare (e.g. Danukalova et al., 2017) and we can compare our results only with data, obtained from the neighbouring boreholes 3 Erdnievskaya and 2 Kosika (Danukalova et al., 2018; Zastrozhnov et al., 2020). The Tyurkyan palynocomplexes from the borehole 3 Erdnievskaya borehole characterize only upper part of this interval and indicate forests and distribution of wet swampy areas, while the data from borehole 2 Kosika indicate the presence of thermophilic broad-leaved species. Similar freshwater mollusc species documented in these two boreholes also indicate the regressive stage between the Apsheron and Baku basins.

5.7.4. Baku time

The following transgression of the Baku basin (the first half of the Middle Pleistocene, ICC) formed a large brackish water reservoir, which was inhabited by *Didacna* ex gr. *crassa*, gastropods and ostracods. Three stages of the deepening of the Baku basin can be determined, which are reflected by the gradual change of the ostracod assemblages. Light and dark coniferous forests grew on the coastal plains at the beginning of this period (Fig. 18). The climate was cool with increasing aridization at the end of this period.

Our spore and pollen data on the lower part of Baku Horizon are in good correlation with those obtained by Tyurina (1961), which up to date provides almost the only available regional palynological characteristics of this interval for the Lower Volga region. Ostracod assemblages documented in the borehole 5 Seroglazovka are in a good correlation with the similar species from the Baku deposits of Turkmenistan (Mandelstam et al., 1962).

Our mollusc data are comparable with the similar species from the borehole 2 Kosika (Zastrozhnov et al., 2020), borehole 3 Erdnievskaya (Danukalova et al., 2018) and data from the geological engineering reports (e.g. Akuz et al., 1961; Smagin et al., 1977). According to Akuz et al. (1961) and Smagin et al. (1977) Baku deposits in the Caspian Lowland are generally located at the depths from 80 to 50 m below the surface. Our data from the borehole 5 Seroglazovka demonstrate comparable depths range interval 130.5–47.6 m for the Baku deposits. Thereby we must admit that deposits, which were previously defined along the Lower Volga riverside cliffs as the Baku Horizon (e.g. Chernyi Yar and Nizhnee Zaimishche localities – Vasiliev and Fedorov (1965), Popov (1983), Sedaikin (1988), Yanina (2005); Kopanovka, Raigorod, Enotaevka, and Vladimirovka localities – Vasiliev and Fedorov (1965)), are in fact the Lower Khazar or Singil beds (the second part of the Middle Pleistocene, ICC) (see details in Zastrozhnov et al., 2018b). Therefore, palaeoenvironmental reconstructions made for the Baku time for these localities should be reconsidered as the late Early Khazar or Singil.

5.7.5. Early Khazar time

At the Early Khazar time (the second half of the Middle Pleistocene, ICC) there was a brackish water reservoir with a frequently changing hydrological regime. This basin was inhabited by brackish water molluscs and ostracods mixed with freshwater species. The palynological spectra of the beginning of this period characterize the distribution of coniferous forests on the coastal plains (Fig. 18). The climate was cool and moderately humid.

There are also almost no published regional palynological data for this period, however we were able to compare our interpreted spectra with the similar spectra in the borehole 2 Kosika (Zastrozhnov et al., 2020). Ostracod species which were typical for the Baku basin existed also during the Khazar period and this conclusion is in good correlation with data for Turkmenistan published by Mandelstam et al. (1962). Mandelstam et al. (1962) also admitted appearance of the very few new species during the Khazar period.

At the end of the Early Khazar, there was a significant regression of the brackish-water basin which resulted in the formation of the Singil lacustrine-liman (lagoon) sediments. The climate of the early Singil time was cool and humid (Fig. 18). Grichuk (1954) also documented conifer spectra in the Chernyi Yar and Raigorod localites and similar data were also obtained from the borehole 2 Kosika (Zastrozhnov et al., 2020). Singil deposits are widespread in the Lower Volga region and are usually exposed at the base of the Volga riverside cliffs. They are also documented by numerous boreholes (e.g. Akuz et al., 1961). Data from Akuz et al. (1961) and Popov (1983) support our conclusion that the stratigraphic position of Singil deposits is not below the Lower Khazar, as was adopted in traditional schemes, but in between the Lower and Upper Khazar (see details in Zastrozhnov et al., 2018b).

5.7.6. Late Khazar time

The renewed phase of the transgression affected the area during the Late Khazar (Late Pleistocene, ICC). By the end of the Late Khazar period, the brackish water basin area reduced significantly and alluvial, lacustrine, and lacustrine-chemogenic sediments started to accumulate. The landscape resembled the modern Volga floodplain with well-developed aquatic vegetation and diverse ichthyofauna. Open and semi-open landscapes were inhabited by *Bison priscus* and *Equus caballus* ssp. (cf. *E. caballus ferus*) (Fig. 18). The small amount of large fossil remains in the Seroglazovka locality, as well as the small number of vertebrate findings in general, probably indicates the proximity of the sea during the sedimentation period.

The marine deposits of the lower part of the Upper Khazar were previously dated by several methods. Thorium-uranium (Th–U), thermoluminescence (TL) and electron paramagnetic-resonance (EPR) methods provided an age range within 127 (130)–117 ka ago (Shkatova and Arslanov, 2004). Optical luminescence (OSL) dating of these deposits gave the following dates: 84±5 ka (volcanic ash, Vladimirovka 1 site, authors' data not published before); 99±8 – >101 ka (volcanic ash, Lenino 3 site, authors' data not published before); >108 ka (Seroglazovka 4 site) (this study).

The formation of Upper Khazar fluvial sediments occurred 114–85 (89) ka ago according to the results of Th–U, TL and EPR methods (Shkatova, 1974; Shkatova and Arslanov, 2004). Sandy deposits of paleo-incisions were dated by the OSL methods: >121, 81±5 ka (Kosika 2/3) (Zastrozhnov et al., 2020); >116, 128±8 ka (Seroglazovka 3); 119, 111±13 ka (Seroglazovka 4) (this study). Krijgsman et al. (2019) recently summarized results of different geochronological methods and different points of view on the age of these deposits.

A detailed palaeomagnetic study of some Lower Volga sections was carried out by Eremin and Molostovsky (1981). In the Seroglazovka 3 section they established a direct magnetic polarity in the Lower Khazar deposits of the bed 3 (our nomenclature). The Upper Khazar sediments (beds 4–7) are characterized by a zone of reverse polarity, correlated with the Blake episode (= "Seroglazka" episode in Shkatova, 2010). In contrast to our results, previous studies suggested Early Khazar age for marine deposits of the beds 2 and 3 (S3 section) (e.g. Shkatova, 1974; 2010; Sedaikin, 1988; Yanina, 2005), and Late Khazar age (Shkatova, 1974, 2010; Yanina, 2005) or even Khvalyn age (Sedaikin, 1988) for overlying sandy deposits of palaeo-incisions.

For the Upper Khazar sediments of the Tsagan-Aman locality, which is located 80 km upstream from the Seroglazovka locality, Tudryn et al. (2013) also documented changes in the water level of the basin and salinity under warm and humid climate at the beginning of the Late Khazar and under cold climate at the end. The findings of remains of the whitefish *Stenodus leucichthys* in the Upper Khazar sediments of the Kosika (Zastrozhnov et al., 2020) and Seroglazovka (this study) localities cannot directly support the possible connection of the Arctic and Caspian basins during some stages of the Late Khazar, however at the same time cannot entirely rule out this possibility.

