ISSN 0097-8078, Water Resources, 2016, Vol. 43, No. 2, pp. 270–282. © Pleiades Publishing, Ltd., 2016.
Original Russian Text © A.A. Svitoch, 2016, published in Vodnye Resursy, 2016, Vol. 43, No. 2, pp. 134–148.

WATER RESOURCES AND THE REGIME OF WATER BODIES

Regressive Periods of the Great Caspian

A. A. Svitoch
Moscow State University, Moscow, 119991 Russia
E-mail: A.Svitoch@mail.ru

Received March 24, 2014

Abstract—The Late Pliocene–Quaternary Great Caspian, in addition to the positive transgressive rhythmics shows regressions of different scales: balakhanskaya, domashkinskaya, tyurkyanskaya, venedskaya, chelekenskaya, chernoyarskaya, atel'skaya, enotaevskaya, mangyshlakskaya, and izerbashzkaya. In these periods, large-scale natural phenomena took place on the Caspian shelf, coasts, and adjacent inundated territories, including sea level drop, drying of a part of seabed, and change of landscapes and the sedimentation character. The neaped water area showed changes in water salt composition and temperature regime, along with a change in faunistic complexes. Different hierarchic state of sea level and different correlation with climate events on the surrounding territories was shown to take place during the regression with predominance of warm (interglacial) periods among them.

Keywords: the Great Caspian, level variations, regression, pliopleistocene, paleogeography

DOI: 10.1134/S0097807816020160

The Great Caspian (GC) is a system of Late Pleistocene–Quaternary water bodies, which existed on the territory of the current Caspian Sea and the surrounding lowland areas. In the recent 3 million years, this unique basin sometimes extended to the bottom of Elborus to Vyatka and Kama, from the Black Sea to the Aral Sea and sometimes decreased to the size of the Sea of Azov (Fig. 1). This fact can be reliably established by the areal and hypsometric position of marine deposits, characterized by fauna, with their structural position taken into account. The key distinction of the history of the ancient Caspian from that of open marine basins is the extent of its level variations and water area, along with variations of its salinity and fauna. The vast geological and hydrological literature on the Caspian shows the sea to have a complex hierarchic structure of positive and negative variations, where each their real position is the joint effect of many components, which strengthen or weaken the main trends in level behavior [30]. The transgressive rhythmics of the Caspian, which was most reliably established based on the vast factual material, extends over the major portion (2/3 to 3/4) of the time of sea existence. The Caspian regressions are less known; they are determined by data on bottom sediments and the paleontological remains they contain, the seismology, bed geomorphology, as well as the paleogeographic and paleohydrological analyses.

Different-scale regressions of GC, which separate its transgressive periods, have been established and studied to different extent. These periods include balakhanskaya, domashkinskaya, tyurkyanskaya, venedskaya, chelekenskaya, chernoyarskaya, atel'skaya, enotaevskaya, mangyshlakskaya, and izerbashzkaya (Table; Fig. 2).

Moreover, some researchers [24, 30] found the signs of freshening in the deposits of akchagyl and apsheron in the form of freshwater elements among salty water fauna, which are an indication to the possible regression of the basin. Even if this was the case, the level drop in GC water bodies should have been small. This assumption is supported by the absence of appreciable interruptions among the major portion of sections of akchagyl and apsheron deposits. Note that the presence of a direct correlation between the salinity of the basin and the position of its level looks not obvious.

DESCRIPTION OF REGRESSIONS

Balakhanskaya Regression

The balakhanskaya regression (GC prehistory) extends over a long balakhanskaya period. It can be traced from the deep regression of pontic basins and the beginning isolation of the Caspian from the Black Sea. According to paleomagnetic data, the accumulation of balakhanskie (productive) deposits on the Azerbaijan territory extends over the lower part of the positive paleomagnetic Gauss period and the entire Hilbert period within an interval of 5.12–2.3 million years [12]. According to [8, 34], the beginning of the akchagylskaya transgression refers to the base of the Gauss period (3.23 million years ago). This estimate suggests that the duration of the balakhanskaya period was ~2 million years, where the accumulation of the upper part of the productive stratum (surakhanskaya

