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MARINE GEOLOGY

Fossil Facies of the Greater Caspian Region

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Abstract—The Pliocene–Pleistocene marine sediments of the Great Caspian region host various lithological fossil facies, which reflect specific sedimentation conditions caused by different structural–geomorphologic settings, tectonic regimes, climates, and hydrologies. The facies of shelf, epicontinental basins, ingression gulfs and estuaries, intermontane and mountainous basins, and deep-sea depressions form a hierarchy of geological bodies from types to subtypes. Paragenetic associations of fossil facies, which form various series in space and along the section, are typical of marine sediments.

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INTRODUCTION

The Caspian Sea in Eurasia is the largest enclosed basin on our planet. During the last 3.3 Ma, this unique basin alternately spread from the foot of Alborz to Vyatka and Kama rivers and from the Black Sea to Mediterranean Sea or was reduced to the size of the Aral Sea.

The modern Caspian Sea and its Late Pliocene–Quaternary basins, which form the Great Caspian region,[1] are characterized by a variety of facial settings caused by different sedimentation, first of all, and structural–geological, geomorphologic, hydrological, and climatic, conditions. The structural and geomorphologic zoning of the modern Caspian Sea is related to the presence of the deep-sea South Caspian and Derbent depressions (maximum depths of 1025 and 788 m, respectively) with steep land slopes and narrow shelf divided by the Apsheron uplift. The shallow North Caspian area is separated from the Middle Caspian by the conditional boundary between the Chechen Island and Tyub Karagan Cape. The current climate differentiation is related to the location of the eastern and southern, western, and northern coasts in arid and semiarid conditions, moderate and subtropical climate, and moderate arid continental climate, respectively.

More diverse sedimentation conditions were typical of the Caspian coast during the ancient transgressions, when the sea flooded the wide valleys of the North Caspian and Central Volga regions, formed the deep gulfs in the Cis-Urals and the Kura and West Turkmen depressions, and eroded the Caucasus, Kopet Dag, and Alborz mountainous coasts promoting the accumulation of sediments from fine-disperse facies of deep-sea depressions and estuaries to the coarse-grained sediments of abrasion benches.

In spite of the existence of numerous works on sedimentation of the Caspian Sea, only a few are dedicated to the fossil facies and their sediments. Let us note the fundamental summary of Kolesnikov [16] on the distribution of composition of the Pliocene Akchagyl (N_2^{ak}) and Absheron (N_2^{ab}) sediments, the works of Zhidovinov et al. [3–14] and Vasil'ev and Obryadchikov [4] on Pliocene facies of the Caspian depression, Ali-Zade [1] on the Akchagyl facies of Turkmenistan, Klenova [15] and Belevich [3] on lithology of the Volga River delta, Pashaly [20] on lithology of Quaternary sediments of Azerbaijan, and Fedorov [4] and Svitoch et al. [27] on sediments and facies of Pleistocene Caspian region. The work of Staroverov [33] on facial models of the southeast of the East European Plain is one of the last. Numerous materials on lithology of the Caspian Pliocene–Pleistocene are published in the monographs on the Geology of the Soviet Union [7–11] and also in works of Klenova et al. [15].

This work is based on materials of proper long-term studies of the Caspian coasts [24–32] and a broad literature.

GEOLOGICAL STRUCTURE

The territory of Caspian transgressions is characterized by complex geological structure. The longitudinal Caspian depression in the center of the region intersects the system of large latitudinal structural elements of the East European (Russian) Platform, epi-Hercinian Scythia–Turan Plate (Platform), and Alpine fold area from the north to the south and represents a specific tectonic depression distinct in structure from geosyncline intermontaine and marginal troughs.

[1] The Great Caspian region is a system of Late Pliocene–Quaternary basins localized in the area of the modern Caspian Sea and surrounding depressions.

Fossil facies of the Great Caspian region

Complex	Facial type (macrofacies)	Facies (mesofacies)	Subfacies (microfacies)
Marine sediments	Shelf (1)	Coastal (1.1)	Beach
			Deep-sea calm accumulation
			Shoal dynamic accumulation
		Calm shoal (1.2)	
		Deep-sea areas (1.3)	
		Dynamic areas (1.4)	
	Epicontinental basins (2)	Shoals (2.1)	
		Deep-sea areas (2.2)	
		Limans and lagoons (2.3)	
	Ingression bays and estuaries (3)	Desalinated areas (3.1)	
		Flooded valleys (3.2)	
		Near-deltaic (3.3)	
	Intermontane depressions and forelands (4)	Caucasian type (4.1)	
		Kopet Dag type (4.2)	
	Deep-sea depressions (5)	South Caspian (5.1)	
		Central Caspian (5.2)	

The northern and northeastern parts of the Caspian region are localized in the south of Caspian syneclise—an area of deep-seated basement and active salt domes. In the south, the depression has a contact with the Scythia–Turan Plate, composed the large tectonic elements: a zone of external boundary depressions, a rift-related uplift of the Karpinskii bar, and the North Buzachi trough.

The south of the Scythia–Turan Plate is occupied by the Central Caspian depression. According to seismic data, the thickness of the crust in its central part (Derbent depression) is about 30 km under a 10–12-km thick sedimentary cover.

The South Caspian depression is sharply distinguished by the peculiarities of its structure. The granitic layer is absent at the most part of its bottom and sedimentary rocks more than 24 km thick lie directly on basaltic layers similarly to the oceanic crust.

The vast territory, spanned by the Caspian transgressions, is characterized by diverse geological evolution and structure.