5.7.7. Khvalyn time and Holocene

At the beginning of the Khvalyn time, the brackish water basin covered the entire Caspian Lowland. By the end of this time, the deposits of the Baer Knolls (Baer Knoll suite) started to accumulate (Fig. 18). In the Seroglazovka locality Yanina (2005) described frost wedges at the base of the bed 10 (layer 3 in her nomenclature). In her original description Yanina (2005) interpreted these deposits as being of subaerial (loess) origin corresponding to the Atelian regression of the Caspian basin (Fig. 3). The Atelian regression is attributed to the end of the Khazar time and is believed to be the longest period of a Caspian low stand during the Late Pleistocene (e.g. Svitoch and Yanina, 1997; Yanina et al., 2020). As described by Goretskiy (1958), the Atelian deposits formed under periglacial conditions and may contain cracks and frost wedges, which were attributed to cryogenesis. However, according to our interpretation, the bed 10 contains thin horizontal bedding of aquatic origin and mollusc fauna, and we suggest it forms an upper part of the Khvalyn marine plain. Our interpretation agrees with Shkatova (1974, 2010) and Sedaikin (1988) (Fig. 3), who assigned a Khvalyn age for this interval, and therefore we also consider Atelian deposits are missing (eroded) in the Seroglazovka locality. The frost wedges, which were described by Yanina (2005) at the base of the bed 10, may indicate cold conditions at the beginning of the Khvalyn time.

The origin of the Baer Knolls still remains poorly understood, although they have been extensively studied since their first scientific description was made by Karl von Baer in 1856 (Baer, 1856). Generally, the Baer Knolls are explained as being either (1) eolian dunes (e.g. Fedorovich, 1941; Ivanova, 1952; Kroonenberg et al., 2005), (2) marine accumulative forms (marine bars, giant ripple marks - e.g. Svitoch and Klyuvitkina, 2006; Badyukova, 2018), (3) deltaic (alluvial-marine) erosion-accumulative features (e.g. Sedaikin, 1977; Lavrishchev et al., 2011) or as being formed under (4) polygenetic geological conditions (fluvial-eolian, marine-eolian etc. - e.g. Britzyna, 1955; Menabde, 1989). Obviously, such a variety of these contrasting explanations results in contrasting interpretations of environmental dynamics of the Caspian Sea in the Late Pleistocene-Holocene. That is partly why there is no widely accepted scenario for the development of the Baer Knolls at this point, although marine hypotheses are dominant among researchers (see Svitoch and Klyuvitkina, 2006 for a summary). However, recently Zastrozhnov et al. (2018) heated the existing discussion and highlighted that eolian hypothesis on the development of the Baer Knolls should not be overlooked and is worth to be considered as the most reasonable. Nonetheless, our data on the Seroglazovka locality do not allow us to unambiguously interpret the genesis of these deposits and therefore to contribute significantly to the existing debate. At this stage we are only able to conventionally assume them to be either of alluvial-marine origin, as was adopted in the official State Geological Map (Lavrishchev et al., 2011), or alternatively of eolian origin as recently discussed by Zastrozhnov et al. (2018) (Table 7).

Geochronological dating of Khvalyn deposits by different methods gives a wide range of values from 77 to 11.8 ka ago (Abramova et al., 1983; Shkatova and Arslanov, 2004; as well as summary given in Krijgsman et al., 2019). Our OSL dating of Khvalyn deposits in the S3 outcrop section indicates an age of 27.2 $\pm$ 1.6 ka (bed 10), while in the adjacent Kosika locality it gives an age of 13.9 $\pm$ 0.8 ka (Zastrozhnov et al., 2020). The deposits of the Baer Knoll suite in the Kosika locality were also dated by the OSL method with ages of 16.7 $\pm$ 0.8 and 18.0 $\pm$ 0.9 Ka (Zastrozhnov et al., 2020). In the S3 outcrop section these deposits have a reverse magnetization as documented by Eremin and Molostovsky (1981).

Our data suggest that during the Holocene, the modern Volga river valley was formed with a characteristic floodplain landscape. Eolian processes were dominant in open spaces.

6. Conclusions

Our integrated multidisciplinary study of the borehole and outcrop sections of the Seroglazovka locality, including detailed lithological description and outcrop mapping, comprehensive biostratigraphic analysis, as well as OSL-dating, allowed us to stratify the Quaternary interval into a series of regional horizons and subhorizons. We correlate them to the adjacent Lower Volga sections and the Regional Stratigraphic Scale. Based on the results of our study, it was possible to determine the main Pleistocene sedimentary and natural environments of the study area.

The reconstruction of the geological history of the Lower Volga region based on the study of riverside sections and drilling data, and reinterpretation of the previous and obtained results is of great scientific interest in terms of understanding the processes which led to the modern faunistic composition of the Lower Volga region. This is also important to study in order to clarify the role of glacial refugia in the settlement of certain species and their further colonization of water basins and land areas with habitable environment. Our study helped to define more accurately the stratification of the Seroglazovka locality, which we therefore consider as the reference section for the Pleistocene of the Lower Volga region.

Data availability

The palaeontological collections are kept at the Institute of Geology UFRC RAS (Ufa) (mollusc shells and bones of fishes, amphibians, reptiles, and small mammals) and the Astrakhan Museum-Reserve (bones of large mammals). The 3D outcrop model of the Seroglazovka locality is available upon request from D.Z. and A.Z. (VSEGEI, St. Petersburg).

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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References

Abramova, T.A., Parunin, O.B., Svitoch, A.A., 1983. Novyye dannyye o khvalynskikh otlozheniyakh razreza Yenotayevka (Nizhneye Povolzh'ye) [New data on the Khvalynsk deposits of the Enotaevka section (Lower Volga region)]. In: Paleogeography of the Caspian and Aral Seas in the Cenozoic. Part 1. Moscow University Press, Moscow, pp. 52–62 (in Russian).

Agadjanian, A.K., 2009. Melkie Mlekopitayushchie Pliocen-Pleistocena Russkoi Ravniny [Pliocene-Pleistocene Small Mammals of the Russian Plain]. Nauka Press, Moscow, p. 676 (Transactions of the Paleontological institute, Is. 289) (in Russian).

Agalarova, D.A., Kadyrova, Z.K., Kulieva, S.A., 1961. Ostrakody Pliotsenovykh i Postpliotsenovykh Otlojeniy Azerbaydjana [Ostracoda from the Pliocene and Post-Pliocene Deposits of Azerbaijan]. Azerbaijan State Publisher Baku (in Russian).

Akuz, I.K., Demyanenko, E.V., Tereszhenko, N.P., Tokarev, N.N., Ugryumov, P.M., Eknadiosyantc, E.K., 1961. Svodnyi Otchet o Kompleksnoi Inzhenerno-Geologicheskoi Syemke Volgo-Akhtubinskoi Poimy i Delty R. Volga Masshtaba 1: 100000 Za 1956-60 [Summary Report on Complex Engineering-Geological Mapping of the Volga-Akhtuba Flood Plain and Volga River Delta in the Scale 1:100,000]. Rostov-on-Don Geological Survey Foundation, pp. 1956–1960 (unpublished, in Russian).

Aleksandrova, L.P., 1976. Gryzuny Antropogena Evropeiskoj Chasti SSSR [Anthropogene Rodents of the European Part of the USSR]. Nauka Press, Moscow (Transactions of the Palaeonlogical institute, Is. 291) (in Russian).

Ali-Zade, A.A., 1967. Akchagyl Turkmenistana [Aktshagyl of Turkmenistan, vol. 2. Nedra Press, Moscow (in Russian).

Ali-Zade, A.A., 1969. Akchagyl Azerbaidjana [Aktshagyl of Azerbaijan]. Nedra Press, Leningrad (in Russian).

Ali-Zade, A.A., 1973. Apsheron Azerbaidjana [Apsheronian of Azerbaijan]. Nedra Press, Moscow (in Russian).

Alizade, K.A., 1954. Akchagylskyi Yarus Azerbaidjana [Aktshagylian Stage of Azerbaijan]. Azerbaijan SSR Academy of Sciences, Baku (in Russian).