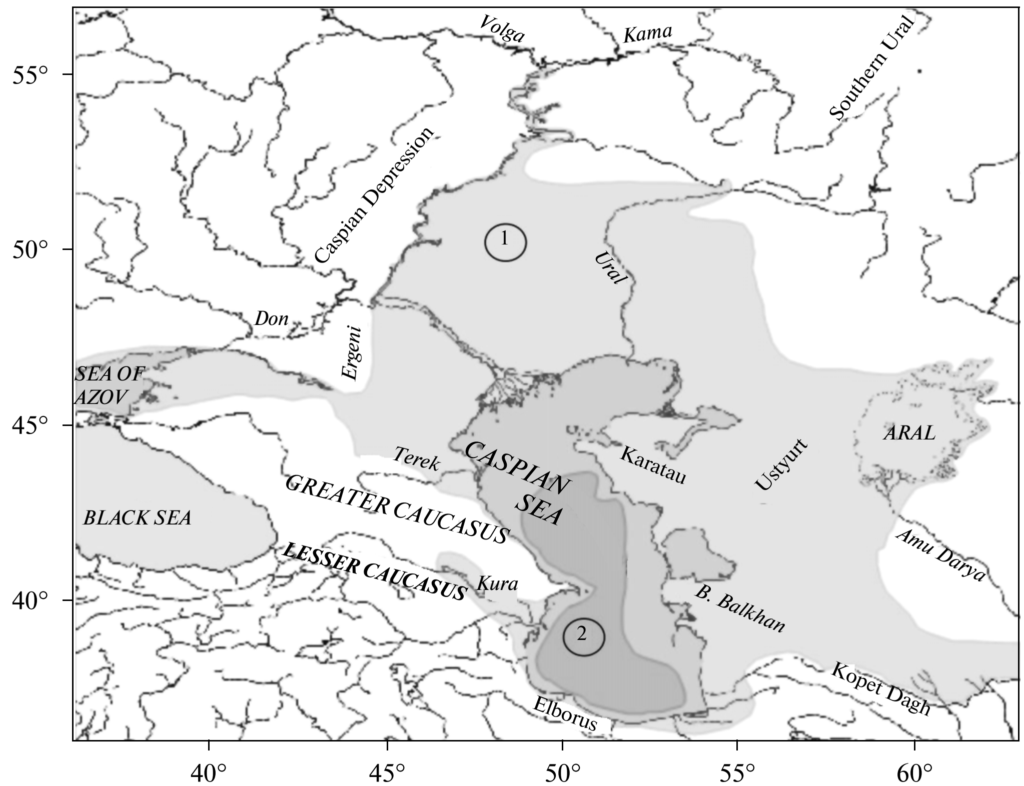

Fig. 1. Scheme of (1) maximal and (2) minimal development of GC water bodies.

suite) took place in the beginning of the akchagyl transgression.

The Balakhanskoe time shows intense uplifts and dislocations in the alpine structures around the Caspian, i.e., the Greater and Lesser Caucasus, Talysh, Alborz, and Kopet Dagh, and sinking of nearby structures, i.e., Tersko–Caspian, Kurinskii, and Prekopetdagh depressions. Folded motions took place in Apsheron–Kobystan, Apsheron–Pribalkhan zones and Western Turkmenia.

Two downfold domains existed in the Caspian Sea depression north and south of the Apsheron Threshold. The South-Caspian Depression, where geodesic and drilling data show 3–4-km sediment stratum to have accumulated, was sinking most rapidly.

The northern part of the Caspian domain, limited from the east and west by the Southern Urals and Privolzhskaya Uplift, was a vast lowland territory, open toward the north, with a well-developed river network and erosion–accumulation and erosion–denudation relief.

The relief of the Caspian region in the balakhanskoe period showed numerous deep river valleys, corresponding to low water level in Caspian depressions. Thus, a vast (250 × 500 km) balakhanskoe lake was filling by sediments of the paleorivers of Volga and Karyn-Zharyk, Uzboi, Araks, Samur, Kura, etc., which had a depth of incision of several hundred meters. Particularly long and overdeepened was the valley of the paleo-Volga, extending from the Vetluga R. to the Apsheron Threshold. Its incision depth near the current Saratov was 300–350 m, reaching 500–600 m near the exit into the Prikaspiiskaya depression, where the width of the valley was in excess of 100 km [20].

The various continental deposits, which were accumulating in the balakhan period, later served as a bed for sediments of akchagyl transgression: balakhanskie (producing) in Azerbaijan, red in Western Turkmenia, kinel'skie in the Volga Region and the west of the Southern Urals, kushumskie in the Caspian region, and podakchagyl north of the Eastern Caucasus.

The producing stratum in Azerbaijan contains large oil and gas fields. This stratum mostly consists of rhythmically layered sand–clay deposits of a large freshwater body and river valleys entering it. An analog of the balakhanskaya (producing) stratum in Western Turkmenia is red beds (chelekenskaya suite). In terms of composition, these are various sand-clay formations of mostly deltaic origin with the predominance of red color and a thickness of >2 km.

Kinel'skie deposits (suite) consist of a series of alluvial, lacustrine–alluvial, and lacustrine sediments of variegated lithological composition; they are abundant in the Middle Volga Region and west of the Southern Urals, where they form erosion paleorelief

