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Data on Stratotypes of the Neopleistocene–Holocene Regional and Local Subdivisions in the Caspian Region

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Abstract—Considered in the work are data characterizing stratotypes of regional and local stratigraphic subdivisions, which are distinguished in the Neopleistocene–Holocene sedimentary succession of the Caspian region. The succession is composed of sediments deposited by the Caspian transgressions and intervening continental sediments of the late Quaternary. Except for stratotypes of the Tyurkyany Horizon and Gyurgyany Formation, which are established in borehole sections, the other ones represent the well-stratified natural sections accessible for examination of their subdivisions distinguished based on biostratigraphic criteria. Mollusks of the genus *Didacna* Eichwald and fossil assemblages of large mammals are used to substantiate stratigraphy of marine and terrestrial deposits, respectively.

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Key words: Neopleistocene, Holocene, Caspian, stratigraphy, biostratigraphy, stratotypes.

"…Stratotype ought to be established for a formation, horizon or local zone"
(*Stratigraphic Code of Russia*, 2006, paragraph 3.1, p. 70)

INTRODUCTION

Description of stratotypes is an important procedure in Quaternary stratigraphy, since their distinguishing is a very difficult problem. In majority, the regional stratigraphic subdivisions are lacking stratotypes, and some stratotypes, which have been established, are described in a schematic mode, frequently without proper attention to regulations of stratigraphic nomenclature (*International Stratigraphic…*, 2002; *Stratigraphic Code…*, 2006).

In many aspects, this situation depends on a high diversity of Quaternary lithofacies containing fossil remains of organisms with subtle evolutionary modifications in their morphology, which cannot be adequately used in biostratigraphy. An exception is the Pleistocene sedimentary succession of the Caspian region with regional subdivisions well substantiated by paleontological methods. After the early work by Andrusov (1889), a whole generation of outstanding researchers (Pravoslavlev, 1908, 1926; Zhukov, 1945; Gromov, 1935; Moskvitin, 1962; Nevesskaya, 1958; Fedorov, 1957; Popov, 1983; and many others) worked out a high-resolution stratigraphic scheme for Pleistocene (Neopleistocene as authorized by the ISC in 1995) marine and continental deposits exposed in coastal zone of the Caspian Sea. Nevertheless, being deprived of described stratotypes many subdivisions of the scheme have been variably ranked in terms of stratigraphic nomenclature. For instance, the upper Khvalynian deposits of low thickness have been ranked in different times as a horizon, subhorizon or beds, the lower Khazarian deposits have been regarded under names of the Kosozh, Singil and Gyurgyany formations, and the Urundzhik and Singil sediments were correlated either with the lower or middle Pleistocene. Besides, subdivision of the Khvalynian sediments was based on geomorphological and lithological criteria, and on absolute dates obtained by different methods, but not on molluscan assemblages found in situ.

It is necessary therefore to revise systematics of Pleistocene stratigraphic subdivisions known in the Caspian region (*Proceedings of the Second…*, 1986) and to establish their valid stratotypes. In this publication of limited volume, we do not describe in full measure the suggested stratotypes in accord with all the ISC regulations. Data presented below forestall this work and have been obtained during the long-lasted study of Pleistocene rocks exposed along the coastline of the Caspian Sea.

DATA ON THE NEOPLEISTOCENE STRATOTYPES OF THE CASPIAN REGION

In this work dedicated to the regional stratigraphic scale of the Caspian Pleistocene (Neopleistocene in the ISC scheme of 1995, Alekseev et al., 1997), we describe horizons divisible into subhorizons, beds and formations, which correspond as a whole to biozone of subgenus *Didacna* Eichwald (Fig. 1A). Nearly all the subdivisions had no stratotypes, and even if the latter were indicated (Tyurkyany, Urundzhik, Gyurgyany horizons), their description was inconsistent with well-known regulations of stratigraphic nomenclature. Factual materials presented below characterize stratotypes of regional and local Neopleistocene subdivisions of the Caspian region. All the stratotypes exposed along coastline of the Caspian Sea (Fig. 1B) are described in the order of their succession in the regional stratigraphic scale.

Lower Neopleistocene

Tyurkyany Horizon. The horizon was originally distinguished by V.E. Khain (1950) based on materials of Craelius drilling (Dashevskaya, 1936), which showed that Apsheronian and Bakunian strata are separated in the Apsheron Peninsula by a thick intervening sequence of clay containing *Dreissena* shells, freshwater gastropods, ostracodes and plant remains. The horizon was termed after eponymous village Tyurkyany, where respective sediments were first recovered by drilling. The horizon stratotype had not been established because of a poor information about the sequence structure and its stratigraphic status. Being regarded as "barren member, intervening or transitional sequence," the deposits under consideration have been tentatively attributed to either the terminal Apsheronian or basal Bakunian regional stages. Quaternary ostracodes, foraminifers and rare shells of Bakunian mollusks, which were found later on in these deposits, motivated their correlation with the basal Quaternary (Mamedov et al., 1988).

Natural coastal exposures with the Tyurkyany deposits are unknown. Accordingly, we have to suggest for the horizon an areal lectostratotype recovered by drilling in the Kyursangya site southeastward of Shirvani. The Apsheronian deposits containing *Apscheronia* sp. are overlain here with scouring and angular unconformity by the Tyurkyany sediments divided into three members (Shikhlinskii, 1967). The lower member up to 90 m thick is composed of gray and brown-gray (variegate) clay resting on basal coquina bed. The middle member of gray sandy clay is up to 40 m thick, and the upper one is represented by variegate (gray, gray-brow and brown) clay with sand intercalations. Two lower members are missing in apical parts of structures, and angular unconformity is observable in this case between the Tyurkyany sediments and the Bakunian beds of long clay. Shells *Didacna parvula* Nal. have been identified in the Tyurkyany deposits recovered by boreholes 9 and 10 (Fig. 1B). Dashevskaya (1936) noted the three-member structure of the Tyurkyany Horizon in the eastern Apsheron Peninsula, the other stratotype area.

Bakunian Horizon. Sjogren (1891) distinguished this horizon in the oldest Quaternary deposits near the town of Baku, though without indication of its stratotype. Golubyatnikov (1914) suggested to regard as stratotype the section of the Bakunian Stage Mt. in the Apsheron Peninsula. In correct terminology, this is the lectostratotype, which has been studied afterward by Nalivkin (1914), Fedorov (1957), Mamedov et al. (1988), and Svitoch et al. (1992, 1997) who suggested different versions of the section structure. The Bakunian Stage Mt. is a flat-topped erosion remnant (mesa) at the limb of the Bibieilat anticline. The most complete section of Bakunian fossiliferous sediments (Svitoch et al., 1992) is exposed on the mesa southeastern slope (Fig. 2A). The following succession of sediments is observable here below beds 1–3 of slightly dislocated Khazarian (?) sandstones, clays and conglomerates:

4. Clay, dark gray, silty, horizontally bedded, containing abundant *Dreissena* and rare *Didacna* shells; thickness 0.8–1 m.

5. Aleurite, light gray, with fine-grained sand interlayers and *Didacna* and *Dreissena* shells; thickness 5 m.

6. Aleurite, brown-gray, containing abundant *Didacna* shells; thickness 10 m.

7. Aleurite, gray to dark gray, sandy, with rare *Didacna* shells; thickness 2.5 m. A distinct transition to underlying bed is lacking visible scour marks.

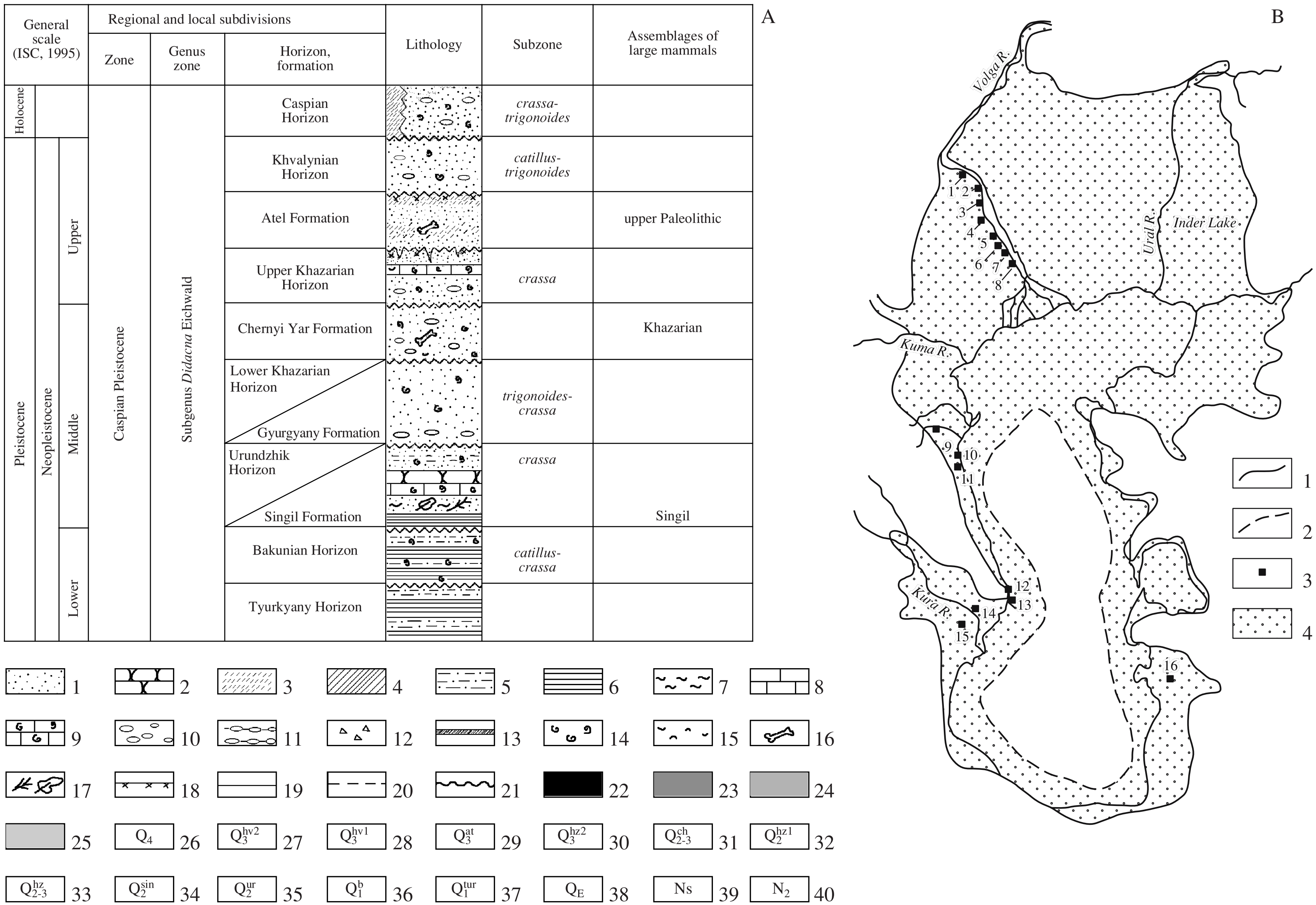
8. Clay, brown-gray; thickness 6 m.