Ananova, E.H., 1960. O pereotlozhennykh kompleksakh pyl'tsy [On redeposited pollen complexes], 1960 Byull. MOIP. Otd. biol. T. 45 (3), 132–135 (in Russian).

Andrusov, N.I., 1902. Materialy k poznaniyu Prikaspyiskogo Neogena. Akchagylskie plasty [Contributions to the knowledge of the Caspian Neogene. The Akchagyl beds]. Mémoires du Com. Géologique XV 174 (in Russian and German).

Andrusov, N.I., 1923. Apsheronskiy yarus [Apsheron stage]. Proceedings of the Geolkom. New ser. 110, 294 (in Russian).

Badyukova, E.N., 2018. Genesis of the Baery Knolls in the northern Caspian plain. Quat. Int. 465A, 11–21.

Baer, K.M., 1856. Uchenyye Zapiski o Kaspiyskom More i Ego Okrestnostyakh [Scientific Notes about the Caspian Sea and Adjacent Regions]. In: Notes of the Imperial Russian Geographical Society. Imperial Russian Geographical Society, St-Petersburg, pp. 181–224 (In Russian).

Baygusheva, V.S., Titov, V.V., Timonina, G.I., Simakova, A.N., Tesakov, A.S., Plicht, J. van der, 2014. Mass burial of late Pleistocene bisons in the northeastern part of the sea of Azov area (port katon, rostov region). Dokl. Earth Sci. 454 (2), 140–142. https://doi.org/10.1134/S1028334X14020196.

Bemis, S.P., Micklethwaite, S., Turner, D., James, M.R., Akciz, S., Thiele, S.T., Bangash, H.A., 2014. Ground-based and UAV-based photogrammetry: a multi-scale, high-resolution mapping tool for structural geology and paleoseismology. J. Struct. Geol. 69, 163–178. https://doi.org/10.1016/j.jsg.2014.10.007.

Bobrov, A.E., Kupriyanova, L.W., Litvintseva, M.V., Tarasevich, V.F., 1983. Spory Paporotnikoobraznykh I Pyltsa Golosemennykh I Odnodolnykh Rastenij Flory Evropeiskoj Chasti SSSR [Spore of Ferns and Pollen of Gymnosperms and Monocotyledoneae Plants of Flora of the European Part of the USSR, vol. 2. Nauka Press, Leningrad, pp. 3–200 (in Russian).

Bogutskaya, N.G., Kiyashko, P.V., Naseka, A.M., Orlova, M.I., 2013. Opredelitel ryb i bespozvonochnykh Kaspijskogo moria [Identification keys for fish and invertebrates of the Caspian Sea]. In: Fish and Molluscs, vol. 1. KMK Scientific Press, St. Petersburg – Moscow (in Russian).

Böhme, M., 2010. Ectothermic vertebrates, climate and environment of the West Runton Freshwater Bed (early Middle Pleistocene, Cromerian). Quat. Int. 288 (1–2), 63–71. https://doi.org/10.1016/j.quaint.2010.06.021.

Böttcher, R., 1994. Niedere Wurbeltiere (Fische, Amphibien, Reptilien) aus dem Quartär von Stuttgart. Stuttgarter Beiträge zur Naturkunde B 215, 1–75.

Britzyna, M.P., 1955. O proizkhozhdenii baerovskikh bugrov nizov'ev Volgi [About the Genesis of the Baer Knolls Relief]. In: Memory of Academician L.S. Berg. Publishing House of the Academy of Science, pp. 320–330 (In Russian).

Buckley, S.J., Howell, J.A., Enge, H.D., Leren, B.L.S., Kurz, T.H., 2006. Integration of terrestrial laser scanning, digital photogrammetry and geostatistical methods for high-resolution modelling of geological outcrops. International Archives of the Photogrammetry, Remote Sensing and Spatial Information Science, 36(B5). In: Proceedings of ISPRS Commission V Symposium,. Dresden.

Buckley, S.J., Howell, J.A., Enge, H.D., Kurz, T.H., 2008. Terrestrial laser scanning in geology: data acquisition, processing and accuracy considerations. J. Geol. Soc. 165 (3), 625–638. https://doi.org/10.1144/0016-76492007-100.

Buckley, S.J., Ringdal, K., Naumann, N., Dolva, B., Kurz, T.H., Howell, J.A., Dewez, T.J., 2019. LIME: software for 3–D visualization, interpretation, and communication of virtual geoscience models. Geosphere 15 (1), 222–235. https://doi.org/10.1130/GES02002.1.

Büyükmeriç, Y., Wesselingh, F.P., 2018. New cockles (Bivalvia: Cardiidae: Lymnocardiinae) from late Pleistocene lake Karapınar (Turkey): discovery of a Pontocaspian refuge? Quat. Int. 465, 37–45. https://doi.org/10.1016/j.quaint.2016.03.018.

Cohen, K.M., Gibbard, Ph, 2016. G1obal chronostratigraphical correlation table for the last 2.7 million years. V. 2016. Subcommission on quatemary stratigraphy (intenational commission on stratigraphy. Cambridge, England. http://www.quaternary.stratigraphy.org.uk/charts.

Conard, N.J., Kitagawa, K., Krönneck, P., Böhme, M., Münzel, S.C., 2013. The importance of fish, fowl and small mammals in the paleolithic diet of the swabian jura, southwestern Germany. In: Clark, J.L., Speth, J.D. (Eds.), Zooarchaeology and Modern Human Origins: Human Hunting Behavior during the Later Pleistocene. Vertebrate Paleobiology and Paleoanthropology. Springer, pp. 173–190. https://doi.org/10.1007/978-94-007-6766-9_11.

Costedoat, C., Gilles, A., 2009. Quaternary pattern of freshwater fishes in Europe: comparative phylogeography and conservation perspective. Open Conserv. Biol. J. 3, 36–48. https://benthamopen.com/contents/pdf/TOCONSBJ/TOCONSBJ-3-36.pdf.

Cumbaa, S.L., McAllister, D.E., Morlan, R.E., 1981. Late Pleistocene fish fossils of *Coregonus, Thymallus, Catostomus, lota*, and *Cottus* from the Old Crow Basin, Northern Yukon, Canada. Can. J. Earth Sci. 18, 1740–1754.

Danukalova, G.A., 1996. Dvustvorchatye Molluski i Stratigraphiya Akchagyla [Bivalves and Aktschagyl Stratigraphy]. Nauka Press, Moscow. Transactions of the Paleontolological institute; Issue 265) (in Russian).

Danukalova, G.A., Zastrozhnov, A.S., Yakovlev, A.G., Kurmanov, R.G., Osipova, E.M., Shterkhun, V.L., 2017. Stratigrafiya Kvartera Astrakhanskogo Svoda (Listy L-38-XI, XII) [Stratigraphy of the Quaternary of the Astrakhan Arch (Sheets L-38-XI, XII)]. Geologicheskyi Sbornik, No. 14. Informatsionnye Materialy/IG UNTc RAN [Geological Collection, No. 14. Information Materials/IG USC RAN]. Svoe izdatelstvo Press, Saint Petersburg, pp. 40–64 (in Russian).

Danukalova, G.A., Kurmanov, R.G., Osipova, E.M., Zastrozhnov, A.S., Zinoviev, E.V., 2018. Paleontologicheskaya kharakteristika pleistocenovykh otlozhenij skvazhiny 3E (Nizhneye Povolzhye) [Palaeontological characteristics of Pleistocene deposits of the borehole 3E (Lower Volga region)]. Geol. Bull. 2, 96–109. https://doi.org/10.31084/2619-0087/2018-2-7.

Danukalova, G., Yakovlev, A., Osipova, E., Kurmanov, R., 2019. Biostratigraphy of the Early Pleistocene (Palaeopleistocene) of the southern Urals region (Russia). Quat. Int. 534, 73–88. https://doi.org/10.1016/j.quaint.2018.11.026.