Transgression–regression rhythmic of the Great Caspian

<table>
<tr><th colspan="2">Transgressions</th><th rowspan="2">Regressopms</th></tr>
<tr><th>period</th><th>stage</th></tr>
<tr><td rowspan="3">Novokaspiiskii</td><td>Novokaspiiskaya</td><td rowspan="2">Izberbashskaya</td></tr>
<tr><td rowspan="2">Dagestanskaya</td></tr>
<tr><td rowspan="2">Mangushlakskaya</td></tr>
<tr><td rowspan="4">Khvalynskii</td><td rowspan="2">Pozdnekhvalynskaya</td></tr>
<tr><td rowspan="2">Enotaevskaya</td></tr>
<tr><td rowspan="2">Rannekhvalynskaya</td></tr>
<tr><td rowspan="2">Atel’skaya</td></tr>
<tr><td rowspan="4">Khazarskii</td><td rowspan="2">Pozdnekhazarskaya</td></tr>
<tr><td rowspan="2">Chernoyarskaya</td></tr>
<tr><td rowspan="2">Rannekhazarskaya</td></tr>
<tr><td rowspan="2">Chelekenskaya</td></tr>
<tr><td rowspan="4">Bakinskii</td><td rowspan="2">Urundzhikskaya</td></tr>
<tr><td rowspan="2">Venedskaya</td></tr>
<tr><td rowspan="2">Bakinskaya</td></tr>
<tr><td rowspan="2">Tyurkanskaya</td></tr>
<tr><td rowspan="5">Apsheronskii</td><td rowspan="2">Late</td></tr>
<tr><td rowspan="3"></td></tr>
<tr><td>Middle (maximal)</td></tr>
<tr><td rowspan="2">Early</td></tr>
<tr><td rowspan="2">Domashkinskaya</td></tr>
<tr><td rowspan="4">Akchagylskii</td><td rowspan="2">Late</td></tr>
<tr><td rowspan="3"></td></tr>
<tr><td>Middle (maximal)</td></tr>
<tr><td>Early</td></tr>
<tr><td></td><td></td><td>Balakhanskaya</td></tr>
</table>

and structural paleodepressions. In the regions further to the south—the Lower Volga Region and the Northern Caspian Region—their age and genetic analogues are sediments of the kushumskaya suite, which fill erosion depressions of the pre-akchagyl relief. Dominating among these in the lower part of the section are coarse boulder–gravel–pebble and gravel–sand or, in the upper part, sand–clay sediments.

Overall, judging by the composition of the balakhanskie deposits, overwhelmingly dominating among them, except for the sediments in the Southern Caspian and Middle Caspian depressions, are terrestrial aqueous formations: alluvial, deltaic, lacustrine, etc., while there are no reliable deposits of large water bodies as identified in [2, 32]. Thus, according to [2], in the late balakhanskaya period, the Caspian Region contained a vast freshwater basin with an area close to the maximum of akchagyl transgression. According to [32], by the late Cimmerian (before the Akchagyl time), a series of dammed freshwater basins existed, including the Southern, Middle, and North Caspian, North Prikaspian, Middle Volga, Bolgarskii, Upper Volga, and Kama–Bel’sk. However, this concept seems to lack a factual basis. The existence of ancient water bodies should be traceable by many signs, primarily, by the presence of large isolated depressions filled with a common sediment stratum, continuous along the strike, mostly of fine lithological composition, as is typical of large shallow water bodies. In fact, a system of small water bodies without large basins existed in the Caspian and Volga regions.

The relief of the bed of akchagyl deposits north of the Derbent depression shows no large depressions corresponding to the identified water bodies. The

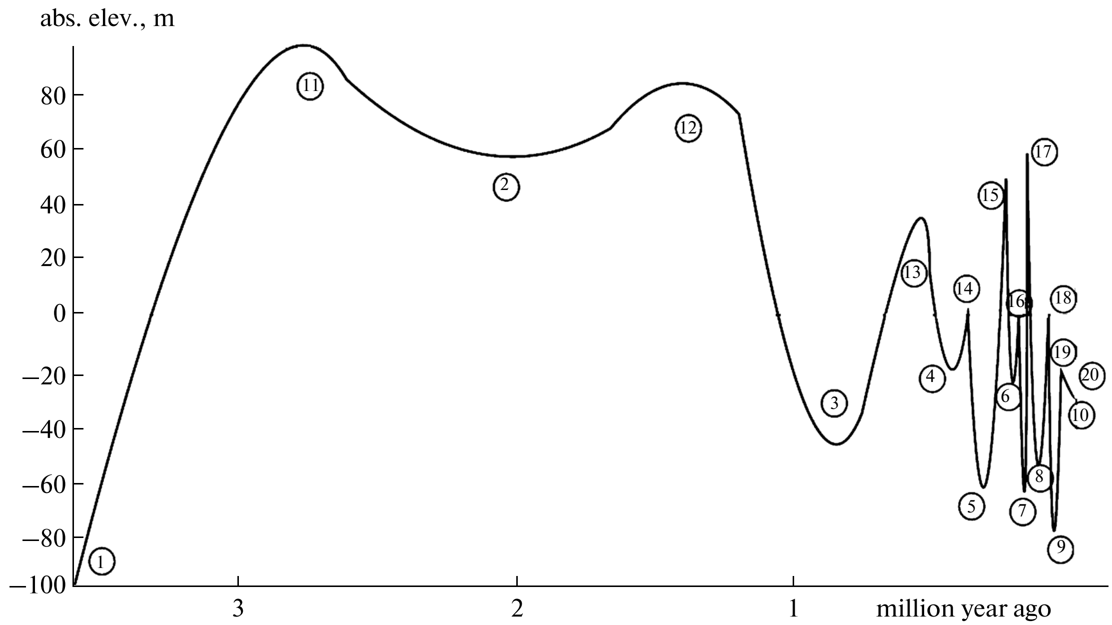

Fig. 2. Transgression–regression rhythmic of GC. Rhythms (periods, stages, oscillations) regressive: (1) balakhanskii, (2) domashkinskii, (3) tyurkanskii, (4) vendskii, (5) chelekenskii, (6) chernoyarskii, (7) atel'skii, (8) enotaevskii, (9) mangyshlakskii, (10) izberbashskii; transgressive: (11) akchagyl'skii, (12) apsheronskii, (13) bakinskii, (14) urundzhikskii, (15) rannekhazarskii, (16) pozdnekhazarskii, (17) rannekhvalynskii, pozdnekhvalynskii, (18) dagestanskii, (20) novokaspiiskii.