9. Sand, brown to yellowish brown, weakly cemented, fine-grained; thickness 1.5 m.

10. Sandstones containing shells of Apsheronian mollusks *Pseudocatillus* sp., *Apscheronia* sp. and others.

The Bakunian beds dipping W–SW under angles of 10°–12° correspond to paleomagnetic zone of normal polarity in the section. Molluscan shells are abundant in beds 4–7 of the section. Bed 7 yields only small thin-walled shells of *Didacna parvula* Nal. Species *D. catillus* Eichw. and *D. rudis* Nal. dominant in Bed 6 occur in association with *Dreissena polymorpha* Pall. and single *D. parvula* Nal., *D. carditoides* Andrus., *Dreissena rostriformis* Desh. Most abundant shells are found in Bed 5, where dominant *Didacna catillus* Eichw., numerous *D. rudis* Nal. and *D. carditoides* Andrus. coexist with *Didacna subcatillus* Andrus., *Dreissena pontocaspia* Andrus., *Dr. rostriformis* Desh., and single specimens of *Didacna parvula* Nal., *D. vulgaris* Andrus., and *Dreissena polymorpha* Pall.

Three faunal subassemblages are distinguishable in the section. The lower monotypic subassemblage (Bed 7) is represented exclusively by mollusks of the *crassa* group. The middle, most diverse subassemblage (beds 6 and 5) is dominated by *Didacna* species of the *catillus* group associated with transitional forms. The upper subassemblage (Bed 4) is clearly depleted in *Didacna* shells and consists mainly of *Dreissena* species. Compositional changes in these subassemblages have been likely controlled by facies-ecologic factors, i.e., by changes in habitat environments of mollusks, which populated paleobasin of the Bakunian time. In addition, the described deposits contain diverse micro-


A
General scale (ISC, 1995)
Regional and local subdivisions
Zone
Genus zone
Horizon, formation
Lithology
Subzone
Assemblages of large mammals
Holocene
Pleistocene
Neopleistocene
Upper
Middle
Lower
Caspian Pleistocene
Subgenus Didacna Eichwald
Caspian Horizon
Khvalynian Horizon
Atel Formation
Upper Khazarian Horizon
Chernyi Yar Formation
Lower Khazarian Horizon
Gyurgyany Formation
Urundzhik Horizon
Singil Formation
Bakunian Horizon
Tyurkyany Horizon
crassa-trigonoides
catillus-trigonoides
crassa
trigonoides-crassa
crassa
catillus-crassa
upper Paleolithic
Khazarian
Singil
B
Volga R.
Ural R.
Inder Lake
Kuma R.
Kura R.
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16
1 2 3 4
Q_4 26
Q_3^{hv2} 27
Q_3^{hv1} 28
Q_3^{at} 29
Q_3^{hz2} 30
$Q_{2\text{-}3}^{ch}$ 31
Q_2^{hz1} 32
$Q_{2\text{-}3}^{hz}$ 33
Q_2^{sin} 34
Q_2^{ur} 35
Q_1^{b} 36
Q_1^{tur} 37
Q_E 38
Ns 39
N_2 40

fauna of ostracodes and foraminifers (Svitoch et al., 1992).

Based on *Didacna* subassemblages, the Bakunian Horizon can be divided into lower, middle and upper members, which recoded successive stages in evolution of the Bakunian sea. The lower member (Bed 7) with the *Didacna parvula* molluscan subassemblage contains the early Pleistocene brackish-water foraminifers (dominant species *Ammonia caspica*) and ostracode assemblage with abundant *Leptocythere* forms. Beds 8 and 9 barren of malacofauna also yield typical Pleistocene foraminifers and can be attributed to Quaternary deposits. The middle member (beds 5 and 6) corresponding to the transgression maximum contains the diverse *Didacna catillus–D. rudis–D. carditoides* subassemblage, brackish-water foraminifers (dominant species *Ammonia novoeuxinica*) and ostracodes of the Bakunian–Khazarian time. The upper member (Bed 4) bearing the *Dreissena rostriformis–Dr. polymorpha* assemblage of mollusks characterizes terminal stage of the Bakunian transgression. According to the described structure, section of the Bakunian Stage Mt. can be accepted for a *lectostratotype* of the Bakunian Horizon and its boundaries (*limitotype*).

Middle Neopleistocene

Urundzhik Horizon is basal one in the middle Neopleistocene of the Caspian region, and respective deposits are widespread in Azerbaijan and Turkmenistan segments of seacoast. Fedorov (1946) distinguished the horizon stratotype in the South Urundzhik tract (Fig. 1B), the Uzboi–Balkhan region of southern Turkmenistan, where it was described by Nevesskaya (1958). In the stratotype (*holostratotype*), a sand bed with redeposited malacofauna is underlain (Fedorov, 1946) by a sequence of light brown to pale pinkish Khazarian clays with interlayers of sand that is coarse-grained, containing gravel and clay pebbles. In the sequence topmost interval, there are abundant plant remains and shells *Unio* sp. and *Anodonta* sp., which give place below to *Dreissena* shells, and then to small *Didacna* shells near the base. The sequence is 3–4 m thick. Below it, there is a bed of the Urundzhik coquina with basal pebbly layer. The coquina bed about 2 m thick contains abundant shells *Didacna eulachia* (Bog.) Fed., *D.* aff. *delenda* Bog., *D. karelini* Fed., *Dreissena rostriformis* Desh., and *Dr. polymorpha* Pall. It overlies with erosion marks the Bakunian sandy clays reddish brown to brown-gray in coloration, containing shells *Didacna parvula* Nal. Thus, the Urundzhik Horizon is represented in its stratotype by the 2-m-thick bed of shallow-water coquina with *Didacna* assemblage, the guide species *Didacna eulachia* (Bog.) Fed. inclusive. The coquina bed resting on eroded surface of the Bakunian clays is overlain by the Khazarian sediments deposited in a highly desalinated basin.

A more representative section of the Urundzhik deposits, which can be suggested for their areal *hypostratotype*, is exposed on limbs of the Mishovdag structure along the northeastern periphery of the Kura depression. In the well-known Neftyanaya Balka outcrop (Fedorov, 1978; Mamedov et al., 1988; Svitoch et al., 1998; Yanina, 2005), there are exposed three thick sequences with hiatuses and angular unconformities in between. The Apsheronian coquinoid limestone beds with gray sand interlayers, which contain abundant smooth and ribbed *Apscheronia* shells and steeply dip under angles of 30° to 40°, are overlain here by the following deposits (from the base upward, Fig. 2B):

Bakunian Horizon (beds 2–10). Lower aleurites and sands with abundant *Didacna parvula* Nal. and *Dreissena polymorpha* Pall. shells grade upward into limestone and sandstone beds bearing *Didacna parvula* Nal., *D. carditoides* Andrus., *D. eulachia* (Bog.) Fed., *Dreissena polymorpha* Pall., *Dr. rostriformis* Desh., and *Monodacna caspia* Eichw.; dip angles 20°–30°, thickness over 50 m.

Urundzhik Horizon (beds 11–20). Grayish yellow sands and aleurites interlayering with sandstone and coquina beds; the assemblage of abundant *Didacna eulachia* (Bog.) Fed., *D. colossea* (Dasch.) Vekil., *D. čelekenica* Fed., rare *D. carditoides* Andrus., and *D. mingetschaurica* Vekil., which are found at the base, is gradually replaced higher by assemblage of *Didacna kovalevskii* Bog. and other *Didacna* forms characteristic of the Khazarian basins. Hiatuses in sedimentation have not been observed. Beds dip gently (10°–15°), thickness about 60 m.

Lower Khazarian (Gyurgyany) deposits (Bed 21). These deposits exposed in northern limb of the structure represent a thin undeformed blanket of gray loose sands containing abundant shells of *Didacna paleotrigonoides* Fed. and *D. subpyramidata* Prav.

In the considered hypostratotype, two diverse subassemblages of malacofauna are well represented, and relationships of the Urundzhik Horizon with boundary beds are easily observable. Palynological spectra of respective sediments (Svitoch et al., 1997, 1998) sug-

Fig. 1. Horizons and formations of the regional stratigraphic scale (A) and localities of their stratotypes (B).

A. Lithology: (1) sand; (2) sandstone; (3) sandy loam; (4) loam; (5) aleurite; (6) clay; (7) clayey aleurite; (8) limestone; (9) coquina; (10) shingle and gravel; (11) conglomerate; (12) rubble; (13) ash; (14) molluscan shells; (15) shell detritus; (16) mammal bones; (17) plant remains; (18) paleosol. Boundaries between beds: (19) distinct, without scouring; (20) gradual; (21) erosion boundary. Taxa occurrence frequency: (22) dominant; (23) abundant; (24) rare; (25) single specimens. Geologic indices: (26) Neocaspian; (27) upper Khvalynian; (28) lower Khvalynian; (29) Atel; (30) upper Khazarian; (31) Chernyi Yar; (32) lower Khazarian; (33) Khazarian; (34) Singil; (35) Urundzhik; (36) Bakunian; (37) Tyurkyany; (38) Apsheronian; (39) Sarmatian; (40) Pliocene.

B: (1) extreme boundary of Neopleistocene transgressions; (2) regression maximum boundary; (3) sections Raigorod (1), Chernyi Yar (2). Nizhnee Zaimishche (3), Nikol'skoe (4), Tsagan-Aman (5), Kopanovka (6), Enotaevka (7), Seroglazovka (8), Shura-Ozen, Kumtorkala (9), Turali (10), Bakai-Kichlik (11), Bakunian Stage Mt. (12), Tyurkyany (13), Mishovdag (14), Kyursangya area (15), S. Urundzhik (16); (4) distribution area of Neopleistocene marine deposits.