Eremin, V.N., Molostovsky, E.A., 1981. Paleomagnitnyy Razrez Pleystotsena Nizhnego Povolzh'ya [Paleomagnetic Section of the Pleistocene of the Lower Volga Region]. Bulletin of the Academy of Sciences of the USSR. Geological series, pp. 71–76 (in Russian).

Fedkovich, Z.N., 1978. Sravnitel'nyy analiz kompleksov akchagyl'skikh mollyuskov Severnogo Prikaspiya, yuga Kuybyshevskogo Zavolzh'ya i Orenburgskogo Urala, a takzhe Turkmenistana i Azerbaydzhana [Comparative analysis of complexes of Akchagyl molluscs of the Northern Caspian region, the south of the Kuibyshev Trans-Volga and the Orenburg Urals, as well as Turkmenistan and Azerbaijan]. In: Garyainov, V.A., Kurlaev, V.I., Krymgolts, G.Ya, Morozov, N.S., Ochev, V.G., Poslavskaya, G.G., Semenov, V.P. (Eds.), Issues of Stratigraphy and Paleontology of SSU. Interuniversity Scientific Collection, vol. 3. Publishing house of the Saratov University, Saratov, pp. 51–61 (in Russian).

Fedorovich, B.A., 1941. Proizkhozhdeniye baerovskih bugrov prikaspiya [genesis of the Baer Knolls in the northern Caspian Plain]. Proc. USSR Acad. Sci. Ser. Geogr. Geophys. 1, 95–116 (In Russian).

Galkin, G.G., 1958. Atlas cheshui presnovodnykh kostistykh ryb [Atlas of freshwater bony fish (Teleostei) scales]. Izvestiya Vsesoyuznogo nauchno-issledovatelskogo instituta ozerno-rechnogo khoziajstva 46, 1–105 (in Russian).

Gittenberger, E., Janssen, A.W. (Eds.), 1998. Nederlandse Fauna 2. De Nederlandse Zoetwatermollusken. Recente en fossiele weekdieren uit zoet en brak water. Nationaal Natuurhistorisch museum Naturalis KNNV uitgeverij – European Invertebrate survey – Nederland.

Gliozzi, E., Rodriguez-Lazaro, J., Nachite, D., Martin-Rubio, M., Bekkali, R., 2005. An overview of Neogene brackish leptocytherids from Italy and Spain: biochronological and palaeogeographical implications. Palaeogeogr. Palaeoclimatol. Palaeoecol. 225, 283–301. https://doi.org/10.1016/j.palaeo.2005.06.015.

Glöer, P., 2002. Die Die Süßwassergastropoden Nord- und Mitteleuropas. Bestimmungsschlüssel, Lebensweise, Verbreitung. Die Tierwelt Deutschlands, 2. Aufl., vol. 73. Conchbooks, Hackenheim, p. 327.

Goretskiy, G.I., 1958. O periglyatsial'noy formatsii [About the periglacial formation]. Bull. komissii po izucheniyu chetvertichnogo perioda (22), 3–23 (In Russian).

Grichuk, V.P., 1954. Materialy k Paleobotanicheskoj Kharakteristike Chetvertichnykh i Pliocenovykh Otlozhenij Severo-Zapadnoj Chasti Prikaspiyskoj Nizmennosti [Materials to the Paleobotanical Characteristics of Quaternary and Pliocene Deposits of the Northwestern Part of the Caspian Lowland]. USSR Academy of Sciences Press, Moscow, pp. 5–79. Proceedings of the Institute of Geography; Vol. 61) (in Russian).

Grichuk, V.P., Zaklinskaya, E.D., 1948. Analiz Iskopaemykh Pyltsy i Spor i Ego Primenenie v Paleogeografii [Analysis of Fossil Pollen and Spore and Using These Data in Palaeogeography]. Geographgiz Press, Moscow, pp. 25–48 (in Russian).

Gromov, I.M., Erbaeva, M.A., 1995. Mlekopitayushchiye Fauny Rossii i Sopredelnykh Territorij. Zaitseobraznyie i Gryzuny [Mammal Fauna of Russia and Adjacent Territories. Lagomorphs and Rodents]. Keys to the fauna of Russia, published by the Zoological Institute of the Russian Academy of Sciences, Saint Petersburg. Issue 167 (in Russian).

Harington, C.R., 2011. Pleistocene vertebrates of the yukon territory. Quat. Sci. Rev. 30, 2341–2354. https://doi.org/10.1016/j.quascirev.2011.05.020.

Hoyle, T.M., Leroy, S.A.G., Lopez-Merino, L., Miggins, D., Koppers, A., 2020. Vegetation succession and climate change across the Plio-Pleistocene transition in Eastern Azerbaijan, central Eurasia (2.77-2.45 Ma). Palaeogeogr. Palaeoclimatol. Palaeoecol. 538, 109386. https://doi.org/10.1016/j.palaeo.2019.109386.

Ivanova, G.A., 1952. K Voprosu O Proizkhozhdenii Baerovskikh Bugrov [On the Origin of the Baer Knolls]. Materials of Institute of Geography, Academy of Science, USSR, pp. 277–391 (In Russian).

Karmishina, G.I., 1975. Ostracody Pliotsena Yuga Evropeiskoj Chasti SSSR [Pliocene Ostracods of the South of the European Part of the USSR]. Izdatelstvo Saratovskogo universiteta, Saratov (in Russian).

Karmishina, G.I., Sedaikin, V.M., 1978. Analiz raspredeleniya ostrakod v pleystotsenovykh otlozheniyakh Nizhnego Povolzh'ya [Analysis of the ostracod distribution in the Pleistocene sediments of the Volga region]. Voprosy stratigrafii i paleontologii [Questions of stratigraphy and paleontology]. Saratov, Izdatelstvo Saratovskogo universiteta. Issue 3, 61–76 (in Russian).

Kirillova, I.V., Svitoch, A.A., 1994. Novye nakhodki srednepleistocenovykh melkikh mlekopitayushchikh i ikh stratigraficheskoye znacheniye [New findings of Middle Pleistocene small mammals and their stratigraphic significance]. Doklady Akademii Nauk [Reports of the Academy of Sciences] 334 (6), 731–734.

Kolesnikov, V.P., 1950. Paleontology of the USSR. Akchagylskiye I Apsheronskiye Molluski [Akchagyl and Absheron Molluscs], vol. 10. Publishing House of the USSR Academy of Sciences, Moscow–Leningrad, pp. 109–259. Part III, Issue 12) (in Russian).

Kovalchuk, O.M., 2013. History of the fossil carp fishes (Teleostei, Cyprinidae) in Ukraine. Acta Zool. Cracov. 56 (1), 41–51. https://doi.org/10.3409/azc.56_1.41.

Kovalchuk, O.M., 2017. Regional fish-based biostratigraphy of the Late Neogene and Pleistocene of southeastern Europe. Vestn. Zool. 51 (5), 375–392. https://doi.org/10.1515/vzoo-2017-0045.

Kovalenko, N.D., 1971. Palinologicheskaya kharakteristika verkhnepliocenovykh otlozhenij severnogo prikaspiya [Palynological characteristics of the Upper Pliocene sediments of the northern Caspian region]. In: Neogene Stratigraphy of the East of the European Part of the USSR. Nedra Press, Moscow, pp. 99–106 (in Russian).