The northernmost regions, which were flooded by Caspian transgressions, are located within the Volga–Kama anteclise with large arch uplifts and depressions. In the east, the anteclise is restricted by the Cis-Ural Trough and has a contact with Caspian depression in the south.

Various geological structures of the south margin of the Ural Hercinides are localized in the east of the Caspian region.

Three large tectonic zones distinct in structure and evolution are distinguished in the Turkmen part of the region: (i) the south of the Scythia–Turan Plate; (ii) the southern regions of fold uplifts of the Kopet Dag and Great Balkhan; and (iii) the eastern part of the South Caspian depression and Cis-Kopet-Dag foreland of Alpine fold area. They are characterized by intense differentiated Neogene–Quaternary movements with formation of deep depressions–troughs and uplifts of the fold relief.

The western frame of the Caspian Sea is composed of tectonic elements of the east of North Caucasus and Alpine meganticlinorium of the Greater and Lesser Caucasus divided by the Kura trough.

The meganticlinorium of the Greater Caucasus is a complex mountainous structure. Its Mesozoic core is composed of a system of partly eroded anticlinoriums and synclinoriums traced on the sea bottom and is divided by the large Kura intermontane trough 450 km long and 170 km wide.

The southern margin of the Caspian region is the North Alborz trough filled by a thick sequence of Neogene–Quaternary rocks, which began to be formed from the middle of the Cenozoic.

A REVIEW OF FOSSIL FACIES

The groups (types) of facies, which represent a complex of genetically related sediments distinct by different sedimentation conditions and, first of all, by structural–geomorphologic setting (table), may be distinguished among Pliocene–Pleistocene facies of the Great Caspian region on the basis of sedimentation style, lithological composition, and the presence of organic relics.

The complex of marine sediments is the largest lithogenetic subdivision of the Pliocene–Pleistocene Caspian region and is a group of macrofacies, which,

in turn, consists of facies (mesofacies) of shelf, epicontinental basins, ingression gulfs and estuaries, intermontane and foreland troughs, and deep-sea depressions. They may be subdivided into subfacies (elemental facies), which reflect the local peculiarities of accumulation and composition of sediments, e.g., the subfacies of beach, calm deep-sea areas, and shallow–dynamic conditions in the coastal part. Thus, a hierarchy of fossil lithological structures (bodies) from complexes to subfacies reflects the structural–temporal and widely extended distribution of sedimentation in the ancient basins (table) and is observed in the sedimentary section of the Great Caspian region. Let us briefly review them.

The shelf facies abundant in the Caspian Sea shelf are subdivided into facies of calm shoals (North Caspian region) and deep-sea dynamic conditions typical of the Caucasus and South Turkmen–Iran shelf by sedimentation conditions and lithology. The first facies are characterized by relatively fine (sandy–silty and clayey) composition in contrast to coarser (sandy, gravel–pebble) sediments with abundant chemo- and biogenic material in the second one.

Facies of epicontinental basins were widely developed in the territories of the Caspian depression and Scythia–Turan Plate during transgression maximums. Facies of shoal, deep-sea areas, limans, and lagoons are distinguished by their lithological composition. These are relatively fine sandy–silty and clayey sediments variously enriched in biogenic carbonates. They are more mixed and coarser at the dynamic shoals relative to mostly muddy and clayey–sandy in ancient lagoons.

Facies of ingression gulfs and estuaries are composed of sediments of desalinated areas of gulfs and estuaries of the flooded river valleys and near-delta territories. As were the facies of epicontinental basins, they were abundant at the maximum of the Akchagyl transgression, which penetrated along the paleo-Volga River to the paleo-Kama River and further along the paleo-Belaya River valley in the West Cis-Urals. In the Absheron period, the facies of this type are typical of the flooded and impounded valleys of the paleo-Volga, paleo-Ural, paleo-Kura, and paleo-Uzboi rivers. These are fine-sandy and silty–muddy sediments.

Facies of intermontane and foreland troughs, the coarsest and most mixed in composition, are abundant in foreland and intermontane depressions of the Greater and Lesser Caucasus, Kopet Dag and Alborz. The Caucasus and Kopet Dag facies contain abundant carbonate rocks. This type was most widespread at the maximum of the Akchagyl transgression.

The facies of deep-sea depressions consist of sediments of the South Caspian and Central Caspian depressions. They, along with shelf facies, are the most stable sediments in time and in area, with typical fine silty–muddy–clayey composition and the presence of mud volcanoes.

Recently, a specific type of slope sediments was identified by seismic studies in the walls of Caspian depressions. They were studied in detail with a high-resolution seismic acoustic technique at the Dagestan slope of the Central Caspian depression [6, 17, 22]. Two types of sediments with different reflection are identified on seismic profiles. The first type represents slope–gravitation sediments with sharp flexure-like bends and reverse dip, which often overlap the reflecting boundaries. These are landslide structures typically concentrated along the western slopes of the antecline uplifts. The second type is the fine sediments of muddy and near-bottom flows with alternation of seismoacoustic members of sedimentary waves and parallel enveloping clayey layers.

FACIAL SERIES AND PARAGENETIC ASSOCIATIONS OF FOSSIL FACIES

Diverse consequence of genetic combinations of facies, which form the facial series in space and along the section, is typical of marine sediments of the Great Caspian region and the most studied Pleistocene part of its section. We may distinguish the "normal" and "discontinuous" (incomplete) series by the genetic composition of facies and the "long" and "short" series by amount and composition of facies.