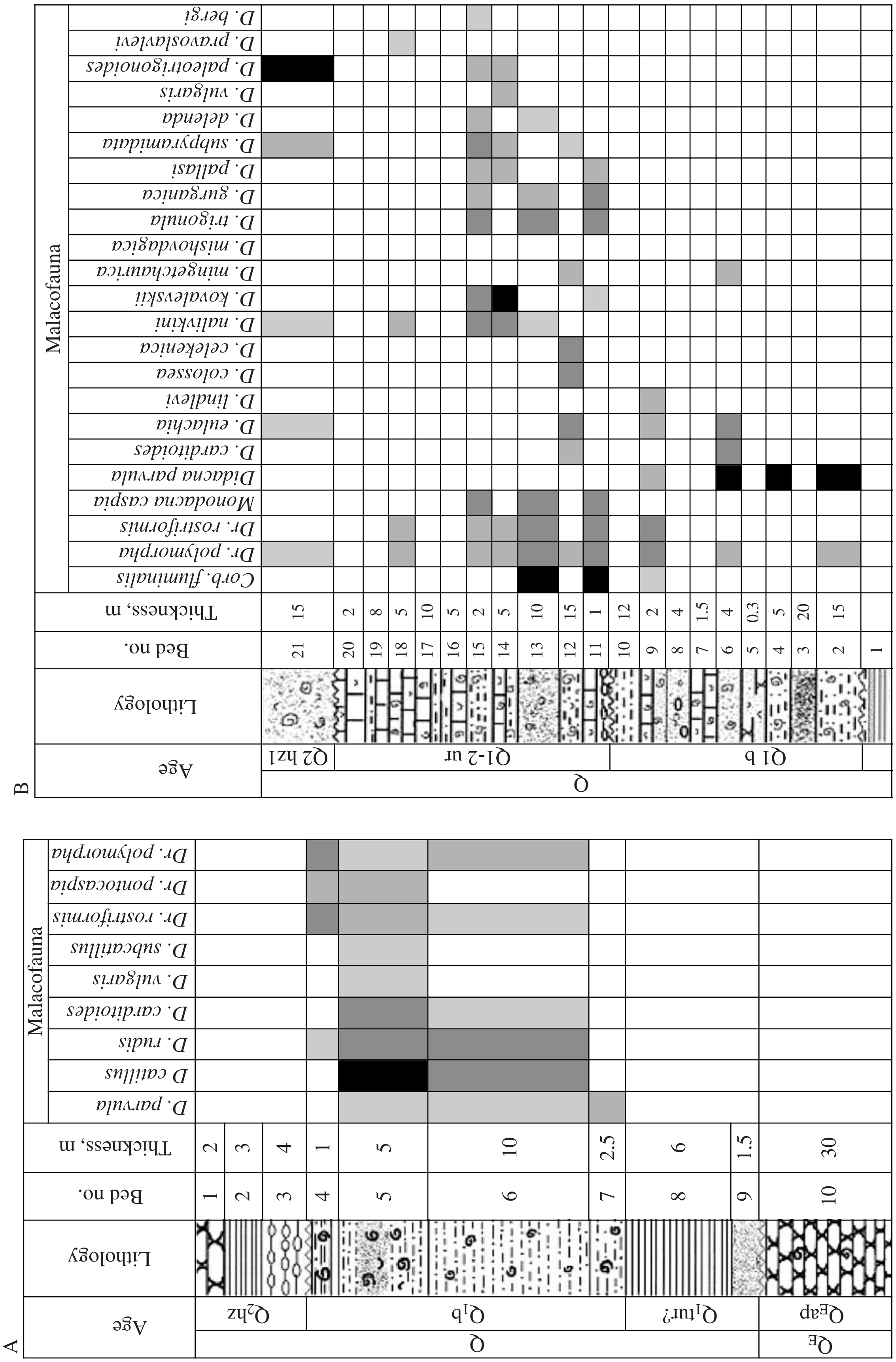


Fig. 2. The Bakunian Stage Mt. (A) and Neftyanaya Balka (B) sections (symbols as in Fig. 1).

gest a warm, humid climate and prevalence of forest coenoses in landscapes.

Singil Formation corresponds to a sequence of predominantly lacustrine-lagoonal and alluvial floodplain sediments, which are exposed at the foot of many coastal scarps on the right side of the Volga River between the Raigorod and Enotaevka. According to drilling results in the Volga valley, deposits of the formation are clamed between the Venedy and Krivichi formations. Pravoslavlev (1918) who was first to distinguish this formation used in nomenclature the ancient name Singil for the Akhtuba, the left watercourse of the Volga River; stratotype has not been indicated. The formation is composed of dark bluish gray clays and compact aleurites, which contain remains of freshwater mollusks, ostracodes, diverse palynological assemblages of forest and forest-steppe landscapes, fossil entomofauna, and carpolites. Bone remains of large mammals buried in the formation represent the well-known Singil terriofauna (Alekseeva, 1978). Section exposed on the Volga River right bank used to be regarded as *stratotype (lectostratotype)* of the formation. Many researchers who studied this exposure (Pravoslavlev, 1926; Grichuk, 1954; Fedorov, 1957; Vasil'ev, 1961; Moskvitin, 1962; Sedaikin, 1988; Svitoch and Yanina, 1997) distinguished here four sedimentary sequences (Fig. 3A, from the base upward):

1. Lower Khvalynian deposits: chocolate-brown clays with sand interlayers and shells *Didacna protracta* Eichw. and *Dreissena rostriformis distincta* Andrus. Indications of pedogenesis are recorded at the top, and clays grade downward into yellowish gray fine-grained sands containing *Monodacna caspia* Eichw. and *Dreissena polymorpha* Pall.; thickness 2 m.

2. Atel Formation: light, grayish brown, loess-like sandy loam indistinctly alternating with powdery fine-grained sand containing carbonate and gypsum inclusions; indications of pedogenesis are detected at the top and near the base. The unit boundaries are distinct in lithologic aspect; thickness up to 9 m.

3. Khazarian continental deposits divided into three members: the upper one of dark brown sandy loam with mycelioid structures is dissected at the top by wedges filled with overlying sediment; the middle member of brown loam and aleurite with rare shells of freshwater mollusks encloses paleosol horizons: an automorphic at the top, representing reference horizon between the Raigorod and Chernyi Yar on the Volga River right bank, and hydromorphic paleosol at the base. The lower member of alternating dark and bluish gray aleurites is enriched in plant remains and contains unionid and sphaeriid shells. Its basal bed of water-bearing sand overlies the uneven top of the Singil Formation; total thickness 15 m.

4. Singil Formation: compact dark to bluish gray, locally clayey aleurites containing inclusions of vivianite and Mn-oxides, plant remains, and shells of freshwater mollusks: *Unio tumidus* Retz., *Unio pictorum* L., *Sphaerium rivicola* Leach., *Anodonta sp., and Lithoglyphus naticoides* C. Pf. Abundant bones buried in the formation are remains of the following large mammals: *Palaeoloxodon antiquus* Grom., *Equus* ex gr. *caballus* Pavl., *Elasmotherium sibiricum* Fisch., *Bison priscus* Grom., *Saiga tatarica* L., *Camellus knoblochi* Nehr., *Megaloceros* sp., and *Cervus* ex gr. *elaphus* L.; apparent thickness 2 m. Carpological remains from the Singil deposits, which have been studied by P.P. Nikitin and P.I. Dorofeev (Moskvitin, 1962; Gromov et al., 1965), suggest a forest-covered landscape and humid climate that was, however, less warm than now.

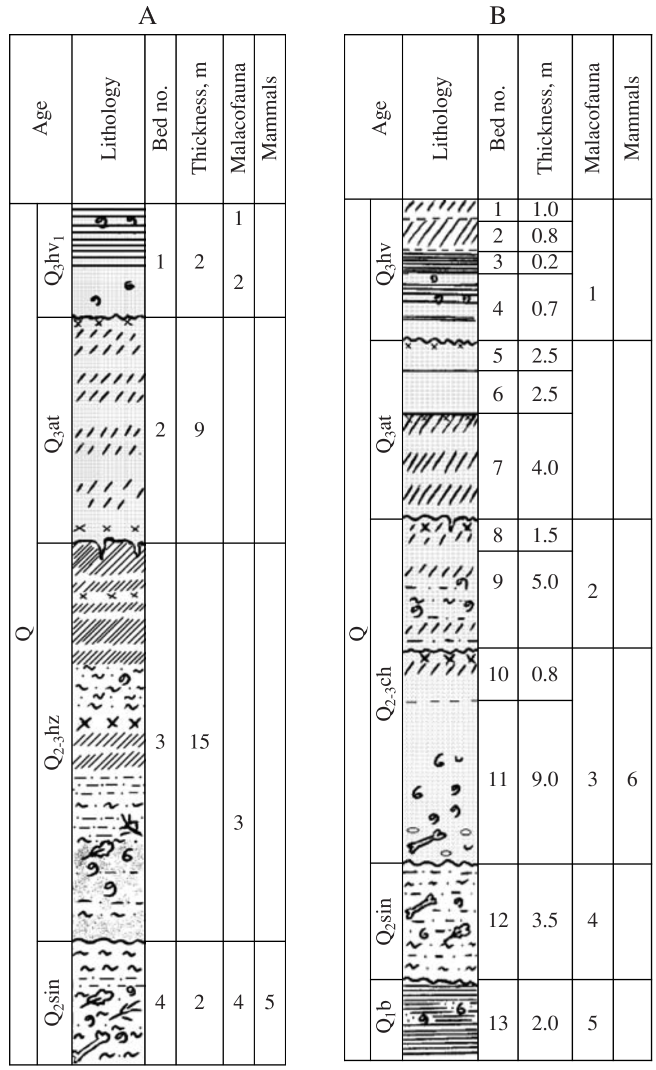


Fig. 3. The Raigorod (A) and Nizhnee Zaimishche (B) sections.

A. Composition of malacofauna: (1) *Didacna protracta, Dreissena rostriformis distincta*; (2) *Monodacna caspia, Dreissena polymorpha*; (3) *Sphaerium, Unio*; (4) *Sphaerium, Unio, Anodonta.* Composition of large mammal fauna: (5) *Palaeoloxodon antiquus, Equus caballus, Elasmotherium sibiricum, Bison priscus, Saiga tatarica, Camellus knoblochi, Megaloceros* sp., *Cervus elaphus.*

B. Composition of malacofauna: (1) *Didacna protracta, D. ebersini, Dreissena rostriformis distincta*; (2) *Unio, Dreissena*; (3) *Viviparus* sp., *Sphaerium* sp., *Dreissena, Didacna pallasi, D. subpyramidata, D. paleotrigonoides, D. delenda, D. subcrassa, D. subcatillus, D. cristata*; (4) *Sphaerium*; (5) *Didacna catillus volgensis, D. parvula, Dreissena rostriformis.* Composition of large mammal fauna: (6) *Elephas trogontherii, Megaloceros germanicus, Bison priscus longicornis, Saiga* sp., *Equus* sp. (other symbols as in Fig. 1).