Krijgsman, W., Tesakov, A., Yanina, T., Lazarev, S., Danukalova, G., Van Baak, C.G.C., Agustí, J., Alçiçek, M.C., Aliyeva, E., Bista, D., Bruch, A., Büyükmeriç, Y., Bukhsianidze, M., Flecker, R., Frolov, P., Hoyle, T.M., Jorissen, E.L., Kirscher, U., Koriche, S.A., Kroonenberg, S.B., Lord-kipanidze, D., Oms, O., Rausch, L., Singarayer, J., Stoica, M., van de Velde, S., Titov, V.V., Wesselingh, F.P., 2019. Quaternary time scales for the Pontocaspian domain: interbasinal connectivity and faunal evolution. Earth Sci. Rev. 188, 1–40. https://doi.org/10.1016/j.earscirev.2018.10.013.

Kroonenberg, S.B., Simmons, M.D., Alekseevski, N.I., Aliyeva, E., Allen, M.B., Aybulatov, D.N., Baba-Zadeh, A., Badyukova, E.N., Davies, C.E., Hinds, D.J., Hoogendoorn, R.M., Huseynov, D., Ibrahimov, B., Mamedov, P., Overeem, I., Rusakov, G.V., Suleymanova, S., Svitoch, A.A., Vincent, S.J., 2005. Two Deltas, Two Basins, One River, One Sea: the Modern Volga Delta Asan Analogue of the Neogene Productive Series, South Caspian Basin. River Deltas—Concepts, Models, and Examples. SEPM Special Publication, 83, pp. 231–256.

Kupriyanova, L.V., Aleshina, L.A., 1972. Pyl'tsa I Spory Rastenij Flory Evropeiskoj Chasti SSSR [Pollen and Spore of the European Part of the USSR Plants, vol. 1. Nauka Press, Leningrad, pp. 3–166 (in Russian).

Kupriyanova, L.V., Aleshina, L.A., 1978. Pyltsa I Spory Rastenij Flory Evropeiskoj Chasti SSSR [Pollen and Spore of Plants of the European Part of the USSR, vol. 2. Nauka Press, Leningrad, pp. 10–184 (in Russian).

Kurmanov, R.G., Alimbekova, L.I., 2015. Apsheronian pollen records from the Northern Caspian based on borehole no. 4 (Tsvetnoe) materials. In: IGPC 610 Third Plenary Conference and Field Trip "From the Caspian to Mediterranean: Environmental Change and Human Response during the Quaternary" (22-30 September 2015, Astrakhan). Moscow State University Press, Moscow, pp. 117–118.

Lavrishchev, V.A., Grekov, I.I., Semenov, V.M., et al., 2011. Gosudarstvennaya Geologicheskaya Karta Rossyiskoi Federatcii. Masshtab 1:1000000 (Tretye Pokolenie). Seriya Skifskaya. List L-38 - Pyatigorsk. Ob'yasnitelnaya Zapiska [State Geological Map of the Russian Federation. Scale 1:1000000 (Third Generation). Scythian Series. Sheet L-38 - Pyatigorsk. Explanatory Notes]. All-Russian geological institute (VSEGEI) Press, Saint Petersburg (in Russian).

Lebedev, V.D., 1960. Presnovodnaya Chetvertichnaya Ikhtiofauna Evropeiskoj Chasti SSSR [Freshwater Quaternary Ichthyofauna of the European Part of USSR]. Moscow University Press, Moscow (in Russian).

Lepiksaar, J., 1994. Introduction to Osteology of Fishes for Paleozoologists. University Press, Göteborg.

Levin, B.A., Simonov, E.P., Ermakov, O.A., Levina, M.A., Interesova, E.A., Kovalchuk, O. M., Malinina, YuA., Mamilov, N.S., Mustafayev, N.D., Pilin, D., Pozdeev, I.V., Prokin, A.A., Roubenyan, H.R., Titov, S.V., Vekhov, D.A., 2017. Phylogeny and phylogeography of the roaches, genus *Rutilus* (Cyprinidae), in the Eastern part of its range as inferred from mtDNA analysis. Hydrobiologia 788 (1), 33–46. https://doi.org/10.1007/s10750-016-2984-3.

Lisiecki, L.E., Raymo, M., 2005. A Pliocene-Pleistocene stack of 57 globally distributed benthic D18O records. Paleoceanography 20, 1–17. https://doi.org/10.1029/2004PA001071. PA1003.

Lister, A.M., McGlade, J.M., Stuart, A.J., 1990. The early Middle Pleistocene vertebrate fauna from Little Oakley, Essex. Phil. Trans. Roy. Soc. Lond. B 328, 359–385.

Livental, V.E., 1929. Ostracoda Akchagylskogo i Apsheronskogo Yarusov po Babazananskomu Razrezu [Akchagylian and Apsheronian Ostracoda of Babazanan Section]. Izvestiya Azerbaidjankogo Politeknieskogo Instituta, Baku, pp. 3–57 (in Russian).

Logvinenko, B.M., Starobogatov, YaI., 1968. Gastropody [Gastropods]. In: Birshtein, Y. A., Vinogradova, L.G., Kondakova, N.N., Kun, M.S., Astakhova, T.V., Romanova, N. N. (Eds.), Atlas Bespozvonochnykh Kaspijskogo Moria [Atlas of Invertebrates of the Caspian Sea]. Pishchevaya promyshlennost, Moscow, pp. 339–385 (in Russian).

Mandelstam, M.I., Markova, L., Rosyeva, T., Stepanaitys, N., 1962. Ostrakody Pliotsenovykh i Poslepliotsenovykh Otlojeniy Turkmenistana [Ostracoda of the Pliocene and Post-Pliocene Deposits of Turkmenistan]. Geologicheskiy Institut Turkmenistana, Ashkhabad, Turkmenistan (in Russian).

Mandelstam, M.I., Schneider, G.F., 1963. Iskopaemyie Ostrakodi SSSR, Semeistvo Cyprididae [Fossil Ostracods of USSR, Family Cyprididae]. Gosudarstvennoe Nauchno-Tehnicheskoe Izdatelstvo Neftianoy i Gorno-Toplivnoy Literatury, Leningradskoe Otdelenie. Leningrad (in Russian).

Markova, A.K., 2014. Fauny melkikh mlekopitayushchikh Evropy konca rannego – nachala srednego pleistocena [Small mammal faunas of the late Early – beginning of the Middle Pleistocene of Europe]. Izvestiya of the Russian Academy of Sciences. Geography series 5, 83–98 (in Russian).

Matoshko, A.V., Gozhik, P.F., Danukalova, G., 2004. Key Cenozoic fluvial archives of Eastern Europe: the Dniester, Dnieper, Don and Volga. Proc. Geol. Assoc. 115, 141–173.

Menabde, I.V., 1989. Paleogeografiya Pozdnego Pleistotsena Nizhnego Povolzh'ya [Late Pleistocene Paleography of the Lower Volga Region]. PhD Thesis. Moscow State University (in Russian).

Moskvitin, A.I., 1962. Pleistotsen Nizhnego Povolzhya [Pleistocene of the Lower Volga region]. USSR Academy of Sciences Press, Moscow (In Russian).

Murray, A.S., Wintle, A.G., 2000. Luminescence dating of quartz using an improved single-aliquot regenerative-dose protocol. Radiat. Meas. 32, 57–73.

Naidina, O.D., Richards, K., 2016. Pollen evidence for Late Pliocene – Early Pleistocene vegetation and climate change in the north Caucasus, north-western Caspian region. Quat. Int. 409, 50–60. https://doi.org/10.1016/j.quaint.2015.12.018.

Nelson, J.S., Grande, T.C., Wilson, M.V.H., 2016. Fishes of the World, fifth ed. John Wiley & Sons Inc., Hoboken NJ (New York).

Nesbit, P.R., Durkin, P.R., Hugenholtz, C.H., Hubbard, S.M., Kucharczyk, M., 2018. 3-D stratigraphic mapping using a digital outcrop model derived from UAV images and structure-from-motion photogrammetry. Geosphere 14 (6), 2469–2486. https://doi.org/10.1130/GES01688.1.