kinel'skie and kushumskie deposits mostly fill pre-akchagyl erosion relief and have lithologically variegated composition, discontinuous along strike, with large amount of coarse deposits. This is especially true of kushumskie deposits, which only partly fill the paleovalleys of the Volga and the Ural (Fig. 3) and mostly have relatively coarse sand–pebble composition, which is not typical of the sediments of large water bodies. Note that that the terrestrial aqueous kinel'skaya stratum, especially its northern regions, contains, among others, sediments of freshwater bodies, but, judging by their discontinuous occurrence, they belong to small isolated lake basins.

In the balakhanskaya period, the climate and vegetation of the Caspian zone were very diverse and had distinct zonal differentiation. In the early XX century, N.I. Andrusov [3] supposed that the climate in the southern part of the area was hot and semidesert. He substantiated this assumption by the red deposits and their high gypsum content. S.A. Kovalevskii [14] considered the remains of thermophilic vegetation, forest and steppe animals as an indication to the existence of evergreen forests and warm steppes in the southeastern Caucasus. Further northward, the area of occurrence of kushumskie deposits, at the early stages of their accumulation, was a steppe zone with the predominance of pigweed phytocenoses; forests of pangol-arctic and American–east Asian flora occurred locally. The mean January temperature was estimated as varying from −3°C to −8°C; the July temperature was estimated to be not less than +19°C [31]. In the late Kushumskoe time, the climate became warmer and wetter; the steppe zones shrank, while broadleaved forests with rich grass cover became widespread.

The kinelian flora of the Middle Volga region as well as zones east of the Volga and near the Caspian Sea belongs to the forest–taiga type. The vegetation shows a distinct zonality from the south to the north—from open treeless landscapes to coniferous pine forests and dark coniferous forests with relicts of turgaiskaya flora. In the end of the Early Kinelian (pre-akchagyl) period, the climate became more continental.

A distinct natural zonality also existed in the area west of the Urals [42], where forest–steppes and grassland steppes dominated in the southern part, broadleaved forests dominated north of this zone, and pine–fir forest with abies and hemlock, in the downstream part of the Kama basin.

The results of the studies mentioned above suggest that, in the balakhanskoe time, before the akchagyl transgression, ~3 million years ago, the major portion of the Caspian region was a vast land area with diverse relief, climate, and landscape. The Caspian depression, 144 thous. km^2 in area extended in the meridional direction in its center; a deep depression—a large freshwater body or lake—lied in its southern part; this depression was sinking rapidly and filling with sediments of the productive and red strata.

The northern part of the Caspian depression was cut by deeply incised (by several hundreds meters) river valleys emptying into the balakhanskoe lake. In the southern, southeastern, and southwestern parts of

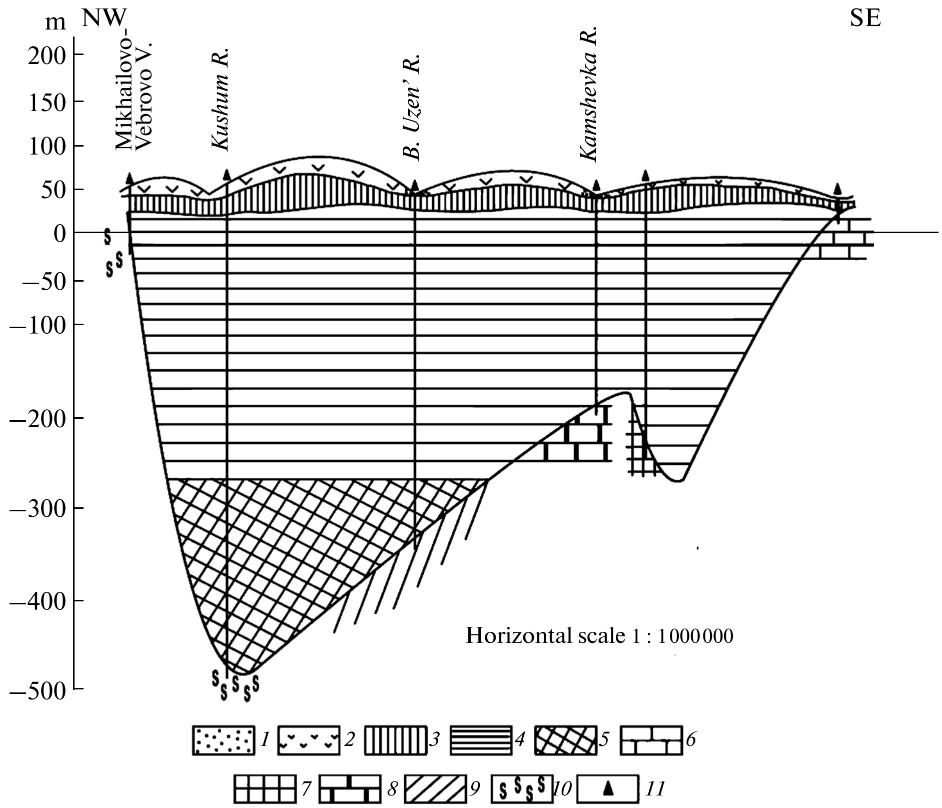

Fig. 3. Profile through the buried Volga valley north of Ershov: (*1*) khvalynskie deposits, (*2*) yellow–brown loams, (*3*) apsheronskie deposits, (*4*) akchagylskie deposits, (*5*) kinel'skie deposits, (*6*) Upper Cretaceous deposits, (*7*) Lower Cretaceous deposits, (*8*) Jurassic deposits, (*10*) Carboniferous deposits, (*11*) wells [10].