Position of the Singil Formation relative to the Bakunian and lower Khazarian (Paleocaspian) horizons is insufficiently clear in the stratotype. *Limitotypes* of the formation can be established downstream, in the Nizhnee Zaimishche and Nikol'skoe sections. It is clearly seen at the foot of scarp at the Nizhnee Zaimishche site (5 km downstream of the settlement Chernyi Yar, Fig. 3B) that uneven, deeply eroded surface of the Bakunian compact aleurites containing guide species *Didacna catillus volgensis* Svit. is overlain by dark bluish gray, compact, clayey aleurite of the Singil Formation that bears shells of freshwater mollusks. In the other section situated 2 km upstream of the village Nikol'skoe, there are exposed near the water edge the Singil dark gray compact clay and aleurites (thickness up to 3 m), which are discordantly overlain by lower Khazarian gray sands with bluish brown clay interlayers and shells of the early Khazarian *Didacna subpyramidata* Prav. and *D. pallasi* Prav. Consequently, deposits of the Singil Formation occur immediately above the Bakunian Horizon and below the lower Khazarian sediments. According to this position in the scale of the Caspian Neopleistocene, the formation is stratigraphic analog of marine deposits left by the Urundzhik transgression in southerly areas of the Caspian region.

Khazarian deposits (after ethnic term "khazary" of people that inhabited the Volga lower reaches in second millennium B.C.) were first described by Andrusov (Provoslavlev, 1913) who did not pointed out their stratotype corresponding undoubtedly to sections of the Volga lower reaches (Pravoslavlev, 1908, 1913; Zhukov, 1945). The Khazarian deposits are divided into lower and upper horizons (Fedorov, 1957) containing guide *Didacna* groups. Stratotypes of horizons have not been suggested.

Lower Khazarian Horizon. Deposits of the horizon are widespread along the Caspian Sea coast. In lowlands, diverse, predominantly terrigenous facies of the horizon occupy large areas; in the Caucasus piedmonts, they are exposed in medium-high terraces. Assemblages of malacofauna from these deposits are dominated by *Didacna* forms of the *trigonoides* group, which occur in association with foraminifers and ostracodes. Sediments yield palynological spectra with prevailing pollen of herbaceous plants, show remanent magnetization of normal polarity, and are over 300 ka old according to results of U–Th dating (Arslanov et al., 1988).

Among many perfect exposures of the Lower Volga stratotype area, the Seroglazovka section (Shkatova, 1973; Popov, 1983; Sedaikin, 1988; Svitoch et al., 1995; Yanina, 2005) located 2 km downstream of the eponymous village is most complete and interesting in stratigraphic aspect, being most suitable for *lectostratotype* of the lower Khazarian Horizon. Along a distance of 2 km, there is observable structure (Fig. 4A) of stratified, variably thick sequence of diverse sedimentary facies containing Caspian mollusks and ostracodes (Svitoch et al., 1995). The upper Khazarian deposits of diverse lithology (Bed 4), which are exposed in a scarp below the Khvalynian and Atel strata and contain the late Khazarian index species *Didacna surachanica* Andrus., overlie the following beds:

5. Brown and bluish gray clays and loams interlayering with gray aleurite and fine-grained sand; in the bed upper part, laminae are frequently deformed into plicae and kettles. The distinct upper boundary bears marks of deep scouring; the lower one is conformable and also distinct in lithologic aspect. Sediments contain abundant remains of the early Khazarian mollusks: *Didacna schuraosenica* Svit. et Tschern., *D.* cf. *cristata* Bog., *Dreissena rostriformis* Desh., less common *Didacna catillus volgensis* Svit., *D. subcrassa* Prav., *D.* cf. *pontocaspia* Pavl., *D.* ex gr. *trigonoides* Pall., *D. pallasi* Prav., *Monodacna caspia* Eichw., and *Hypanis plicatus* (Eichw.). Species *Didacna schuraosenica* dominant in the bed lower part are associated higher with numerous *Didacna* cf. *cristata* and *Dreissena rostriformis.* Fossil ostracodes are classed with *Cyprideis torosa* (Jones.), *Bacunella dorsoarcuata* (Zal.), *Caspiolla gracilis* Liv., *Paracyprideis naphtatscholana* (Liv.), *P. enucleata* Schar., *Tyrrhenocythere pseudoconvexa* (Liv.), *Aurila azerbaidjanica* (Liv.), *A. papillosa* (Liv.), *Leptocythere bacuana* (Liv.), *L. martha* (Liv.), *L. arevina* (Liv.). Popov (1983) correlated the bed with the Girkany level; Sedaikin (1988) with the lower Khazarian. Shkatova (1973) regarded aleurites of Bed 5 and sands of Bed 4 as representing stratotype of the upper Khazarian Seroglazovka Marinium.

6. Sand, yellowish to light gray, fine-grained, thin bedded, enclosing interlayers of brown-gray silty sand locally transformed into flaggy sandstone with carbonate cement and lenticular coquina intercalations. Fossils found in the bed upper part are *Didacna paleotrigonoides* Fed., *D. schuraosenica* Svit. et Tschern. (dominant), abundant *D. catillus volgensis* Svit., *D. subcrassa* Prav., *D.* cf. *cristata* Bog., *Monodacna caspia* Eichw., *Hypanis plicatus* (Eichw.), *Micromelania caspia* Eichw., *Dreissena rostriformis* Desh., fairly frequent *Didacna ovatocrassa* Prav., and comparatively rare *D. pallasi* Prav., *D.* ex gr. *trigonoides* Pall., *D. nalivkini* Wass., *Dreissena polymorpha* Pall., and *Theodoxus pallasi* (Lindh.). In the middle part, abundant *Didacna catillus volgensis* Svit. coexist with less numerous *Didacna paleotrigonoides* Fed., *D. subcatillus* Andrus., *Dreissena rostriformis* Desh., and single *Didacna subpyramidata* Prav., *D. subcrassa* Prav., *D.* zhukovi Fed., and *Monodacna caspia* Eichw. The lower boundary distinct in terms of lithology is locally deformed, marked by sand pockets penetrating into underlying bed; thickness 3–4 m.

7. Aleurite, brown to dark brown, compact, locally clayey or sandy, containing unionid shells, *Viviparus* sp., *Sphaerium* sp., *Micromelania caspia* Eichw., *Dreissena polymorpha* Pall., and *Dr. caspia* Andrus. (Singil Formation); apparent thickness about 1 m.

The lower Khazarian marine deposits (beds 5 and 6) having distinct position between Singil and upper Khazarian sediments are of two-member structure, characterizing stages in development of transgression. In Azerbaijan, the lower Khazarian Horizon is represented by deposits of the Gyurgyany Formation, which has been distinguished by Dashevskaya (1936) in the eponymous Cape Gyurgyany of the Apsheron Peninsula. These deposits are either deformed into synclinal folds or form accumulative blankets on a series of ter-

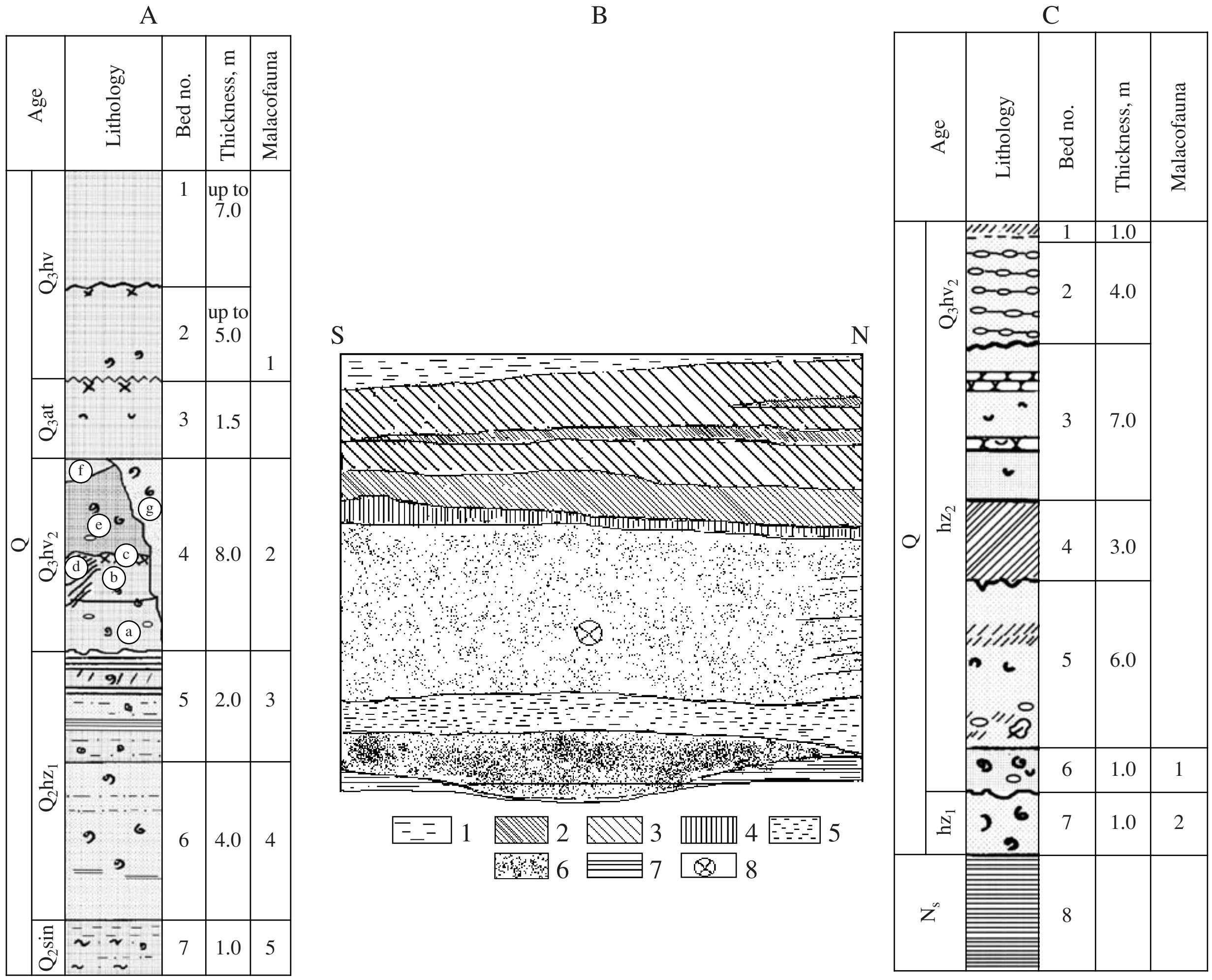


Fig. 4. The Seroglazovka (A), Chernyi Yar (B, figure from work by Gromov, 1935), and Kumtorkala (C, after Rychagov, 1997) sections.

A. Composition of malacofauna: (1) *Didacna praetrigonoides, Dreissena rostriformis*; (2) *Didacna surachanica, D. nalivkini, D.* cf. *pontocaspia, D. schuraosenica, D. pallasi, D. trigonoides chazarica, D. subcrassa, Dreissena rostriformis, Dr. caspia, Dr. polymorpha, Hypanis plicatus, Corbicula*; (3) *Didacna schuraosenica, D. cristata, D. catillus volgensis, D. subcrassa, D. pontocaspia, D. pallasi, D. trigonoides chazarica, Monodacna caspia, Hypanis plicatus*; (4) *Didacna paleotrigonoides, D. schuraosenica, D. catillus volgensis, D. subcrassa, D. cristata, D. ovatocrassa, D. pallasi, D. nalivkini, D.* ex gr. *trigonoides, D. subcatillus, D. subpyramidata, Monodacna caspia, Hypanis plicatus, Dreissena polymorpha, Corbicula fluminalis*; (5) *Unio, Viviparus, Sphaerium* (letter symbols a–f are explained in the text).