Nevesskaja, L.A., 2007. History of the genus *Didacna* (Bivalvia: Cardiidae). Paleontol. J. 41 (9), 861–949. https://doi.org/10.1134/S0031030107090018.

Nevesskaja, L.A., Popov, S.V., Goncharova, I.K., Guzhov, A.V., Yanin, B.T., Polubotko, I. V., Byakov, A.S., Gavrilova, V.A., 2013. Dvustvorchatyye Molluski Rossii i Sopredelnykh Stran v Fanerozoye [Phanerozoic Bivalvia of Russia and Surrounding Countries]. Transactions of the Palaeonlogical institute, Nauchnyi Mir, Moscow. Issue 294 (in Russian).

Nikolsky, G.V., 1945. Kratkij obzor iskopayemoj chetvertichnoj fauny presnovodnykh ryb SSSR [Brief overview of the Quaternary fossil fauna of freshwater fishes from the USSR]. Izvestiya Vsesoyuznogo geographicheskogo obshchestva 77 (5), 288–292 (in Russian).

Nikolsky, G.V., 1952. Ryby Novgorod-Siverskoi Pizniochetvertynnoi Fauny [Fishes of the Novgorod-Siversky Late Quaternary Fauna]. Zbirnik prac Zoologichnogo muzeyu 25, 94–95 (in Ukrainian).

Pawłowska, K., 1963. Ichtiofauna łupkow interglacjalnych (Masovien I) z Barkowic Mokrych koło Sulejowa. Acta Palaeontol. Pol. 8 (4), 475–493.

Popov, G.I., 1956. Apsheronskyi yarus yugo-zapadnogo turkmenistana [Apsheron stage of the south-western Turkmenistan]. V. 1. In: Proceedings of the Institute of Geology of the Turkmenistan Academy of Sciences, Ashkhabat, p. 216 (in Russian).

Popov, G.I., 1983. Pleistocen Chernomorsko-Kaspijskikh Prolivov [Pleistocene of the Black Sea – Caspian Sea Passages]. Nauka Press, Moscow (in Russian).

Popov, S.V., Shcherba, I.G., Ilyina, L.B., Nevesskaya, L.A., Paramonova, N.P., Khondkarian, S.O., Magyar, I., 2006. Late Miocene to Pliocene palaeogeography of the Paratethys and its relation to the Mediterranean. Palaeogeogr. Palaeoclimatol. Palaeoecol. 238, 91–106. https://doi.org/10.1016/j.palaeo.2006.03.020.

Postanovleniya Mezhvedomstvennogo Stratigraphicheskogo Komiteta i Ego Postoyannykh Komissij [Provisions of the Interdepartmental Stratigraphic Committee and its Permanent Commissions], 1999. All-Russian Geological Institute (VSEGEI) Press, Saint Petersburg, pp. 26–29 (in Russian). https://vsegei.ru/ru/about/msk/postanovleniya/msk1999_31.pdf.

Postanovleniya Mezhvedomstvennogo Stratigraphicheskogo Komiteta i Ego Postoyannykh Komissij [Provisions of the Interdepartmental Stratigraphic Committee and its Permanent Commissions], 2008. All-Russian Geological Institute (VSEGEI) Press, Saint Petersburg, pp. 125–126 (in Russian). https://vsegei.ru/ru/about/msk/postanovleniya/msk2008_38.pdf.

Prat, F., Delpech, F., Cancel, N., Guadelli, J.-L., Slott-Moller, R., 2003. Le Bison des steppes, *Bison priscus* Bojanus, 1827, de la grotte d'Habarra à Arudy (Pyrénées-Atlantiques). Paléo 15, 97. https://journals.openedition.org/paleo/1362.

Radu, V., 2005. Atlas for the identification of bony fish bones from archaeological sites. Contrast, Bucureşti.

Ratnikov, V.Yu, 2002. Pozdnekaynozoyskiye Zemnovodnye i Cheshuichatye Presmykayushchiyesia Vostochno-Evropeiskoj Ravniny [Late Cenozoic Amphibians and Reptiles of the East European Plain]. Voronezh University Press, Voronezh, p. 138 (Proceedings of the Research Institute of Geology of the Voronezh State University; Issue 10) (in Russian).

Rekovets, L., Čermák, S., Kovalchuk, O., Prisyazhniuk, V., Nowakowski, D., 2014. Vertebrates from the Middle Pleistocene locality Lysa Gora in Ukraine. Quat. Int. 326–327, 481–491. https://doi.org/10.1016/j.quaint.2013.10.016.

Schreve, D.C., Bringland, D.R., Allen, P., Blackford, J.J., Gleed-Owen, C.P., Griffiths, H.I., Keen, D.H., White, M.J., 2002. Sedimentology, palaeontology and archaeology of late Middle Pleistocene river Thames terrace deposits at Purfleet, Essex, UK. Quat. Sci. Rev. 21, 1423–1464. https://doi.org/10.1016/S0277-3791(01)00100-7.

Sedaikin, V.M., 1977. K voprosu o proizkhozhdenii i vozraste baerovskikh bugrov Nizhnego Povolzh'ya [On the origin and age of the Baer Knolls of the Lower Volga Region]. Matters of Geomorphology of the Volga Region, Saratov 1 (4), 17–27 (in Russian).

Sedaikin, V.M., 1988. Opornye Razrezy Chetvertichnykh Otlozhenyj Severo-Zapadnogo Prikaspiya [Key Sites of the Quaternary Deposits of the North-Western Fore-Caspian Region]. VINITI No. 1594-B-88 (in Russian).

Sedaikin, V.M., Shulgin, V.I., Karmishina, G.I., 1973. Otchet Po Teme № 34: Sostavleniye Prognoznoi Karty Chetvertichnykh Otlozhenij Yugo-Zapadnoj Chasti Prikaspijskoj Nizmennosti (Astrakhanskaya Oblast) Masshtaba 1:200000 na Nerudnoye Syrye po Rabotam 1971–1973 Gg. [Report on Topic No. 34: Preparation of a Forecast Map of Quaternary Sediments in the Southwestern Part of the Caspian Lowland (Astrakhan Region) at a Scale of 1:200000 for Non-metallic Materials. According to the Works of 1971–1973], vol. 1. Astrakhan – Saratov (unpublished) (in Russian).

Sher, A.V., 1997. An Early Quaternary bison population from Untermassfeld: *Bison menneri* sp. nov. In: Kahlke, R.-D. (Ed.), Das Pleistozän von Untermassfeld bei Meiningen (Thuringen), Teil 1. Monographien des Romisch-Germanishen Zentralmuseums Mainz, 40. Monographien des Romisch-Germanishen Zentralmuseums, Mainz, pp. 101–180.

Shick, S.M., Agadjanian, A.K., Iosifova, YuI., Markova, A.K., Pisareva, V.V., Semenov, V. V., Tesakov, A.S., 2015a. Proekt regionalnoj stratigraphicheskoj shkaly eopleistocena centra i yugo-vostoka Vostochno-Evropeiskoj platformy [Project of the regional stratigraphic scheme of the Eopleistocene of the center and south-east of the East European platform]. In: Fundamental Problems of Quaternary, Results and Main Trends of Further Studies. Proceedings of the IX All-Russian Conference on Quaternary Research. Institute of geography of the Siberian branch of the Russian Academy of Sciencespress, Irkutsk, pp. 505–507 (in Russian).

Shick, S.M., Agadjanian, A.K., Iosifova, YuI., Pisareva, V.V., Semenov, V.V., Tesakov, A. S., 2015b. Proekt regionalnoj stratigraphicheskoj shkaly gelaziya centra i yugo-vostoka Vostochno-Evropeiskoj platformy [Project of the regional stratigraphic scheme of the Gelazian of the center and south-east of the East European platform]. In: Fundamental Problems of Quaternary, Results and Main Trends of Further Studies. Proceedings of the IX All-Russian Conference on Quaternary Research.