the Caspian region, it is bounded by the piedmonts and high mountain systems of the actively rising Greater and Lesser Caucasus, Talysh, Alborz, and Kopet Dagh, alternating with deep intermountain and piedmont depressions (Kurinskaya, Caspian, Kubinskaya, West Turkmenian, etc.), open toward the Caspian depression.

A typical feature of the zone at the northern and eastern boundaries of the Caspian depression is the alternation of lowland (Pribalkhanskaya depression, Manych, Karagi), low-mountain, and plateau-type (Mangyshlak, Ustyurt, Stavropol plateau, Common Szyrt, etc.) structures. Vast northern areas in the Caspian area—the Northern Caspian region, the Lower and Middle Volga region, the area east of Kama region, and the southern area east of the Urals, limited by Ergeni and Privolzhskaya Highland from the west and by Urals piedmont from the east, and open to the north, show mostly plain erosion–denudation relief with a well-developed network of river valleys filled with kinel'skie deposits.

An important fact is that the deep river valleys, which are typical of the balakhanskoe time, have been filled only partly by the kinel'skii and kushumskii alluvium (Fig. 3). Therefore, erosion relief persisted to this time but was leveled later by akchagyl and post-akchagyl deposits. Note also that, except for the South Caspian and Middle Caspian lakes, there were no vast freshwater bodies in the Caspian region in balakhanskoe time. The climate in the area was warm or moderately warm, dry in the southeast, wet in the southwest and north without signs of abrupt cooling, which would suggest glaciations in the nearby northern regions.

Domashkinskaya Regression

The domashkinskaya regression is conventionally identified as a long period between the akchagyl and apsheronskaya transgressions. Its name is due to the deposits of domashkinskaya series (layers) identified in 1902 by S. Nestruev by sections in the Middle Volga region. The domashkinskie beds form a stratum of freshwater sand–clay deposits, widespread in the northern Caspian Region and containing freshwater mollusks: Unio tumidus kujalnicensis., U. odessanus, Viviparus sinzovi, etc. The regression consists in a drop of the level of the akchagyl'skii basin due to the cessation of the inflow of sea (oceanic) water from outside and its disappearance as a freshened marine water body of oceanic type, and the time of the final disappearance of the akchagyl fauna and the drying out of the marginal parts of the water body. The end of the regression coincides with the beginning of the apsheronskaya transgression—a small (a few meters) sea level rise, its weak salinization, the appearance of first brackish-water apsheron mollusks. The basin is turning into an appreciable brackish-water body. Overall, the drop of the Caspian level in the domashkinskaya period was small, as can be seen from the absence of interruptions between akchagyl and apsheron deposits on the major portion of sea water area. Thus, in the Northern Caspian Region, these deposits show concordant bedding and considerable similarity in the material composition, fauna, and plant remains. In the southern part of the region, on Cheleken [2], they have no unconformity; the passage is gradual, according to fauna. Some signs of interruption between akchagyl and apsheron deposits, suggesting the cessation of marine sedimentation, can be seen in the periphery of those basins. Thus, in the north, in the section of the Lower Kama, verkhneakchagyl floridine clays of biklyanskii horizon are overlain, with deep erosion, by clays of omarskii horizon [4].

In Lower Volga, in the upper akchagyl, the liman deposits of the voevodskii horizon are overlain, with deep erosion, by coarse alluvium of the lower part of the demskii horizon of the lower apsheron. In the Western Turkmenia, on Kopet Dagh and Malyi Balkhan, the akchagyl deposits are overlain by lower apsheron sediments with abrupt nonconformity.

Judging by the positions of the level of the akchagyl and apsheron basins, their level variations in the period of domashkinskaya regression was asymmetric, with a considerable initial drop and a lesser subsequent rise. At the boundary between ackhagyl and apsheron, the climate of the region became cooler, and fir taiga with an admixture of pine, abies, and hemlock became widespread in the north. According to [24], during this regression, the climate became more arid and continental; xerophytic and pigweed vegetation groups became widespread.