B. (1) Khvalynian deposits reworked in subaerial environment; (2) Khvalynian chocolate-brown clays; (3) Khvalynian loams; (4) Atel loams and sands; (5) Khazarian cross-bedded sands; (6) Kosozh sands; (7) Bakunian clays; (8) occurrence site of *Elephas trogontherii* cranium.

C. Composition of malacofauna: (1) *D. pallasi, D. nalivkini, D.* cf. *paleotrigonoides, D. catillus-rudis*; (2) *D. pallasi, D.* aff. *nalivkini, D. subpyramidata, Dreissena* (other symbols as in Fig. 1).

races at the altitude of 90 to 200 m. In composition, they correspond to diverse sandy and pebbly rocks, less commonly to coastal carbonate-clayey deposits up to 50 m thick, containing molluscan assemblage of *Didacna nalivkini* Wass., *D. subpyramidata* Prav., *D. paleotrigonoides* Fed., *D. gurganica* (Dasch.) Vekil., *D. lindleyi* (Dasch.) Fed., *D. trigonula* (Dasch.) Vekil., *D. vulgaris* Andrus. and others (Vekilov, 1969). Fedorov (1957) described an interesting section of the Gyurgyany Formation in eastern limb of the Surakhany anticline, where it includes two facial members. The lower one is represented by ash-gray and bluish carbonate sands of deepwater origin, which contain small *Didacna nalivkini* Wass., *D.* cf. *subpyramidata* Prav. and other shells. The upper member of coastal detrital limestones yields *Didacna nalivkini* Wass., *D. paleotrigonoides* Fed. and others.

Chernyi Yar Formation. The formation corresponding to a thick sequence of alluvial sands in the Volga River valley resides in stratigraphic niche between the lower and Upper Khazarian horizons, being traceable between the Raigorod and Nikol'skoe in sections of the Volga River right bank. Its most complete section near the village Chernyi Yar has been examined by many researchers (Gromov, 1935; Zhukov, 1945; Grichuk, 1954; Fedorov, 1957; Vasil'ev, 1961; Moskvitin, 1962; Sedaikin, 1988; Svitoch and Yanina, 1997). In 1932, participants of field excursion organized for the European Association of Quaternary Research visited this observation point, where Gromov (1935) discovered cranium of *Elephas trogontherii* Pohl., the guide forms of the Khazarian mammal fauna. The cranium has been found in outcrops of the village southern outskirt, and the respective section can be accepted for *lectostratotype* of the Chernyi Yar Formation. According to description by Gromov and drawing reproduced from his work (Fig. 4B), the Khvalynian Horizon (sands and brown clays) and Atel Formation (compact sands with paleosol) overlie in this section a lenticular bed of silty sand loose at the base (thickness 4.0 m) and grading downward into sequence (9.0 m) of cross-bedded quartz sand containing red clayballs, fragmented and intact *Viviparus* and cardiid shells, and bone remains of large mammals. In addition to aforementioned *Elephas* form, the mammal remains are classed with *Megaloceros* and *Equus* sp. The described sands overlie deeply eroded surface of the Singil silty loams and dark blue clays containing plant remains and shells of freshwater mollusks.

In the stratotype, sediments of Chernyi Yar Formation are represented predominantly by fluvial inequigranular cross-bedded sands deposited under dynamic conditions of ancient Volga stream. Palynological spectra of sediments characterize forest-steppe and steppe coenoses dominated by Chenopodiaceae and *Betula* sect. *Nanae* pollen associated with abundant spores of *Bryalis*, Polypodiaceae, and *Selaginella selaginoides* (Grichuk, 1954). In addition to bones of large mammals of the mid-Middle Neopleistocene in common opinion, the sands under consideration contain remains of small mammals *Citellus pygmaens* Poll., *Arvicola* cf. *sapidus* Muller, *Eolagurus* cf. *lutens* Pall., *Microtus* sp. of the terminal Middle Pleistocene (Kirillova and Svitoch, 1994), abundant shells of freshwater mollusks (*Pisidium amnicum* Mull., *Valvata piscinalis* Mull, etc.) and redeposited shells of Apsheronian, Bakunian and Khazarian brackish-water mollusks. A fact important for determination of the formation lower boundary is occurrence in the sands of redeposited Early Khazarian index species *Didacna subpyramidata* Prav., *D. paleotrigonoides* Fed., and *D. pallasi* Prav. derived by scouring from underlying Lower Khazarian deposits.

Upper Neopleistocene

Upper Khazarian Horizon corresponds to sediments of a relatively limited and short Caspian transgression, which took place at the time of the Mikulinian Interglacial (warming phase of the initial Late Neopleistocene) in distinction from larger transgressions during epochs of cooling in the Russian plain (Svitoch and Yanina, 1996; Yanina, 2005). The Upper Khazarian deposits are confidently established in the Seroglazovka section (Volga lower reaches), on the eastern coast of Caspian Sea (Fedorov, 1957), in piedmonts of Dagestan Mountains and on the Apsheron Peninsula. They bear *Didacna* shells of the *crassa* group predominantly, the index species *Didacna surachanica* Andrus. According to results of U–Th dating the carbonate shells of the molluscan genus *Didacna* Eichw. from sections of Dagestan (Shura-Ozen River) and Azerbaijan (Khadzhi-Kairamanly), age of the Upper Khazarian deposits varies from 78400 ± 2600 to 100000 ± 3500 years (Arslanov et al., 1988). The horizon stratotype is not identified.

The complete sections of Upper Khazarian sediments, which have been studied in detail (Fedorov, 1957; Rychagov, 1997; Svitoch and Yanina, 1997) and can be regarded as areal *lectostratotype* of the horizon, are exposed in walls of the Shura-Ozen River valley 6 km northward of the town Makhachkala, the Dagestan coast of Caspian Sea. A section of the right valley wall (edge altitude 85 m) 2.5 km away northeastward from the Kumtorkala Station includes the following beds (Fig. 4C, from the top downward):

1. Loam and sandy loam, grayish brown, unstratified, containing small pebbles; thickness about 1.0 m, contact indistinct.

2. Loose pebbly conglomerate, cross-bedded, containing lenses of yellow sand and isolated, variably rounded boulders; thickness up to 4.0 m, contact uneven.

3. Detrital sand and sandstone with lenticular cross-bedding characteristic of coastal marine deposits; thickness 6–7 m, sharp lithologic contact.

4. Loam, gray-brown, 2.5 to 3.0 m thick; large pockets below uneven contact are filled with sand.

5. Sequence of yellow clayey sand, brown sandy loam and loam, with thin interlayers of small pebbles, coquina and plant remains; being truncated by overlying bed, it is of variable thickness (up to 6.0 m maximum), having distinct lithologic contact.

6. Coquina with sandy fill, with gravel inclusions and pebbles. Among shells, Fedorov identified *Didacna nalivkini* Wass., *D. pallasi* Prav., *D.* sp., fragments of *D.* cf. *paleotrigonoides* Fed. and *D. catillus-rudis* Nal., *Dreissena polymorpha* Pall., and *Dr. distincta* Andrus. In addition, Yanina and Svitoch (1990) identified *Didacna pallasi* Prav. and *D. schuraosenica* Svit. et Tchern. The bed with distinct lithologic contacts is about 1.0 m thick.

7. Sand light gray, containing fragmented and intact shells *Didacna pallasi* Prav., *D.* aff. *nalivkini* Wass., *D. subpyramidata* Prav., *D.* sp., reworked Bakunian *Didacna* species, *Monodacna caspia* Eichw., *Dreissena distincta* Andrus., and *Dr. polymorpha* Pall. determined by Fedorov; thickness about 1 m.

According to Rychagov (1997) beds 3–6 belong to the Upper Khazarian Horizon that is deduced from the U–Io date of 77.5 ± 4.0 ka (LU-429) obtained for shells from Bed 6. In his opinion, underlying sands of Bed 7 are of the Early Khazarian age because of a distinct contact between beds 6 and 7, which are of different mineral composition. Fedorov who studied composition of malacofauna arrived at the same conclusion. Sands of Bed 7 rest on the Neogene foliated clay.

In the stratotype area of the Volga lower reaches, section of the Upper Khazarian Horizon is of different type, reflecting the Paleovolga influence. Here, in the Seroglazovka reference section (Shkatova, 1973; Svitoch and Yanina, 1997), which can be regarded as *parastratotype* of the horizon, the Upper Khazarian sediments are sandwiched between beds with paleontological remains of the Atel Formation and Lower Khazarian Horizon (Fig. 4A). These sediments are divided into several members of different lithofacies. The basal Member "a" is composed of gray fine-grained well-sorted sands with fine cross-lamination, which contain abundant shells *Didacna surachanica* Andrus., *D. nalivkini* Wass., *D.* cf. *pontocaspia* Pavl. and less common *D. schuraosenica* Svit. et Tschern., *D. pallasi* Prav., *Dreissena caspia* Andrus., and *Dr.* rostriformis Desh. This member resting on eroded surface of underlying deposits is overlain by Member "b" of greenish gray unstratified, silty ferruginate sands crowned by Member "c" of dark bluish gray sandy loam with signs of hydromorphic pedogenesis. Along the strike, the last member grades into brown clay beds and intervening gray sand interlayers (Member "d"). Members "a–c" forming a buried relief remnant are overlain with scouring by gray cross-bedded sands of Member "f" containing abundant shells *Didacna trigonoides chazarica* Svit., *D.* cf. *pontocaspia* Pavl., *Monodacna caspia* Eichw., *Dreissena polymorpha* Pall., more rare *Didacna surachanica* Andrus., *D. nalivkini* Wass., *D. subcrassa* Prav., *D. pallasi* Prav., *Dreissena caspia* Andrus., *Dr. polymorpha* Pall., *Hypanis plicatus* (Eichw.), *Micromelania caspia* Eichw., *Corbicula fluminalis* Mull., *Sphaerium* sp., and single *Didacna schuraosenica* Svit. et Tschern., *D. zhukovi* Fed., and *Unio* sp. The last member is connected via gradual transition with overlying gray-yellow sands with fine horizontal lamination. The described sequence encloses a lens of light brown to dirty-yellow sand with sandy loam interlayers (Member "g"). Characteristic of the lens are coarse lenticular to cross-stratified bedding and basal interlayers of clayballs and carbonate concretions. The diverse freshwater to brackish-water malacofauna of the lens is represented by *Unio* sp., *Corbicula fluminalis* Mull., *Sphaerium* sp., *Dreissena polymorpha* Pall., *Dr. celekenica* Andrus., *Micromelania caspia* Eichw., *Didacna pallasi* Prav., *D.* ex gr. *trigonoides* Pall., rare *Didacna surachanica* Andrus., and *D. schuraosenica* Svit. et Tschern. Member "g" is up to 8 m thick. In the Upper Khazarian deposits of the Seroglazovka section, Eremin and Molostovskii (1981) established two zones of reversed paleomagnetic polarity 0.5 and 1.2 m thick, corresponding to Blake event (section intervals 3.7–4.2 and 5.0–6.2 m). Judging from the section structure, the Upper Khazarian deposits accumulated during three stages with intervening erosion event. The first stage corresponded to accumulation of marine (Member "a"), lacustrine-lagoonal (Member "b") and lacustrine-palustrine (Member "c") sediments of the buried terrace. The second stage that commenced after erosion event resulted in accumulation of coastal-marine, deltaic and shallow-water marine deposits (members "d" and "e"), and finally, alluvial and deltaic sediments of the third stage (Member "f") filled in the deep incisions after preceding event of deep erosion. In conclusion we should mention that the Seroglazovka section providing a very complete and obvious stratigraphic information has no analogues in the Caspian region.