Institute of geography of the Siberian branch of the Russian Academy of Sciences press, Irkutsk, pp. 507–508 (in Russian).

Shkatova, V.K., 1974. Stratigrafiya Pleistocenovykh Otlozhenij Nizovyev Rek Volgi i Urala i Ikh Korreliatsiya [Stratigraphy of the Pleistocene Sediments of the Lower Volga and Ural Rivers and Their Correlation]. Thesis for Obtaining a Degree of Candidate of Geological Sciences. Geological Institute (VSEGEI), Leningrad (in Russian).

Shkatova, V.K., 2010. Paleogeography of the Late Pleistocene Caspian basins: geochronometry, paleomagnetism, paleotemperature, paleosalinity and oxygen isotopes. Quat. Int. 225, 221–229. https://doi.org/10.1016/j.quaint.2009.05.001.

Shkatova, V.K., Arslanov, KhA., 2004. Pozdniy pleystotsen Nizhney Volgi: geokhronometriya, paleo-magnetizm, izotopy kisloroda [Late Pleistocene of the Lower Volga: geochronometry, paleomagnetism, oxygen isotopes]. In: Ekologiya Antropogena i Sovremennosti: Priroda i Chelovek [Ecology of the Anthropogen and the Present: Nature and Man]. Collection of Scientific Reports Presented at the International Conference (Volgograd - Astrakhan - Volgograd, September 24-27, 2004). Humanistika Press, St. Petersburg, pp. 94–100 (in Russian).

Smagin, B.N., Troyanovskyi, S.V., Bushueva, V.P., Kuznetsova, V.I., Shadrukhin, A.V., 1977. Otchet Po Kompleksnoj Geologo-Gidrologicheskoj I Inzhenerno-Geologicheskoj Siemke Masshtaba 1:200000 Listov L–38–XI, XII [Report on Integrated Geological-Hydrogeological and Engineering Mapping in the Scale of 1: 200,000, L–38–XI, XII]. Astrakhan Complex Geological Expedition NV TGU. Astrakhan Geological Survey Foundation (unpublished, in Russian).

Sokolov, V.E. (Ed.), 1994. Dreissena: Sistematika, Ekologiya, Prakticheskoye Znacheniye [*Dreissena*: Systematics, Ecology, Practical Importance]. Nauka Press, Moscow (in Russian).

Stancheva, M., 1989. Taxonomy and biostratigraphy of the Pleistocene ostracods of the western Black Sea shelf. Geol. Balc. 19 (6), 3–39.

Stefaniak, K., Kovalchuk, O., Kotusz, J., Stachowicz-Rybka, R., Mirosław-Grabowska, J., Winter, H., Niska, M., Sobczyk, A., Barkaszi, Z., Kotowski, A., Malkiewicz, M., Alexandrowicz, W.P., Raczyński, P., Badura, J., Przybylski, B., Ciszek, D., Urbański, K., 2020. Pleistocene freshwater environments of Poland: a comprehensive study of fish assemblages based on multi-proxy approach. Boreas. https://doi.org/10.1111/bor.12489.

Suzin, A.V., 1956. Ostracody Tretichnykh Otlojeniy Severnogo Predkavkaziya [Ostracoda of Tertiary Deposits of the Northern Fore-Caucasus. Gosudarstvennoe Nauchno-Tehnicheskoe Izdatelstvo Neftianoy i Gorno-Toplivnoy Literature]. Leningradskoe otdelenie, Leningrad (in Russian).

Svitoch, A.A., Klyuvitkina, T.S., 2006. Baerovskiye Bugry Nizhnego Povolzh'ya [Baer Knolls from the Lower Volga Region]. Faculty of Geography, Moscow State University (in Russian).

Svitoch, A.A., Makshaev, R.R., 2020. Incompleteness of the geological record in Middle-Upper Pleistocene key sections of the northern Caspian Lowland. Quat. Int. 540, 78–96. https://doi.org/10.1016/j.quaint.2019.04.030.

Svitoch, A.A., Yanina, T.A., 1997. Chetvertichnye Otlozheniya Poberezhiy Kaspijskogo Moria [Quaternary Deposits of the Caspian Sea Coasts]. RASKhN Press, Moscow (in Russian).

Svitoch, A.A., Yanina, T.A., Bratanova, O.N., 1995. Biostratigrafiya opornogo razreza khazarskikh morskikh otlozhenij Severnogo Prikaspiya u s. Seroglazovka [Biostratigraphy of the reference section of the Khazar marine deposits of the Northern Caspian region near Seroglazovka]. Stratigr. Geol. Correl. 3 (1), 98–102 (in Russian).

Sytchevskaya, E.K., 1976. Iskopaemye Shchukovidnye SSSR i Mongolii [Fossil Pikes of USSR and Mongolia]. Nauka Press, Moscow, pp. 111–116 (Transactions of the Palaeonlogical institute, Issue 156) (in Russian).

Sytchevskaya, E.K., 1989. Presnovodnaya Ikhtiofauna Neogena Mongolii [Freshwater Ichthyofauna of the Neogene of Mongolia]. Nauka Press, Moscow (Trudy Sovmestnoj Sovetsko-Mongolskoj Paleontologicheskoj Ekspeditsii, Issue 39) (in Russian).

Tarcerie, S., Bearez, P., Pruvost, P., Bailly, N., Vignes-Lebbe, R., 2016. Osteobase. https://www.osteobase.mnhn.fr. accessed 28 January 2019.

Thiel, C., Buylaert, J.-P., Murray, A., Terhorst, B., Hofer, I., Tsukamoto, S., Frechen, M., 2011. Luminescence dating of the Stratzing loess profile (Austria) - testing the potential of an elevated temperature post-IR IRSL protocol. Quat. Int. V 234 (1–2), 23–31. https://doi.org/10.1016/j.quaint.2010.05.018.

Trifonov, V.G., Simakova, A.N., Çelik, H., Tesakov, A.S., Shalaeva, E.A., Frolov, P.D., Trikhunkov, YaI., Zelenin, E.A., Aleksandrova, G.N., Bachmanov, D.M., Latyshev, A. V., Ozherelyev, D.V., Sokolov, S.A., Belyaeva, E.V., 2020. The Upper Pliocene – Quaternary geological history of the Shirak Basin (NE Turkey and NW Armenia) and estimation of the Quaternary uplift of lesser Caucasus. Quat. Int. 546, 229–244. https://doi.org/10.1016/j.quaint.2019.11.004.

Tudryn, A., Chalié, F., Lavrushin, Yu.A., Antipov, M.P., Spiridonova, E.A., Lavrushin, V., Tucholka, P., Leroy, S.A.G., 2013. Late Quaternary Caspian Sea environment: late Khazarian and early Khvalynian transgressions from the lower reaches of the Volga River. Quat. Int. 292, 193–204. https://doi.org/10.1016/j.quaint.2012.10.032.

Turner, Ch, 1998. Volcanic maars, long Quaternary sequences and the work of the INQUA subcomission on European Quaternary stratigraphy. Quat. Int. 47/48, 41–49. https://doi.org/10.1016/S1040-6182(97)00069-4.

Tyurina, L.S., 1961. Sporovo-pyl'tsevaya kharakteristika chetvertichnykh i verkhnepliotcenovykh otlozhenij nizovogo Povolzhya [Palynological characteristic of the Quaternary and Late Pliocene deposits of the Lower Volga region]. Materials of meeting on studying the Quarternary 1, 288–295.

Urban, B., 1995. Palynological evidence of younger Middle Pleistocene interglacials (Holsteinian, Reinsdorf and Schoningen) in the Schoningen open cast lignite mine (eastern Lower Saxony, Germany). Mededelingen Rijks Geological Dienst 52, 175–186.