The normal (complete or incomplete) series consists of paragenetic facies, which reflect the consequent lateral and temporal change in sedimentation regime. Relatively complete facial series are observed in the Akchagyl sections of the Kura depression and West Turkmenistan, Absheron and Lower Quaternary Baku (Q_1^b) of the Absheron Peninsula, Middle Quaternary Khazar (Q_2^{hz}) and Upper Khvalynsk (Q_3^{hv}) sediments of the Lower Volga region with combination of various marine and lagoon sediments, which form the series with repeated type of sedimentation. The erosion of these sections has little effect on their mode of occurrence and only reduces the thickness of fossil facies.

The incomplete facial series includes various sediments with different depth of erosion or the absence of sedimentation features that results in reduction of their thickness and loss of some members of genetic series.

Complete marine sections are locally characterized by their cyclic structure, which reflect the stages and repeated accumulation of sediments caused by discontinuous course and the sign of change in sea level. Relatively complete rhythmicity is noted for the Akchagyl of Turkmenistan [1].

The sections of the Caspian coasts are characterized by the following association of facies. The sediments of the delta, the delta front, the estuary (liman), and the coastal marine facies are consecutively combined in the estuaries of the valleys from bottom to top. The depressions are filled by the lagoon–beach (bar)–shoal series of sediments, whereas mountainous coasts

are characterized by the beach–deep-littoral sequence, which forms the "long" or "short" facial littoral series [7].

The character (type) of facial series definitely indicates paleogeographic conditions and the course of the sedimentation regime. The thick sections with normal facial series, first of all, indicate long similar sedimentation conditions and, in significant degree, a stable tectonic regime, oscillation of the basin level, etc. On the other hand, the sections with mixed facial series point to inconstant and unstable sedimentation processes and tectonic conditions and are often localized at the contacts of tectonic and geomorphologic structures, e.g., in the Duzdag and Karadzha ridges in Azerbaijan.

Different sections of the Caspian coasts are characterized by their own facial series. The "short" series of marine sediments of the deep-sea and shoal facies of the open marine gulfs, deltas, and marine shoal are typical of the Lenkoran and Kura depressions. The facies of shelf–beach–lagoon, shelf shoal–delta–marine sediments–deluvium, and marine beach–eolian sediments are characteristic of the coastal valley of the mountainous Caucasus coast. The North Caspian depression coasts are characterized by marine-shoal–hydrophitic flora, lagoon–beach of marine shoal–delta, knoll sequence–kultuk (ilmen), and marine sediments–eolian sediments. The "short" facial series are characteristic of the eastern coast of Caspian Sea: dynamic shoal–beach, shoal–beach, shoal–saline gulf (sora).

Variously combined marine and continental sediments of the Caspian coastal regions may be classified as a certain type of paragenetic association of sediments. The most exotic modern and rare fossil gravitation–marine and eolian-marine associations related to a certain coast structure are characterized by different degree of combination and sequence of change of sediments: from gradual change in association of marine and continental sediments to sharp (chaotic) change at beach areas covered by landslide products. The most exotic marine–eolian type is characterized by a certain mechanic (granulometric) composition of rocks, sedimentation conditions, relief morphology, and strongly distinct ecological conditions for flora and fauna communities. Numerous publications on this lithological phenomenon are reviewed by Nalivkin [19], who distinguished a series of dunes of the coastal valleys closely related to the sediments of the open shelf.

The marine–eolian association is especially widespread in arid areas. The formation of significant amount of eolian sands due to the dispersion of marine sequences requires the presence of (i) vast areas of dry marine sediments free of flora and soil composed of sandy material poorly cemented and easily transported by the wind; (ii) long unidirectional wind activity necessary for the transit of a large amount of sandy material for a certain distance; and (iii) areas suitable for accumulation and formation of subaerial relief forms. Such conditions occur mostly on the open Caspian coasts with more intense wind activity.

This sedimentation type also includes wind removal of the great masses of eolian dust from Central Asian deserts to the Caspian Sea with further precipitation and formation of specific facies of bottom sediments. The eolian dust from the Karakum desert composes up to 13% of the marine sediments of Caspian Sea [23].

Gravitation–marine (landslide) sediments are abundant in areas with steep coasts eroded by the sea. The landslide sediments, however, in most cases are reworked by wavy dynamics, their fossil analogs are rare, and their preservation requires large volumes of the rocks and fast cessation of dynamic wavy reworking.

The analysis of fossil facial series allows the reconstruction of a temporal sequence of change in sedimentation conditions and forecast of possible changes in regimes of formation of sediments at a constantly variable level of the Caspian Sea. For example, its uplift up to 20 m will lead to migration toward the shoal–hygrophyte flora–lagoon–beach and shoal–lagoon–kultuk (ilmen) facial series in the North Caspian region, in the area of the Baer knolls, at the shoal plain coasts.

In contrast to major facial series, the old Caspian sediments are rare spatially and temporally inherit the lihtological composition. For example, the Absheron, Baku, Khazar, and Khvalynsk sediments are lithologically distinct in the most complete sections of marine Caspian sediments, which expose the sediment of several transgressions: Baku Stage Mountain, Gor'kii Erik (Baskunchak), Alexandrov-Gai, Chernyi Yar and Mishov Dag [30]. In the stratigraphic section of the Absheron Peninsula (Baku Stage Mountain), the Absheron, Baku, Khazar, and Khvalynsk sediments include sandstones, clays and silts, limestones and conglomerates, and sands, respectively. Marine Pleistocene includes clays, sands, and loamy sands (section near Lake Baskunchak), clays, sands, and loams (Volga–Ural interfluve near Alexandrovski Gai), silts, sands, and chocolate clays (Lower Volga region, Chernyi Yar section), silts and sands, limestones and silts, and loamy sands (Nephtyanaya Balka section, Kura depression). This indicates that, in addition to the sedimentation features, the sedimentation conditions of ancient Caspian basins constantly changed, which is expressed in various structures of sections.