Atel Formation of the Volga lower reaches is composed of Upper Neopleistocene sediments occurring between the Upper Khazarian and Khvalynian horizons. It was distinguished by Pravoslavlev (1908, 1926) and termed after the abandoned name Atel of the Volga River; its stratotype has not been indicated. In terms of lithology and facies, the formation is composed predominantly of terrestrial aquatic and less common subaerial deposits: loams and sandy loams with basal loess-like sands (Akhtuba Beds after Moskvitin, 1962) containing relicts of automorphic and hydromorphic paleosols and shells of terrestrial and freshwater mollusks. The Mousterian site of Paleolithic man has been discovered, along with the upper Paleolithic assemblage of large mammal bones, spores and pollen of steppe vegetation, at the Sukhaya Mechetka locality in the Volgograd suburbs (Moskvitin, 1962).

Complete sections of diverse structure, which characterize the Atel Formation, are known on the Volga right bank between the Volgograd and Seroglazovka. One of the most interesting is the Nizhnee Zaimishche section 3 km downstream of the settlement Chernyi Yar. The following succession of beds is exposed here in a coastal scarp downstream of the floodplain terrace (Fig. 3B, from the top downward):

1. Loam and sandy loam, brown in lower part and gray higher, slightly humified, having blurred lower boundary; thickness 1 m (post-Khvalynian deposits).

2. Loam rusty brown, vaguely laminated in lower part; transition to underlying sediments is gradual, thickness 0.8 m (upper part of the Lower Khvalynian deposits).

3. Interlayering of chocolate-brown clay with fine horizontal lamination and gray fine-grained well-sorted sand with abundant shells of *Didacna protracta* Eichw., *D. ebersini* Fed., and *Dreissena rostriformis distincta* Andrus; thickness 0.2 m, lower boundary is uneven, in places with pockets (Lower Khvalynian deposits).

4. Sand, yellow to yellowish gray, well-sorted, fine-grained, with thin laminae of chocolate-brown clay and shells of Khvalynian mollusks concentrated in lenses and interlayers near the top; thickness 0.7 m, the lower boundary is uneven, eroded (basal bed of Lower Khvalynian deposits).

5. Sand, gray-yellow, compact, calcareous near the top; thickness 2.5 m, lower boundary is distinct.

6. Sand, yellow, well-sorted, fine-grained, with distinct lower boundary; thickness 2.5 m.

7. Sandy loam and sand, yellow to rusty brown, with calcareous concretions in upper part and lenticular disconnected

laminae in the lower one; thickness 4 m. Lower boundary is distinct, eroded. Beds 5–7 with pedogenic marks in the middle and near the top represent the Atel Formation. Gopher bones, fish vertebrae, shells of freshwater mollusks and ostracodes *Candona parallella albicans* Brady have been found in paleosol interlayer (Sedaikin, 1988).

8. Sandy loam and sand, rusty brown, with pedogenic marks at the top and vague horizontal lamination in the lower part; thickness 1.5 m, boundary transitional.

9. Aleurite and sandy loam, bluish gray, with interlayers and pockets of slightly ferruginate sand; pancake concretions at the base originated in past water-bearing layer, and large unionid shells are confined to the bed middle part. The bed is 5.0 m thick, with distinctly eroded lower boundary. These sediments with relicts of hydromorphic paleosol have been deposited in a stagnant basin (continental equivalents of the Upper Khazarian marine sediments).

10. Loam, brown, fine-grained, in places calcareous, with intercalations of sandy loam and gray, horizontally laminated sand. The bed 0.8 m thick has blurred lower boundary (paleosol of automorphic type crowning the Chernyi Yar beds).

11. Sandy loam and sand, compact, well-sorted, brown, grading downward into yellow fine-grained ferruginate sand. In the lower part, gray, fine- to medium-grained sand with characteristic cross-lamination rests on basal sand with coarse cross-stratification and shells of freshwater molluscan genera *Viviparus, Sphaerium*, and *Dreissena* forming coquina interlayers. Remains of small mammals occur near the base. The bed 9.0 m thick has distinctly eroded lower boundary (the Chernyi Yar alluvium).

12. Aleurite, brownish gray, with horizontal microlamination and interlayers of gray, slightly ferruginate sand; dark bluish gray basal aleurite is monolithic, with conchoidal fracture, overlying sharp uneven lower boundary; thickness 3.5 m (the Singil Formation).

13. Clay, gray to dark gray, horizontally bedded, with thin laminae of gray, sometimes ferruginate aleurite; malacofauna of the bed is represented by *Didacna catillus volgensis* Svit., *D. parvula* Nal., and *Dreissena rostriformis* Desh.; apparent thickness 2 m (the Bakunian marine deposits).

The upper boundary of Atel Formation is defined in this section at the contact with sediments containing the Lower Khvalynian malacofauna. Position of its lower boundary is more problematic, because the respective stratigraphic level is barren of guide fossils. This boundary is detectable more confidently in the Seroglazovka section, where gray-brown sandy loams of the Atel Formation with paleosol at the top overlie with scouring the diverse marine facies of the Upper Khazarian Horizon, which bear *Didacna surachanica* Andrus. Thus, age constraints of the Atel Formation correspond to the end of Late Khazarian and commencement of Early Khvalynian transgressions of the Caspian Sea.

Khvalynian Horizon crowns the Upper Neopleistocene of Caspian region. Being distinguished by Andrusov (Pravoslavlev, 1913), it was termed after ancient name of the Caspian Sea. Its stratotype undefined originally corresponds to sections of the Volga lower reaches in unanimous opinion of specialists. In distinction from sediments of older Caspian transgressions, Khvalynian deposits are commonly exposed at the surface of spacious lowland areas of the Caspian coast up to the altitude of +50 m. In piedmonts, they form fill terraces on wave-cut benches. The horizon is divided in two subhorizons corresponding to respective transgressive stages of the Khvalynian sea, which have been separated by the Enotaevka epoch of terrestrial sedimentation (Brotskii and Karandeeva, 1953). The Khvalynian deposits are subdivided based on malacofauna and geomorphological criteria.

On the right side of the Volga lower reaches, there are known perfect, closely spaced and well correlated Enotaevka, Kopanovka and Tsagan-Aman sections, which are well exposed and can be regarded as *areal lectostratotype* of the Khvalynian Horizon completely characterizing its general structure and sediments of lower and upper subhorizons (Fig. 5).

The Enotaevka section (Fig. 5A) has been examined by many researchers (Zhukov, 1945; Brotskii and Karandeeva, 1953; Fedorov, 1957; Vasil'ev, 1961; Moskvitin, 1962; Sedaikin, 1988; Svitoch and Yanina 1997). This seems to be the only section of the Volga right bank, where Khvalynian marine sediments are separated by the Enotaevka Beds of continental deposits (Brotskii and Karandeeva, 1953). Shkatova (2005) considered this section as lectostratotype of the Khvalynian Marinium. The Upper Khvalynian sediments are exposed here under a thin bed (0.2 m) of subaerial deposits, being represented by two sand beds containing Khvalynian mollusks. The beds are about 1 m thick in total. Radiocarbon dates obtained for carbonate shells from Upper Khvalynian sediments of the Enotaevka section correspond to 7.33 ± 0.5 (MGU-796) and 7.70 ± 0.25 (MGU-794) ka (Abramova et al., 1983). The Lower Khvalynian chocolate-brown clays with thin aleurite interlayers (Bed 4) grade downward in the section into yellow-gray well-sorted fine- to medium-grained sands (Bed 3), which bear shells *Didacna protracta* Eichw., *D. ebersini* Fed., and *Dreissena rostriformis distincta* Andrus. dated by radiocarbon method at 11.82 ± 0.25 ka (MGU-793). Summary thickness of the Lower Khvalynian deposits is 4.5 m. The upper beds 1 and 2 contain abundant, well-preserved pollen and spores. Prevailing in palynological spectra is pollen of herbaceous and fruticose plants, including dominant *Artemisia* and Chenopodiaceae associated with fairly abundant Gramineae. Liliaceae, Polygonaceae, Ranunculaceae and other families represent miscellaneous herbs. In the group of arboreal pollen, palynomorphs of conifers (*Haploxilon, Diploxilon*) coexist with representative pollen of broad-leaved *Quercus, Tilia*, and *Ulmus.* The Upper Khvalynian deposits overlie sands containing the Early Khvalynian mollusks *Didacna subpyramidata* Prav. and others.