Tyurkyanskaya Regression

The tyurkyanskaya regression is a long regressive stage, separating the apsheron and bakinskaya transgressions. This name is due to the deposits of the tyurkyanskaya suite of the Apsheron Peninsula. The Caspian Sea has considerably dried out by the end of the Late Pleistocene to become a freshwater–brackish-water body 208 thous. km^2 in area [39], filling the South Caspian and a part of the Middle Caspian depressions. The sea, in the form of small bays, extended only to the Apsheron Peninsula and the Kura Lowland. Subaerial and subaqual sedimentation predominated in this time on the major portion of the Caspian Region. The low level in the Caspian depressions caused active incision of the rivers flowing into it, which was most pronounced in the region west of the Urals and the Caspian and Volga regions

The shoreline of the regressive Caspian Sea in the form of a submerged abrasive step was identified at the elevations from –280 to –120 m abs. elevation. In the southeastern part of the Middle Caspian depression, at depth of 145–150 m contains a complex of accumulative forms (bars) 5–10 km in width and more than 100 km in length, referred to the pre-bakinskoe time [5]. In [17], the identified step of the pre-bakinskaya abrasion on the continental slope of Derbentskaya depression at a depth fo 360–370 m was supposed to be a sign of its landslide origin. Seismic data show large clinoforms to form a system of conjugate deltas all over the Middle Caspian [27].

The Caspian level was below its current position as can be seen from the small areas and depths of sediment occurrence in the territory of current land. Thus, on the Astrakhan dome fold, a parametric well (123) within interval 93–110 m penetrated Paleo-Volga alluvium, lying between apsheron and bakinskie deposits [10]. The incision depth of the Paleo-Volga in the balakhanskoe (kinel'skoe) time in this region is 400–500 m, implying that the level of its local water bodies, receiving river systems of the balakhanskaya and tyurkyanskaya time, was different, i.e., it was much lower in the balakchanskii period.

The age and duration of the tyurkyanskaya regression period can be evaluated by the paleomagnetism of its deposits (a boundary of Brunhes–Matuyama zones) and by their position in the summary section (separates apsheron and bakinskie deposits). The duration of the period is conventionally estimated at ~0.2 million years.

The facies composition of sediments is different; genetically predominant among them are terrestrial aqueous (alluvial, deltaic, lacustrine), rarer, brackish-water or subaeral formations, reflecting a long regression period. Deep Caspian depressions were filling by fine clay–aleurite material, while on their western periphery, in Azerbaijan, coarser, mostly, sand–pebble deposits were accumulating in bays. On the east, in Western Turkmenia, tyurkyanskie deposits are mostly represented by continental sand–clay, rarely, pebble alluvial and proluvial formations and the lower part of sands of karakumskaya suite. In the north, in the Caspian region, sand facies of alluvium were overwhelmingly predominant, filling branched erosion network, fine lacustrine deposits of relief depressions and loams of the top of szyrt stratum.

The regression water body was much freshened, as can be seen from the shells of freshwater and brackish-water gastropod mollusks in its deposits: Lithoglyphus sp., Planorbis sp., Limnaea sp., Melanoris sp.; bivalves Dreissena ex gr. rostriformis, and seed shrimps: Candoniella subellipsoida, Yliocyprus bella, Eucyprus famosa, Cyprides littoralis, Loxoconcha eichwaldi, etc. [1]. The upper part of the section was found to contain rare brackish-water bakinskie bivalves Didacna catillus. Tyurkyanskie deposits in Turkmenia contain plant remains and pollen of woody plants, implying wetter and cooler climate than we have now [15]. Paleontological findings in the Palin-Tyukan Range indicate to the presence of southern elephants of the form Archidiscodon meridionalis in Azerbaijan in that time. In late Apsheron—in Tyurkyanskoe time—the Southern Caspian was arid, and the major portion of the exotic thermophilic and moisture-loving plants (taxodiaceae, nut, and ginceng family) died away [36]. Judging by the rare pollen of grassland vegetation in szyrt loams of the Northern Caspian region, the climate was dry and warm during their accumulation. In the Southern Ural region, meadow and steppe vegetation with abundant xerophytes was predominant among open landscapes at the beginning of formation of the general-szyrt suite. Later, as the climate became colder and wetter, periglacial steppes became widespread. Therefore, the climate was warm and relatively dry at the beginning of the tyurkyanskaya period and relatively cold and wet at its end. The climate events on the East European Plain showed the same pattern: the petropavlovskoe interglacial period (MIS-21) with diverse forest vegetation was followed by pokrovskoe cooling (MIS-20) with the predominance of periglacial steppes [21]. According to [39], the tyurkyanskaya regression is correlated with the early and late il'inskit interglacial periods.

Venedskaya Regression

The venedskaya (mishovdagskaya) regression is determined conventionally. It was called by the alluvial suite identified by G.I. Goretskii [7] in the ancient Volga valley. In other Caspian regions, the deposits of this regression have not been identified. This seems to have been a small and short regression of the Caspian with an area of 336 thous. km^2 [39], separating the bakinskaya and urundzhikskaya transgression in the end of the late and the beginning of the early Pleistocene (the period of disappearance of bakinskii complex of mollusks).

Deposits of venedskii alluvium occur in the Lower Volga valley, where they fill a deep erosion incision, overlay bakinskie marine deposits, and underlay singil'skie formations. By their composition, these are fine- and very fine-grained sands with interlayers of clays and loams, containing vivianite. In the areas of occurrence of deposits of bakinskaya and urundzhikskaya transgressions, signs of interruption of sedimentation can be seen between them in the form of erosion of the roof of bakinskie deposits, the presence of basic horizons, and an uneven boundary between the layers. They are especially distinct in the sections of Pribalkhanskii region and on Cheleken. In the Southern Urundzhik section, the ground of the bed of shell deposits with Didacna eulachia etc. was found to contain pebble beds of carbonate rocks overlying eroded roof of bakinskie clays with Didacna parvula [35]. In the Mishovdag section (Azerbaijan), urundzhikskie deposits are separated from the underlying bakinskie and overlying khazarskie deposits by signs of interruption and angular discordance [31].