The composition of the Pliocene–Pleistocene sediments of the Great Caspian region is mostly caused by lithopetrographic peculiarities of the feeding provinces: the mountains of the Greater and Lesser Caucasus, Kopet Dag and Alborz, basins of Volga, Ural, and Emba rivers, and heterogeneous structures of the Scythia–Turan Plate. The sedimentation conditions significantly effect the composition of sediments. For instance, the high carbonate contents of Quaternary marine sediments of the eastern Caspian coast are mostly related to their formation in well-warmed

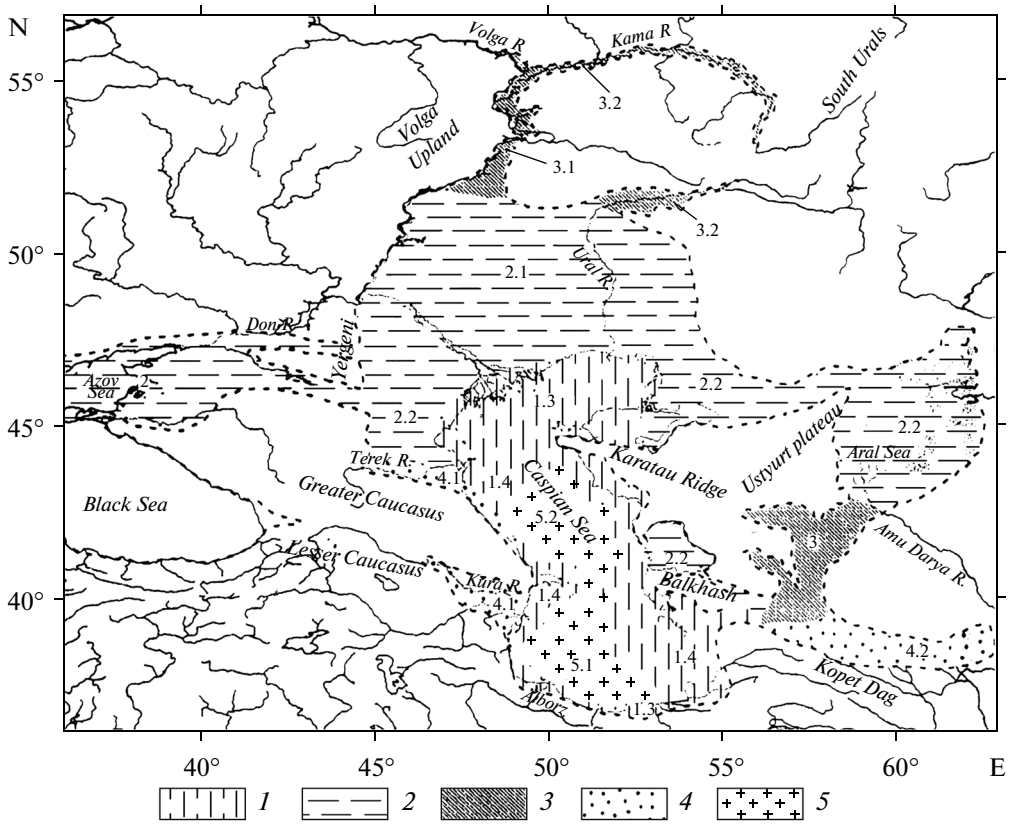

Fig. 1. Genetic facies of the Akchagyl Sea. Here and in Figs. 2, 3, 4, and 5, facies of: (*1*) shelf (mesofacies of: 1.1, coastal; 1.2, calm shoal; 1.3, deep-sea areas; 1.4, dynamic areas); (*2*) epicontinental basins (mesofacies: 2.1, shoals; 2.2, deep-sea areas; 2.3, limans and lagoons); (*3*) ingression gulfs and estuaries (mesofacies: 3.1, desalinated areas; 3.2, flooded valleys; 3.3, near-deltaic areas); (*4*) intermontane depressions and forelands (mesofacies: 4.1, Caucasian type; 4.2, Kopet Dag type); (*5*) deep-sea depressions (mesofacies: 5.1, South Caspian; 5.2, Central Caspian).

marine shoals oversaturated in biogenic carbonate material in the arid and semiarid climate.

Specific peculiarities of sedimentation are recorded in each Caspian transgression. For example, the silty–muddy-clayey sediments of the deep-sea parts of the Baku Sea with calm sedimentation conditions and thick sediments (up to 500 m and more) are the finest in Caspian Pleistocene. The coarser Khazar sediments (sands, often lithified, with interlayers of organic limestones) typically correspond to dynamic shoal and beach conditions. The chocolate clays [18] and the knoll sequence are typical of the Lower and Upper Khvalynsk sediments of the Lower Volga region, respectively. Sandy facies are dominant among the Upper Khvalynsk and New Caspian sediments on all coasts.

FACIES OF THE LARGEST BASINS OF THE GREAT CASPIAN REGION

The largest basins of the Great Caspian were recorded during the Akchagyl, Absheron, Baku, early Khazar, and early Khvalynsk transgressions, when their area exceeded that of the modern sea in three and more times.