The Kopanovka section situated upstream (Fig. 5B) was first described by I.V. Mushketov and reexamined more than once afterward (Fedorov, 1957; Vasil'ev, 1961; Moskvitin, 1962; Svitoch, 1967; Shkatova, 1973; Sedaikin, 1988; Yanina, 2005). In a coastal scarp situ-

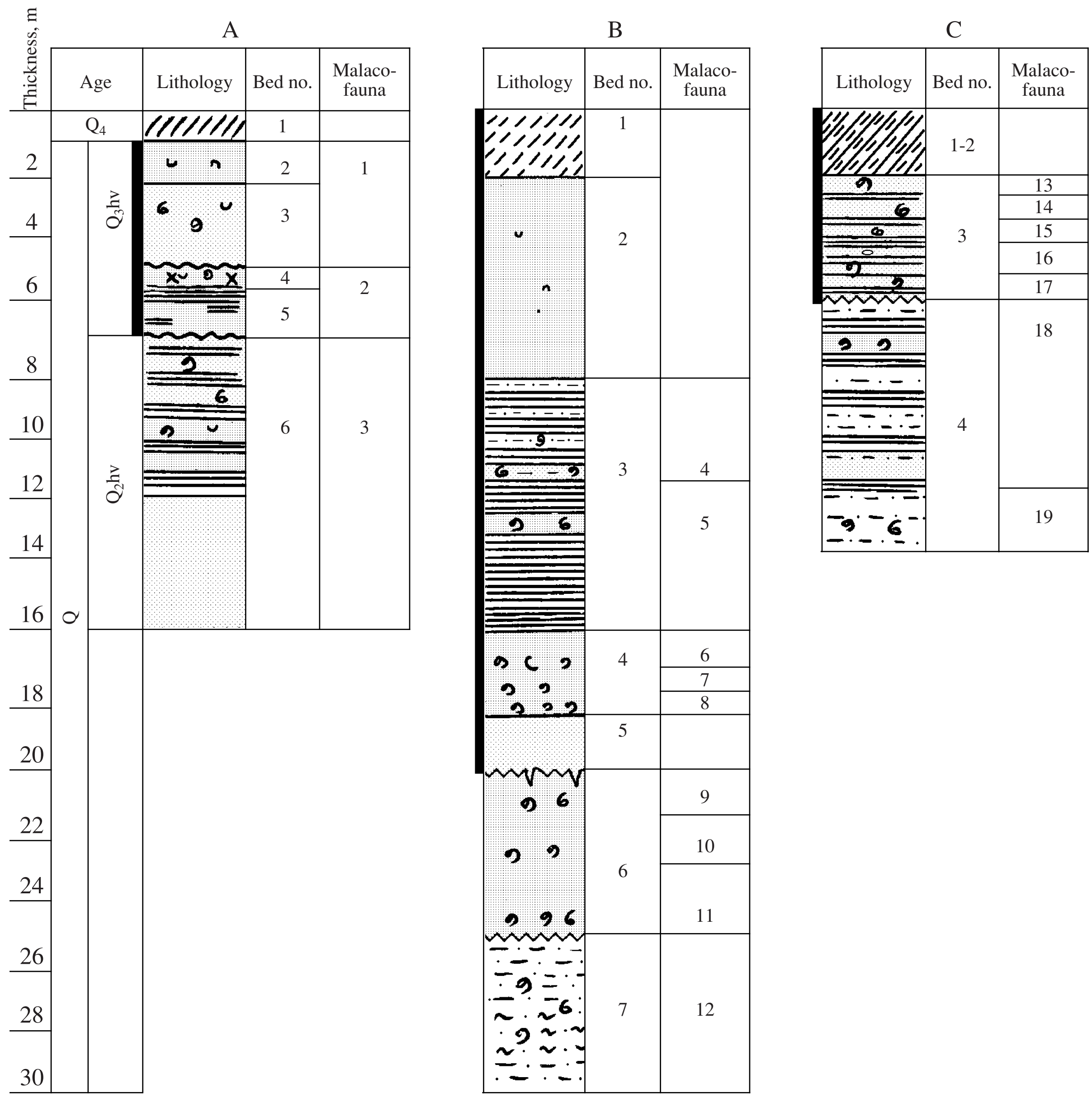


Fig. 5. The Enotaevka (A), Kopanovka (B), and Tsagan-Aman (C) sections.

Composition of malacofauna: (1) *Dreissena polymorpha*; (2) *Didacna protracta, D. ebersini, Dreissena rostriformis distincta*; (3) *Didacna subpyramidata*; (4) *Didacna ebersini, Dreissena polymorpha*; (5) *Didacna protracta, D. delenda, Dreissena rostriformis distincta*; (6) *Didacna parallella borealis, D. ebersini, D. protracta, Monodacna caspia, Adacna vitrea, Dreissena polymorpha. Dr. rostriformis distincta*; (7) *Didacna ebersini, Monodacna caspia, Adacna vitrea, Dreissena polymorpha*; (8) *Dreissena polymorpha*; (9, 10) *Corbicula fluminalis, Planorbis, Viviparus, Sphaerium, Unio, Didacna pallasi, D. paleotrigonoides, D. subpyramidata, Monodacna caspia, Adacna laeviuscula, Hypanis plicatus, Dreissena rostriformis distincta*; (11) *Didacna paleotrigonoides, D. subpyramidata, D. pallasi, D. pontocaspia, D. lindleyi, Monodacna caspia*; (12) *Didacna subpyramidata, D. pallasi;* (13) *D. protracta media, D. parallella borealis, D. ebersini*; (14) *D. protracta protracta, Dr. rostriformis distincta*; (15) *D. parallella borealis, D. ebersini, D. protracta, Monodacna caspia*; (16) *Didacna ebersini, Monodacna caspia, Dreissena polymorpha*; (17) *Dr. polymorpha*; (18) *Didacna cristata, D. subcatillus, Monodacna caspia, Hypanis plicatus, Adacna laeviuscula;* (19) *Didacna subpyramidata, D. paleotrigonoides, D. cristata, D. pallasi, D. pontocaspia, Monodacna caspia, Hypanis plicatus, Adacna laeviuscula* (other symbols as in Fig. 1).

ated northward of the village, the following beds are exposed (from the top downward):

1. Silty loam, gray, slightly humified, grading into brown compact sandy loam and containing abundant calcareous nodules at the depth 0.7–1.0 m. Indistinct lower boundary is concealed under slop; thickness up to 2.0 m.

2. Sand, dirty yellow to gray, compact, with vague fine banding and fossil molehills, grading downward into dark brown compact silty sand that is fine-grained and banded. In

lowermost gray sand, there is visible horizontal, diagonal and lenticular stratification. Sands are up to 6.0 m thick in total, having sharp lower boundary ("Bugrovaya Sequence" of the Upper Khvalynian).

3. Clay, chocolate-brown, with interlayers of ferruginate brown aleurite and sand. Shells *Dreissena polymorpha* Pall. and *Didacna ebersini* Fed. are confined to the upper sand interlayer. Below the depth level of 2.5 m, brown massive clay with splintery fracture encloses laminae of silty clay. Lower sand interlayers contain abundant shells *Didacna protracta* Eichw., *D. delenda* Bog., and *Dreissena rostriformis distincta* Andrus. Laminae are locally plicated. Lower boundary is distinct; thickness varies from 1.5 to 8.0 m.

4. Sand, gray, with coquina interlayers composed of Khvalynian molluscan shells. Malacofauna of the upper coquina interlayer is represented by dominant *Didacna parallella* Bog. var. *borealis* Fed., *Monodacna caspia* Eichw., numerous *Dreissena rostriformis distincta* Andrus., and less frequent *Didacna ebersini* Fed., *D. protracta* Eichw., *Adacna vitrea* Eichw., and *Dreissena polymorpha* Pall. Species prevailing in the middle part are *Monodacna caspia* Eichw., *Didacna ebersini* Fed., *Adacna vitrea* Eichw., and *Dreissena polymorpha* Pall. Shells of *Dreissena polymorpha* Pall. are dominant in the lower interlayer; total thickness 1.3 m, boundary is sharp.

5. Sand, yellow, well-sorted, thin-banded, inequigranular, containing dispersed Mn-oxides and abundant pancake-shaped concretions. Sand penetrates into deep fractures of underlying bed separated by a sharp boundary; thickness 1.2 to 3.5 m. Beds 3–5 represent the Lower Khvalynian fossiliferous deposits clayey in upper part and sandy below.

6. Sand, bright yellow to light gray, cross-bedded, predominantly fine-grained, containing clayballs and abundant shells of freshwater (*Corbicula fluminalis* Mull., *Planorbis* sp., *Viviparus* sp., *Sphaerium* sp., *Unio* sp.) and marine (*Didacna pallasi* Prav., *D. paleotrigonoides* Fed., *D. subpyramidata* Prav., *Monodacna caspia* Eichw., *Adacna laeviuscula* Eichw., *Hypanis* plicatus (Eichw.), *Dreissena rostriformis distincta* Andrus.) mollusks. Small Caspian mollusks *Didacna paleotrigonoides* Fed., *D. subpyramidata* Prav., *D. pallasi* Prav., *D.* pontocaspia Pavl., *D. lindleyi* (Dash.) Fed., and *Monodacna caspia* Eichw. are identified in the intermediate interval of light gray, well-sorted, fine-grained sand with vague horizontal bedding. The basal bed of inequigranular, mostly coarse-grained sand with clayballs contains abundant shells *Didacna pallasi* Prav., *D. subpyramidata* Prav., and *D*. pontocaspia Pavl. Eroded lower boundary is distinct; total thickness up to 5 m.

7. Aleurite, bluish gray, locally clayey, ferruginate in the upper part, with horizontal bedding, containing numerous *Didacna subpyramidata* Prav. and rare *D. pallasi* Prav.; apparent thickness 4 m. Beds 6 and 7 correspond to fossiliferous deposits of the Lower Khvalynian Horizon.

The Tsagan-Aman section located further upstream (Fig. 5C) is of particular interest with respect to paleontological characterization of Khvalynian Horizon. Five of six known molluscan assemblages (Menabde et al., 1991), which reflect stages of the Khvalynian transgression (commencement, maximum and termination), have been established in this section. The AMS method of radiocarbon dating yielded the following dates for the Lower Khvalynian deposits of the section: 12000 ± 130 (AA37204), 12445 ± 75 (AA37203) and 12470 ± 80 (AA37365) years (Leonov et al., 2002).

In conclusion we should mention that deposits of the considered areal stratotype characterize completely the Khvalynian Horizon structure in the Lower Volga region and to a lesser extent in the other Caspian areas. On the West Caspian coast, it is of different structure observable in the local parastratotype of the Dagestan coast (Rychagov, 1997; Svitoch and Yanina, 1997; Yanina, 2005), where in the section of abrasion cliff of the Bakai-Kichlik Cape the following beds are exposed (Fig. 6A, from the top downward):

1. Loam, light brown, with pedogenic marks at the top; thickness 1.2 m.

2. Loam, brown-gray, horizontally bedded, with pedogenic marks at the top and distinct erosion contact; thickness 1.5 m (the post-Khvalynian deposits).

3. Sand, yellow, inequigranular, with small pebbles and gravel at the base, showing stratification of coastal-marine type; the Late Khvalynian guide mollusks of the bed are represented by *Didacna praetrigonoides* Nal. et Anis., *D. parallella* Bog., *Dreissena polymorpha* Pall., and *Dr. rostriformis distincta* Andrus. The lower contact of the bed 0.6 to 0.8 m thick is uneven (the Upper Khvalynian deposits).

4. Sand fine-grained, more rudaceous near the base with rare pebbles and gravel, showing horizontal wavy and less common cross-stratification, bearing rare shells of the Early Khvalynian *Didacna parallella* Bog. and *Dreissena polymorpha* Pall. Contact is distinct in terms of lithology; thickness 4.0–4.5 m (the Lower Khvalynian deposits).