The regression time appears to fall on the end of Early Pleistocene; the depth and duration of this regression have not been determined reliably. Judging by a similarity between the bakinskii and urundzhikskii mollusk complexes, the regression separating them was not very long, though deep enough in terms of environmental and geomorphologic changes. Didacna catillus, typical mollusks of the bakinskoe sea, disappeared in this period. In the Lower Volga region, deep erosion incision of the paleo-Volga was taking place, followed by its filling with venedskii alluvium.

Chelekenskaya Regression

Its name is due to Cheleken Peninsula, whose sections were found to contain signs of an interruption between marine urundzhiksie and khazarskie deposits. Clear signs of interruption in the form of horizons of erosion and angular discordance were also recorded in the Mishovdag section.

The chelekenskaya regression is a large deep Caspian regression with drying of the top and, possible, middle part of the shelf—a final period of disappearance of predominant forms of bakinskaya fauna. The depth of the regression is demonstrated by the absence of bakinskie and urundzhikskie deposits in the coastal part of Dagestan shelf down to the present-day depth of 20 m [29]. This period shows a deep erosion incision on the Caspian shelf and in the ancient valley of the Lower Volga with the subsequent filling by Volga alluvium.

The age and duration of the chelekenskaya regression are determined by its position between the urundzhikskaya and khazarskaya transgressions of the Caspian. This appears to have been the beginning of the Middle Pleistocene (350–300 thous. years ago).

In addition to marine sediments of the lower shelf and deep-water depressions, the deposits of the chelekenskaya regression include the deposits of ushtal'skaya suite of Kurinskaya depression, the upper part (astrakhanskie beds) of singil'skie deposits, alluvium of the lower krivichskaya suite of the Lower Volga Region, and, maybe, the middle part of the karakumskaya suite of Western Turkmenia. The krivichskie deposits near Enotaevka fill the ancient Volga valley [22]. By their composition, these are mostly channel alluvial facies, i.e., consertal gray sands with interlayers of dark loams and lenses of coarse-grain material on the base of gravel and pebble, mostly of siliceous-quartz rocks and confluent sandstones. The deposits fill a deep paleoerosion incision in the valley, and their thickness reaches a few tens of meters. The krivichskie sediments were found to contain shells of freshwater mollusks Lithoglyphus aff. naticoides, Valvata piscinalis, Bithynia tentaculata, Viviparus duboisianus, Dreissena polymorpha and various pollen and spores, which form forest, forest-steppe, and steppe palinological spectra. Kosozhskaya flora [22], which characterizes the climatic optimum of the Early and Middle Pleistocene and containing no representatives of cold-loving flora, originate from the bottom part of the krivichskie deposits.

The Caspian benthos in the residual water body has changed considerably during the chelekenskaya regression: in the opinion of P.V. Fedorov [35], this was the most radical change in the fauna in the Caspian Pleistocene. Bakinskie mollusks disappear and representatives of the subsequent khazarskaya fauna form, incuding numerous trigonoid forms of didacna. In this period, deep erosion incision can be seen in the valleys of the Lower Volga and Amu Darya with its subsequent filling by alluvium of nizhnekrivichskaya and karakumskaya suites. Alluvial–proluvial plumes formed along the sides of Kurinskaya depression. Red astrakhan clays of the Lower Volga were accumulating in the period with unstable geomagnetic field of the Earth [31]. Judging by the palinological spectra of deposits of the nizhnekrivichskaya suite, the climate of the Northern Caspian region was warm and moderately wet [7]. This was an optimum of the likhvinskoe interglacial period, which manifested itself soil buried in the roof of astrakhanskie beds as well as numerous outcrops of gypsum and lime.

Chernoyarskaya Regression

The chernoyarskaya regression is a short, low-amplitude drop in the Caspian level. It was established by alluvial deposits of chernoyarskaya suite, filling the Lower Volga valley and overlaying nizhnekhazarskie or singil'skie deposits with erosion and overlain by atel'skie formations with an abrupt contact. The deposits contain many remains of mammals of khazarskii faunistic complex, whose habitat landscapes were identified as steppe; they also contain palinological spectra of forest-steppe and steppe types [7]. The accumulation of sediments in the Paleo-Volga channel was taking place at the levels close to the present-day dry-season level of the Volga or somewhat higher.

In other parts of the Caspian coast, coeval analogs of deposits of the chernoyarskaya suite, suggesting Caspian regressions, can be assumed to be the upper part of the alluvial of karakumskaya suite and a stratum of continental deposits with buried soils overlying gyurganskie deposits of Mishovdag structure in Azerbaijan.

Overall, the sediments of the chernoyarskii horizon correspond to the time interval of the second half and the end of the Middle Pleistocene (thermoluminescent data are 122–184 thous. years ago) and have limited occurrence on the Caspian coasts.

The drop of the Caspian level in the post-early khazarskoe time is estimated at 40 m [29]. If so, the top part of the Caspian shelf could become dry for short periods within the chernoyarskaya regression.