The facies of the Akchagyl Basin (Fig. 1). The enormous area of the Akchagyl Basin and different hydrological transgression conditions caused the diversity of composition of fossil sediments and the presence of all facies of marine sediments (Fig. 1): shelf, epicontinental basins, ingression gulfs and estuaries, intermontane and foreland troughs, and deep-sea depressions. Various epicontinental sediments of shoals and deep areas of limans and lagoons are most widespread. They are located in the Caspian depression, south of the Central Volga region, and the Scythia–Turan Plate. By composition, these are mostly fine clayey and fine-silty sediments, coarser (sandy–pebble) sediments of dynamic shoals, and muddy–clayey sediments of ancient lagoons.

At the maximum of the Akchagyl transgression, when the sea penetrated through the river valleys to the north of the Central Volga region and Cis-Urals, the fine sediments with desalinated and fresh fauna and flora relics of ingression gulfs and estuaries were mostly abundant. The mountainous coasts in the west and the east of the basin underwent active abrasion and the gravitation landslide facies further reworked into coarse beach sediments were most abundant.

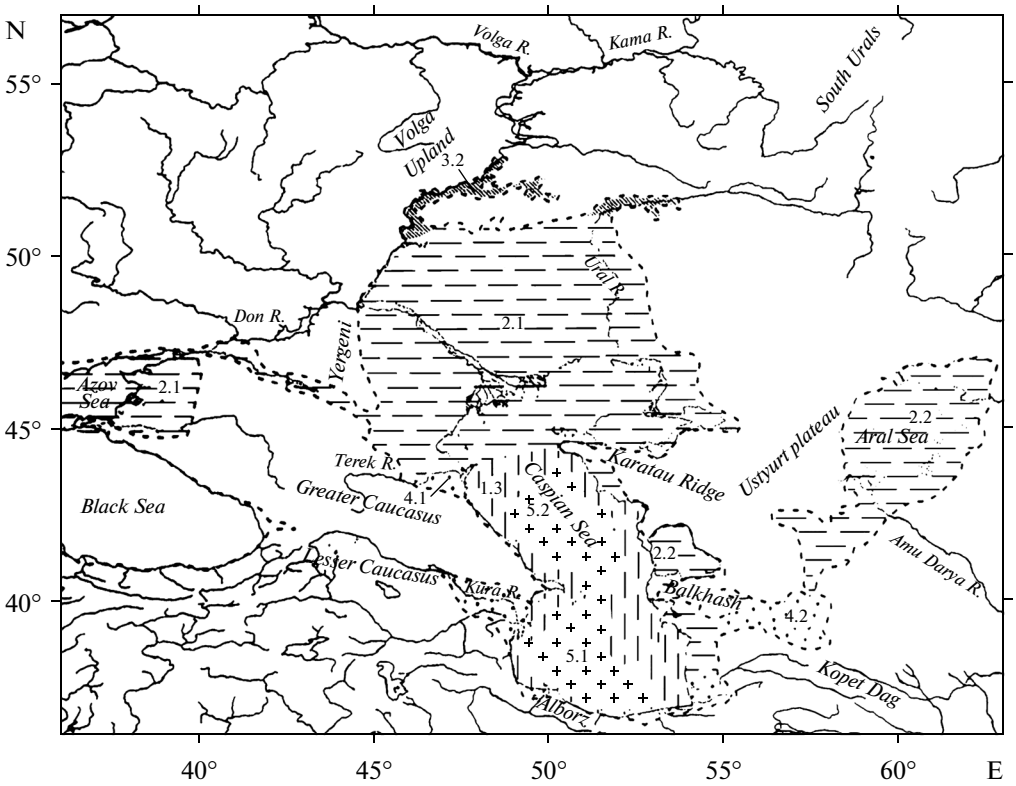

Fig. 2. Genetic facies of the Absheron Sea.

Extremely mixed lithofacial composition and thickness of sediments in the Akchagyl period are typical of the mountainous coasts, foreland, and intermontane and intramontane depressions of Caucasus and West Turkmenistan. As a rule, this is a combination of fine–clayey sediments typical of calm areas, which are facially alternated along their periphery by the coarse pebble facies of dynamic shoals. Volcanic ash and breccias are plentiful in Caucasus coast and Turkmenistan; organic carbonates are also typical of the West Turkmenistan.

The facies of shelf and Caspian depressions are the fine clayey–silty sediments with specific microlayering due to rhythmic sedimentation. The sedimentation conditions in the marginal parts of the basin repeatedly changed because of transgressions–regressions. For example, in the Akchagyl Stage of the Central Volga region, the desalinated facies (the beginning of transgression) are replaced by lagoon-marine facies (maximum of transgression) and again by fresh facies (regression). In the Krasnovodsk Peninsula, Andrusov [2] noted the presence of coarse terrigenous, clayey–calcareous, and sandy sediments in the basement, middle part, and in the top of the Akchagyl Stage, respectively.

The facies of the Absheron Basin (Fig. 2) are highly diverse, like those of the Akchagyl sediments, including facies of shelf, epicontinental basins, ingression gulfs, and estuaries, intermontane and foreland depressions, and deep-sea depressions. The flooded areas retained the position of fossil facies. Deep-sea silty–clayey sediments fill the Caspian depressions, bounded by various shelf sediments. As in the Akchagyl period, the facies of epicontinental shelf of different lithology are most abundant in the Absheron Sea. Due to the significant reduction of this sea, the areas with abundant facies of ingression gulfs and foreland depressions are notably reduced in the Northern Caspian region and West Turkmenistan. In the north of the basin, at maximum of transgression, the sea penetrated to Samara Trans-Volga region along the relief depressions and formed fine sandy–silty–clayey ingression sediments with relict flora and shells of fresh mollusks. To the south, in the North Caspian region and modern North Caspian Sea, they are replaced by mixed epicontinental facies with mostly sandy shallow sediments in the margin of the basin, sandy–clayey shoal sediments with plentiful shells, and relatively deep-sea clayey sediments [4].