5. Conglomerate consisting of small, well-rounded pebbles, enclosing lenses of detrital sandstone; thickness 0.6–0.7 m (the Khazarian deposits).

6. Sand, inequigranular, with abundant pebbles, gravel and small boulders near the base. Fragmented and intact shells of Khazarian mollusks represent species *Didacna nalivkini* Wass. (prevail), *D. paleotrigonoides* Fed., and *Dreissena polymorpha* Pall. (rare). This 0.2- to 0.3-m-thick bed of Khazarian deposits overlies the deeply eroded Neogene rocks.

Radiocarbon dates obtained for shells from beds 3 and 4 correspond respectively to 11508 ± 200 (MGU-691) and 14570 ± 250 (MGU-692) years.

Caspian (post-Khvalynian) Horizon. Deposits of this horizon are known since the time of academic expedition by P. Pallas; Andrusov (1889) considered them as sediments of the Caspian Stage, Pravoslavlev (1908) as the Sary sequence, Zhukov (1945) as post-Khvalynian strata. The conventional term Neocaspian deposits appeared after works by Fedorov (1957, and later on). Considering diverse post-Khvalynian deposits, we suggest to rank marine sediments of the Neocaspian transgression as synonymous subhorizon of the Caspian Horizon with stratigraphic range corresponding to the Middle–Upper Holocene. In addition, the Caspian Horizon includes lower continental sediments of the Mangyshlak regression, which separate the Neocaspian deposits from the Upper Khvalynian Subhorizon; upper strata represent recent marine and continental deposits.

Rychagov (1975) suggested to regard the Turali section situated 5 km southward of the town of Kaspiisk,

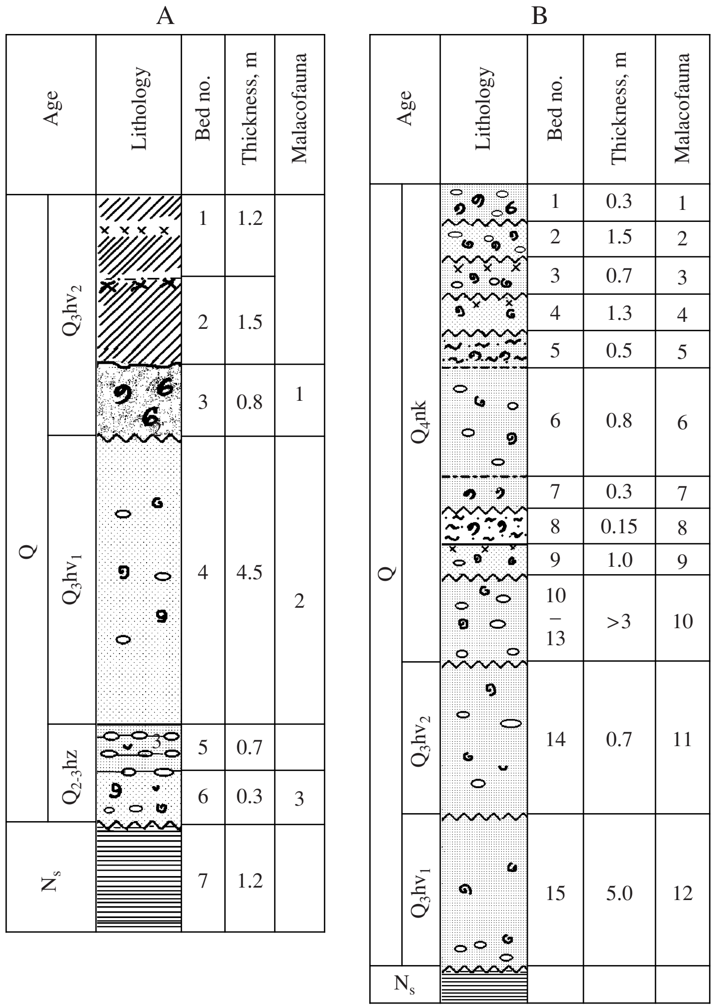


Fig. 6. The Bakai-Kichlik (A) and Turali (B) sections.

A. Composition of malacofauna: (1) *D. praetrigonoides, D. parallella, Dreissena*; (2) *Didacna parallella, Dreissena polymorpha;* (3) *Didacna nalivkini, D. paleotrigonoides, Dreissena polymorpha.*

B. Composition of malacofauna: (1) *Didacna baeri, D. crassa, D. barbotdemarnyi, D. parallella, D. trigonoides, D. profundicola, Monodacna caspia, Adacna vitrea, A. laeviuscula, Dreissena polymorpha, Cerastoderma glaucum, Mytilaster lineatus, Abra ovata*; (2) *Didacna crassa, D. baeri, D. trigonoides, Monodacna caspia, Adacna vitrea, Dreissena polymorpha, Cerastoderma glaucum, Mytilaster lineatus, Abra ovata*; (3) *Didacna baeri, D. trigonoides, Dreissena polymorpha, Cerastoderma glaucum*; (4) *Didacna baeri, D. longipes, D. praetrigonoides, D. trigonoides, Monodacna caspia, Adacna vitrea, A. laeviuscula, Hypanis plicatus, Dreissena polymorpha, Cerastoderma glaucum*; (5) *Didacna crassa, D. baeri, Cerastoderma glaucum, Dreissena polymorpha*; (6) *Didacna crassa, D. trigonoides, Cerastoderma glaucum*; (7) *Didacna crassa, Cerastoderma glaucum*; (8) *Cerastoderma glaucum*; (9) *Didacna crassa, D. trigonoides, D. baeri, D. praetrigonoides, Monodacna caspia, Adacna laeviuscula, Dreissena polymorpha, Cerastoderma glaucum*; (10) *Didacna crassa, D. trigonoides, D. baeri, D. longipes, Adacna laeviuscula, Dreissena polymorpha, Cerastoderma glaucum, Hypanis plicatus*; (11) *Didacna praetrigonoides, D. parallella, D. delenda, D. subcatillus, D. crassa, Dreissena polymorpha*; (12) *Didacna parallella, D. trigonoides, Dreissena rostriformis distincta, Dr. polymorpha* (other symbols as in Fig. 1).

the Dagestan coast of the Caspian Sea, as *lectostratotype* of the Neocaspian deposits. Sediments of the Holocene transgression form here a system of diverse relief forms in marine-deposition coast. One of the latter, the Turali bay barrier (maximum altitude 21.1 m), represents a series of beach bars arranged en echelon and extending from the south to the north. In its root part, the barrier structure is adjoined to the Late Khvalynian terrace (altitude –12 m), whereas recent small terraces and bars are situated on its seaside. The composite section of this structure (Fig. 6B) includes Lower to Upper Khvalynian and Neocaspian marine deposits. The lower part of Neocaspian deposits is represented predominantly by rudaceous sandy to pebbly deposits, actually by sands of diverse grain size with diagonal and cross-stratification and associated shingle and gravel intercalations (beds 13–9), which are indicative of dynamic environments of sedimentation. These beds are overlain by brown to bluish gray fine-grained aleurites and clay with admixture of peat slime (beds 8–5).

Stratotypes of regional and local subdivisions of the Neopleistocene and Holocene in the Caspian region

General scale	ISC scale, 1995		Stratigraphic rank	Stratotypes		
				section	rank	locality
Holocene	Holocene		Caspian Horizon	Turali	Lectostratotype	Dagestan
Pleistocene	Neopleistocene	Upper	Khvalynian Horizon	Tsagan-Aman, Kopanovka, Enotaevka Bakai-Kichlik	Composite lectostratotype Parastratotype	Volga lower reaches Dagestan
			Atel Formation	Nizhnee Zaimishche	Lectostratotype	Volga lower reaches
			Upper Khazarian Horizon	Shura-Ozen Seroglazovka	Composite lectostratotype Parastratotype	Dagestan Volga lower reaches
		Middle	Chernyi Yar Formation	Chernyi Yar	Lectostratotype	Volga lower reaches
			Lower Khazarian Horizon	Seroglazovka	Lectostratotype	Volga lower reaches
			Gyurgyany Formation	Gyurgyany Cape	Holostratotype	Apsheron Peninsula
			Singil Formation	Raigorod Nizhnee Zaimishche, Nikol'skoe	Lectostratotype Composite lectostratotype	Volga lower reaches
			Urundzhik Horizon	S. Urundzhik Mishovdag	Holostratotype Hypostratotype	W. Turkmenistan Kura depression
		Lower	Bakunian Horizon	Bakunian Stage Mt.	Lectostratotype	Apsheron Peninsula
			Tyurkyany Horizon	Tyurkyany	Lectostratotype	Apsheron Peninsula

The section is crowned by gray to dark gray inequigranular sands of beach bars (beds 4–1). Eleven species of Neocaspian malacofauna represent assemblages characterizing diversity of ecologic conditions in coastal zone: relatively deep dynamic settings, quiet shoals, and isolated lagoons (Yanina et al., 2005). A series of radiocarbon dates is known for Holocene deposits of the Turali section (Svitoch et al., 2006). The pebbly–sandy core of the Turali bay barrier was formed 4.5–5.0 ka ago (maximum of the Neocaspian transgression), whereas western and eastern flanks of this structure originated later, 2.7–2.3 ka ago.

CONCLUSIONS

Data considered in this work characterize stratotypes of principal stratigraphic subdivisions in the Neopleistocene regional scale (Table) and the entire succession of respective sediments in the Caspian region, which approximately corresponds to the Brunhes Cronozone of paleomagnetic scale. The described stratotypes include sediments of the Bakunian, Urundzhik, Early and Late Khazarian, Khvalynian, and Neocaspian transgressions in the region, which are separated by intervening continental, predominantly terrestrial-aquatic deposits of the Singil, Chernyi Yar, and Atel formations. In fact, these are lectostratotypes, because stratotypes proper either have never been distinguished or adequately described.

All the suggested stratotypes are simultaneously limitotypes of boundaries between the considered subdivisions. Being situated in classical investigation areas of the Caspian Neopleistocene (Volga lower reaches, Apsheron Peninsula, Kura depression, Dagestan coast, and western Turkmenistan), all stratotypes, except for those of the Tyurkyany Horizon and Gyurgyany Formation recovered by drilling, correspond to natural perfectly studied and exposed sections accessible for examination and containing abundant and diverse fossils. It is important that subdivisions of the Caspian Neopleistocene are distinguished in this work based on biostratigraphic criteria, i.e., on molluscan assemblages of the genus *Didacna* Eichwald (*catillus, crassa*, and *trigonoides* groups) in the case of marine deposits and on the Singil, Khazarian, and upper Paleolithic assemblages of large mammal remains in the case of intervening continental sediments. Data of micropaleontology (ostracodes, foraminifers), palynology, carpology, paleomagnetism, geochronology, lithology, and geomorphology have been also taken into account in order to get comprehensive characterization of stratotype sections.

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