Van Houdt, J.K., Hellemans, B., Volckaert, F.A.M., 2003. Phylogenetic relationships among Palearctic and Nearctic burbot (*Lota lota*): Pleistocene extinctions and recolonization. Mol. Phylogenet. Evol. 29, 599–612. https://doi.org/10.1016/S1055-7903(03)00133-7.

Vasile, Ş., Kovalchuk, O., Petculescu, A., Venczel, M., 2020. Early Pleistocene freshwater fishes of Copăceni (Dacian Basin, southern Romania). Palaeontol. Electron. 23 (1), 1–14. https://doi.org/10.26879/1014.

Vasiliev, Yu.M., Fedorov, P.V., 1965. O stratigraficheskom polozhenii verhnehazarskih otlozheniy Nizhnego Povolzhya v edinoj shkale Kaspijskoj oblasti [On stratigraphic position of the Upper Khazarian deposits in the uniform scheme of the Caspian Area]. Izvestiya SSSR, Seriya Geology 12, 48–57 (in Russian).

Vronsky, V.A., 1965. Palinologicheskiye Kompleksy Verkhnepliocenovykh i Chetvertichnykh Otlozhenij Yugo-Zapada Prikaspiyskoy Nizmennosti i Ikh Stratigraficheskoye Znacheniye [Palynological Complexes of the Upper Pliocene and Quaternary Deposits of the South-West of the Caspian Lowland and Their Stratigraphic Significance]. Thesis for Obtaining a Degree of Candidate of Biological Sciences, Rostov-on-Don (in Russian).

Wesselingh, F.P., Alçiçek, H., 2010. A new cardiid bivalve from the Pliocene Baklan Basin (Turkey) and the origin of modern Ponto-Caspian taxa. Palaeontology 53, 711–719.

Yakhimovich, V.L., Nemkova, V.K., Verbitskaya, N.P., Sukhov, V.P., Popov, G.I., 1970. Etapy Geologicheskogo Razvitiya Bashkirskogo Preduralya v Kainozoe [Stages of the Geological Development of the Bashkirian Fore-Urals during Cenozoic]. Kainozoi Bashkirskogo Predural'ja [Cenozoic of the Bashkirian Fore-Urals]. V. II, Part 3. Nauka Press, Moscow (in Russian).

Yakhimovich, V.L., Danukalova, G.A., Yakovlev, A.G., 1998. Molluscs and small mammals from Pliocene deposits middle Volga region (sections Domashkinsky versheny). Meded. Ned. Inst. Toegepaste Geowetenschappen TNO 60, 375–416.

Yanina, T.A., 2005. Didacny Ponto-Kaspiya [Didacnas of the Ponto-Caspian Basin]. Madgenta Press, Smolensk, p. 300 (in Russian).

Yanina, T., Bolikhovskaya, N., Sorokin, V., Romanyuk, B., Berdnikova, A., Tkach, N., 2020. Paleogeography of the Atelian regression in the Caspian Sea (based on drilling data). Quat. Int. https://doi.org/10.1016/j.quaint.2020.07.023.

Zagwijn, W.H., 1996. Borders and boundaries: a century of stratigraphical research in the Tegelen-Reuver area of Limburg (The Netherlands). In: Abstracts of the INQUA-SEQS Conference "The Dawn of the Quaternary", pp. 2–9.

Zastrozhnov, D.A., Zastrozhnov, A.S., Spiridonov, V.A., Kayukov, A.E., 2018. The Baer Knolls of the Caspian Depression as Late Quaternary aeolian landforms: pros and cons, or only pros? In: Gilbert, A., Yanko-Hombach, V. (Eds.), Proceedings of UNESCO-IUGS-IGCP 610 and INQUA IFG POCAS Focus Group Joint Plenary Conference and Field Trip, October 14–21, 2018, Antalya, Turkey. Dokuman Evi, Avcilar, Istanbul, pp. 195–198.

Zastrozhnov, A., Danukalova, G., Shick, S., van Kolfschoten, Th, 2018a. State of stratigraphic knowledge of Quaternary deposits in European Russia: unresolved issues and challenges for further research. Quat. Int. 478, 4–26. https://doi.org/10.1016/j.quaint.2017.03.037.

Zastrozhnov, A.S., Danukalova, G.A., Golovachev, M.V., Titov, V.V., Tesakov, A.S., Simakova, A.N., Osipova, E.M., Trofimova, S.S., Zynoviev, E.V., Kurmanov, R.G., 2018b. Singil deposits in the quaternary scheme of the lower Volga region: new data. Stratigr. Geol. Correl. 26 (6), 647–685. https://doi.org/10.1134/S0869593818060060.

Zastrozhnov, A., Danukalova, G., Golovachev, M., Osipova, E., Yakovlev, A., Yakovleva, T., Kurmanov, R., Zenina, M., 2018c. Seroglazovka locality: key Quaternary site of the north Caspian depression, Russia. In: Gilbert, A., Yanko-Hombach, V. (Eds.), Proceedings of UNESCO-IUGS-IGCP 610 and INQUA IFG POCAS Focus Group Joint Plenary Conference and Field Trip, October 14–21, 2018, Antalya, Turkey. Dokuman Evi, Avcilar, Istanbul, pp. 191–194.

Zastrozhnov, A., Danukalova, G., Golovachev, M., Titov, V., Osipova, E., Simakova, A., Yakovlev, A., Yakovleva, T., Aleksandrova, G., Shevchenko, A., Murray, A., Tesakov, A., Sadikhov, E., 2020. Biostratigraphical investigations as a tool for palaeoenvironmental reconstruction of the Neopleistocene (Middle–Upper Pleistocene) at Kosika, lower Volga, Russia. Quat. Int. 540, 38–67. https://doi.org/10.1016/j.quaint.2018.11.036.

Zavialov, E.V., Shlyakhtin, G.V., Tabachishin, V.G., Makarov, V.Z., Berezutskiy, M.A., Yakushev, N.N., 2002. Genezis prirodnykh usloviy i osnovnye napravleniya sovremennoy dinamiki arealov zhyvotnykh na severe Nizhnego Povolzhya. Soobshenie III. Genesis fauny i flory v tchetvertitchnoe vremya. Pleistotcen [Genesis of natural conditions and fundamental trends of contemporary dynamic of animals' natural habitats in the north of Lower Volga region. Report III. Genesis of fauna and flora in Quaternary. Pleistocene]. Povolzhskiy Journal of Ecology 3, 217–235 (in Russian).

Zhadin, V.I., 1952. Molluski Presnykh Vod SSSR [Molluscs of the Freshwaters of the USSR]. Academy of Sciences of USSR Press, Moscow, Leningrad (Opredeliteli po faune SSSR. Trudy ZIN AN SSSR; T. 46) [Transactions of the Zoological institute of the Academy of Sciences of the USSR; Vol. 46] (in Russian).

Zhamoida, A.I., Girshgorn, L.C.H., Kovalevsky, O.P., Oleynikov, A.N., Prozorovskaya, E. L., Khramov, A.N., Shkatova, V.K., 2019. Stratigraphicheskyi Kodeks Rossii [Stratigraphic Code of Russia]. corrected, third ed. VSEGEI Press, St. Petersburg (in Russian). https://vsegei.ru/ru/about/msk/sc_2019.pdf.

Zhidovinov, N.Y., Kovalenko, N.D., Kuznetsova, N.I., Eremin, V.N., 1981. O rezul'tatakh izucheniya neogenovykh i chetvertichnykh otlozheniy po Astrakhanskoy parametricheskoy skvazhine 123 [On the results of the study of Neogene-Quaternary deposits of Astrkhan stratigraphic well 123]. In: Kamaletdinov, V.L., Yakhimovich, V.L. (Eds.), Pliocene-Pleistocene of the Volga-Ural Region. Nauka press, Moscow, pp. 132–136 (in Russian).