Extremely mixed lithofacial composition is typical of the Absheron sediments of the Caucasus coast. In the South Dagestan, these are conglomerates, pebbles, sandstones, detrital limestones, and clays [8]. The coastal shoal sandy–clayey sediments with interlayers of sandstones, shellstones, and conglomerates are dominant in the intermontane depressions of Azerbaijan [12].

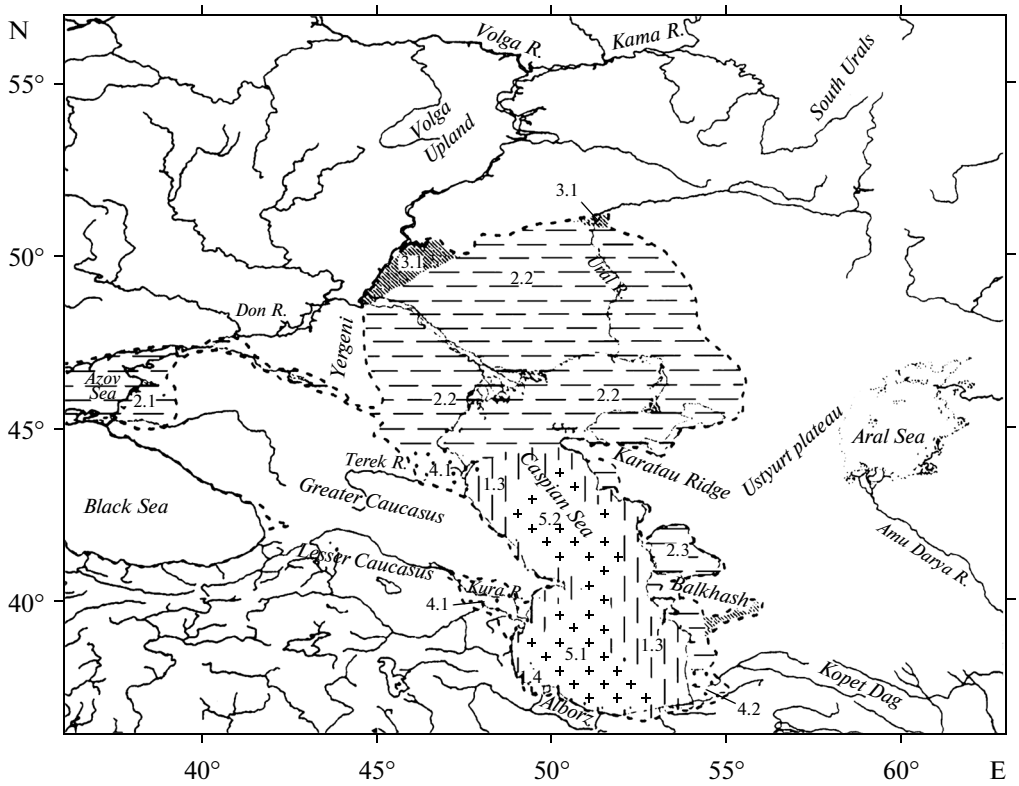

Fig. 3. Genetic facies of the Baku Sea.

On the eastern coast, the Absheron Sea reached the Aral and Sarykamysh depressions, where it formed shallow-water coarse epicontinental sediments: pebbles, conglomerates, ooze sandstones, and shell limestones, rare sands and silts with clay interlayers [11].

Two lithofacial zones are distinguished in structure of West Turkmenistan [11]: the north area with a weak tectonic activity and relatively homogeneous lithofacial composition and the south area in tectonically active structures caused the facial mixing of sections. The following lithological types are distinguished [11]: Cheleken (coastal deltaic), West Kopet Dag (thick marine carbonates and terrigenous sediments), and Krasnovodsk (shallow-water sandy–carbonate facies relatively consistent in area). Popov [21] indicated that the clayey composition of the Absheron lower horizons with a fine delicate sculpture of mollusk shells typical of both species inhabited the deep parts of the basin are characteristic of the Absheron Peninsula and Turkmenistan.

In general, like for the Akchagyl Stage, the distribution of facies of Absheron sediments by the area and along the section depend on structural location and wide longitudinal extension of the basin caused its climate differentiation. In the north of the basin, the facies, consistent by area, composition, and thickness were dominant in relatively calm tectonic setting and at abundant contribution of fresh waters. The facial composition was most diverse and coarser to the south, in area of the Turan Plate with differentiated tectonic movements. Actively submerged Caspian depressions were filled by the fine sediments of the deep-sea facies. The southern regions with subtropical climate and active Alpine tectonics were characterized by various terrigenous sediments (pebble, silts, clays) with abundant carbonate rocks and variable thickness of the section.

The facial composition of sediments of Baku transgression is highly diverse (Fig. 3) with dominant fine facies of the deep-sea parts of ingression gulfs and open marine shoals. These thick mostly clayey sequences filled actively submerged Kura depression and accumulated in the large deep-sea gulf of the Baku Sea with a limited access of coarse material, a significant amount of which is noted only along the margin of the depression. The facial composition of the Baku sediments in the Absheron Peninsula is distinct. Judging from the reference section of the Baku Stage Mountain, sands and clays accumulated in the beginning and at maximum of transgression under conditions of the deep sublittoral, whereas sands with interlayers of detrital shells were formed later, at the dynamic coastal shoal. Exclusively dynamic conditions of the coastal shelf were typical of the Caucasus mountainous coasts. The active uplift of the coastal ridges at the mountainous slopes promoted the formation of abrasion terraces, which are locally covered by coarse sediments of bench and dynamic beach.

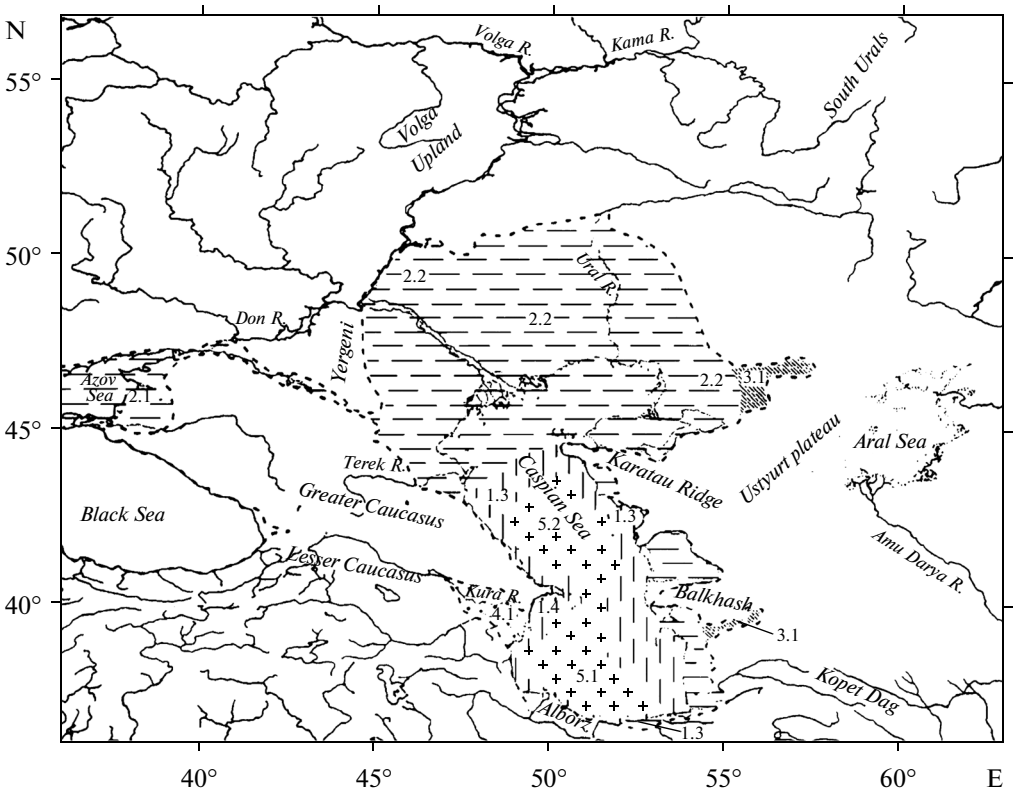

Fig. 4. Genetic facies of the Early Khazar Sea.

The facies of open calm shoals were dominant in the vast territories of the West Caspian region and Volga–Ural interfluve in the Baku period. The sandy facies in the periphery of the basin correspond to the coastal sedimentation and shallow areas of the sea. The sandy–silty–clayey facies correspond to more remote areas of the sea bottom, whereas clayey sediments were formed in the central and the deep parts with relatively calm sedimentation conditions. The facies of dynamic shoal represented by continuous pebble–gravel talus are dominant east of the Ural River valley, in the area of active salt domes (Chelkar, Inder).

In the eastern coast, the fine sediments of the deep and shoal gulfs of epicontinental basins accumulated in the deep gulfs of the Baku Sea to the south and east of Cheleken, in the Atrek depression, and in the area of the modern Kara-Bogaz-Gol. The abrasion coasts of low mountains and plateaus with low-thick discontinuous cover of pebbles and limestones of dynamic facies of bench and shallow beach were localized between the gulfs. The high carbonate content and epigenetic variability of the rocks caused by the hot arid climate are the typical features of sedimentary facies of the eastern coast.

The facies of the early Khazar Basin (Fig. 4) are widely developed in all Caspian coasts and penetrated far via modern and ancient relief depressions. The Khazar sandy, sandy–pebble, and terrigenous–carbonate sediments of dynamic shelf and coastal shoal facies compose the accumulative cover of the medium height terraces in the Caucasus foreland. The carbonate rocks (especially shell limestones and pebbles–gravels with biogenic-calcareous cement) abundant at the eastern coast indicate well-warmed dynamic shoals and the presence of shellstone banks.

The most extensive fields of the Lower Khazar marine sediments located in the North Caspian region are traced to the Cis-Syrt bench in the north and to eastern slopes of the Yergeni highland in the west. They are characterized by rather mixed composition with dominant facies of epicontinental shallow sands, silts, and sandy clays.

In the flooded valley of the Lower Volga region, the sandy and sandy–clayey marine sediments of the flooded valleys form vertically and horizontally complex mutual facial series with alluvium of ancient Volga River. The shells of Khazar mollusks may be redeposited in younger alluvial sediments, which is often interpreted as evidence of the presence of several horizons of marine Khazar sediments. The facial transitions of marine Khazar sediments of shelf type to deltaic and alluvial-deltaic sediments of a part of the Karakum Formation are established in the eastern Caspian coast.

The facies of the Early Khvalynsk Basin (Fig. 5). The lithofacial composition of the Lower Khvalynsk sediments varies from chocolate clays of the Lower Volga region to pebbles and shellstones of Caucasus and eastern coasts. The average thickness of sediments is low

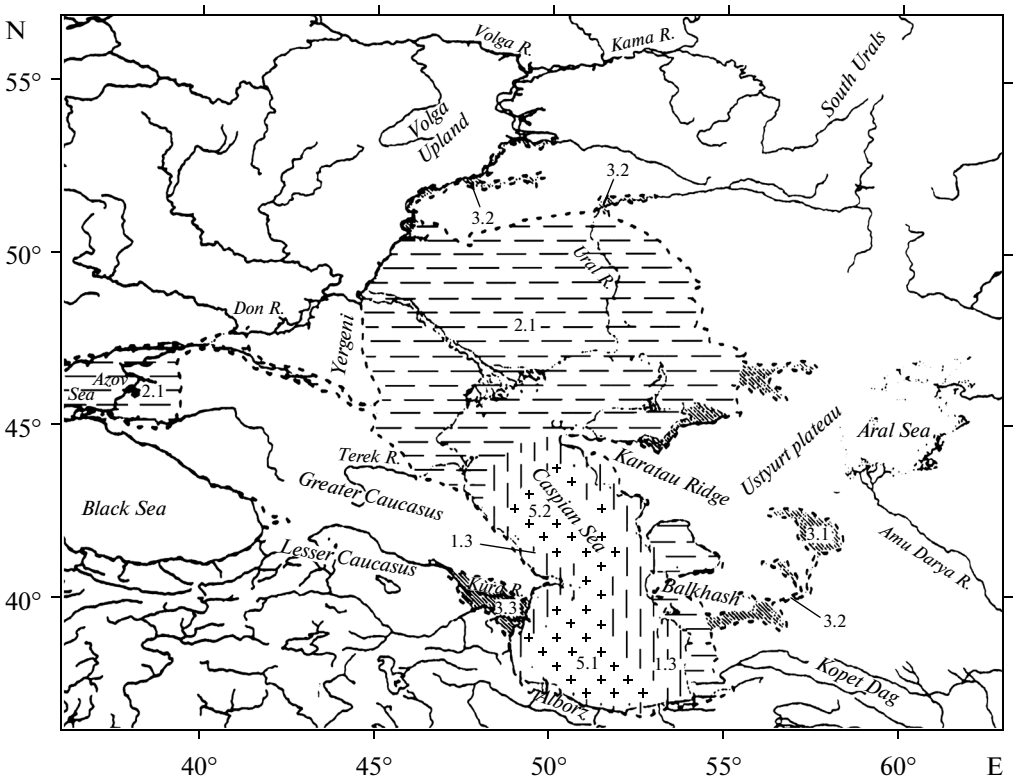

Fig. 5. Genetic facies of the Early Khvalynsk Sea.

(first meters, rarely more) and the maximum thicknesses observed in the Kura and West Turkmeni depressions exceed 150 m [5]. The sediments with break features lie on various Pleistocene and older sediments. The rare gradual alternation of alluvial–deltaic and ingression–marine sedimentation is typically observed in the river valleys flooded by ancient Caspian Sea.

The loamy and layered sediments (facies) of epicontinental shallow basin of the North Caspian region, coarse sands and pebbles of dynamic shoals of the middle and southern Caspian shelf, and silts and clays of the deep-sea facies of Caspian depressions are mostly widespread. Specific facies of the Early Khvalynsk Sea without analogs in other ancient and modern Caspian sediments are chocolate clays—an excellent lithological reference strongly restricted to the Khvalynsk estuaries in the Volga and Ural rivers, Volga River delta, and West Caspian depressions [18].

The genetic and temporal analogs of chocolate clays (a member of intercalated clays and sands confined to the depressions of pre-Khvalynsk relief) are abundant in the interfluve of the Volga and Ural rivers. A hydromorphic soil, which, probably, registers the break between the Lower and Late Khvalynsk sediments, is developed at the top of the Lower Khvalynsk sediments in the valleys of the Bol'shoi and Malyi Uzen rivers.

CONCLUSIONS

(1) Fossil facies of different lithology present among marine Pliocene–Pleistocene sediments of the Great Caspian region reflect various sedimentation regimes related to different geological–geomorphologic, climate, and hydrological conditions of the bottom of basins and ambient coastal territories.

They represent the hierarchical lithological bodies from complex to subfacies. The facies of shelf, epicontinental basins, ingression gulfs and estuaries, intermontane and foreland troughs, and deep-sea depressions may be distinguished and stably traced in the ancient basins (table).

(2) The marine sediments of the Great Caspian are characterized by paragenetic associations of fossil facies, which form various spatial and vertical facial series ("normal," "broken," "long," and "short").

(3) Specific lithological combinations (paragenetic associations) are present in the coastal regions of the Great Caspian region among the adjacent marine and continental sediments. The most exotic closely related gravitation–marine and eolian–marine sediments characterize a certain structure of the coast and seaside land and its natural state.

(4) The facial composition of sediments of the Great Caspian region is most diverse during its greatest transgressions: Akchagyl, Absheron, Baku, Early Khazar, and Early Khvalynsk. The huge area of these basins caused a diversity of facial conditions, the com-

position of facies with all above noted facies, limited development of various epicontinental sediments, and the mode of their occurrence. The shoal sediments of limans and lagoons were abundant in the plain coasts at maximum of transgression, whereas clastic sediments various in composition and thickness were typical of the foreland and mountainous depressions.

Overall, the certain proximity of location of facies is typical of the large basins of the Great Caspian region, which indicates its similar and stable sedimentation conditions over last three million years.

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