Atel'skaya Regression

The name of the atel'skaya regression was chosen in accordance with the continental deposits identified by P.A. Pravoslavlev in sections of the Northern Caspian region in atel'skaya suite (Atel' is the ancient name of a Volga branch) [26]. This is a deep long-time regression of the Caspian Sea in the middle of the Late Pleistocene, separating the khazarskii and khvalynskii transgressive stages, a period of considerable changes in the Caspian benthos [38].

The depth of the regression is determined from the position on the shelf of various coastal relief forms and deposits it consists of. Three levels (cuts) of atel'skaya regression were established [30]. The initial level left a series of submerged offshore bars along the eastern coast of the Caspian at a depth of ~20–25 m. The maximal level, when the sea level dropped to the elevations of –100 to –120 m, was identified by seismic studies on the slope of the Middle Caspian depression, where a large buried delta was discovered (with a thickness of 80–90 m and an area of >2.5 thous. km^2) [16]. A series of buried abrasion benches, which fix the third stage of regression, lies higher, at depth of 45–50 m. In the western part of Mangyshlak Threshold, seismoacoustic data clearly show erosion disconcordances and accumulative bodies, referred to atel'skaya regression [16]. In the interval between the peak of late khazarskaya transgression to the peak of regression, the level drop of the Caspian Sea was in excess of 100 m and the basin area decreased to 228 thous. km^2 [39].

The time of regression is identified by the stratigraphic position of the appropriate continental deposits, the character of fossils they contain, and the absolute dating. The majority of researchers believe this to be the middle of the Late Pleistocene (70–30 thousand years ago).

Out of all continental formations of Caspian regression periods, atel'skie deposits are most widespread, occurring on all Caspian coasts. In the Northern Caspian, these are the so-called atel'skie sandy loams and clay loams with stratotype sections in the Lower Volga region, which are represented by complex aqueous terrestrial and subaeral facial formations, separated by buried soils.

On the water divides of the Volga–Ural interfluves, atel'skie deposits are mostly represented by subaeral facies, while on the western Caspian coast, in Azerbaijan, these are Binagad lacustrine kirs.

During the atel'skaya regression, the climate was cold continental (Early Wurm). In this time, cold steppe and semidesert landscapes dominated on the dried up shelf of the Northern Caspian; soil deformations took place there. In the beginning of the atel'skaya period, open areas dominated in the Lower Volga region, pigweeds and numerous cereals, wormwoods, and herbs dominated in the vegetation. The area was developed by ancient people (Mousterian dwelling site at Sukhaya Mechetka ravine). Later, the climate became more severe, frost cracks appeared in soils, wood species disappeared, and landscapes became similar to cold semideserts. The dried up shelf of the eastern and southeastern Caspian coasts formed a dry area with dominating semidesert and desert landscapes. During the Middle Wurm (srednevaldaiskoe) warming, the climate of the northern Caspian coasts might be warmer with a wider occurrence of coniferous–small-leaved forests.

The end of the atel'skaya regression coincides with the ostashkovskaya (late-valdaiskaya, Late Wurm) glacial age; open cold landscapes were widespread on the shelf. The Caspian Sea, which had become much shallower and lesser in area, showed considerable faunistic changes—numerous khazarskie didacnas of crassa group (Didacna crassa nalivkini) and the species close to them (D. surachanica, D. Pravoslavlevi) died almost completely, the main components of khvalynskaya fauna (mollusks of trigonoides group: Didacna trigonoides, D. Praetrigonoides), which prefer less salt habitats, formed in the sea.

Enotaevskaya Regression

The enotaevskaya regression, which separated the early and late khvalynskaya transgression, took place in the Early Holocene (9.5–8.6 thous. years ago); it was simultaneous with the late preboreal and early boreal. Notwithstanding its short duration, the regression was deep; according to [17], the sea level lied 70–80 m below its current position, as was established by the position of a buried (second) delta on the north of the Middle Caspian bed. Other researchers estimate the regression as less deep: signs of a shoreline were found at depth of 16–17 m [15] or 43–45 m [27], while, according to [7], the depth was 36 m below its current value. In that time, the area of the Caspian Sea was ~205 thous. km^2, and its water volume was 69.1 thous. km^3 [4]; according to [39] the area was 288 thous. km^2.

According to drilling records on the Northern Caspian, sediments of enotaevskaya regression are represented by sand lenses with shells, often filling erosion incisions. In the Northern Caspian region, signs of this regression were first detected in a reference section at Enotaevka V., where roofs of nizhnekhvalynskie deposits can be seen in the form of weak soil transformation. In that time, the reduced water area of the khvalynskoe sea showed considerable faunistic changes—a decrease in the species diversity in associations of didacna mollusks.

Mangyshlak Regression

The mangyshlak regression separates the late-khvalynskaya and novokaspiiskaya transgressions. This is the most reliably reconstructed regression events in the Caspian, which took place 7.2–6.4 thous. year ago and is reflected in a vast body of factual data. The regression was established by M.M. Zhukov [11] based on materials on the overdeepening of Volga branches, which caused a drop in its level by 20–22 m below its current position. A.V. Shnitnikov [37] estimated the level drop at 10–12 m; and V.G. Rikhter [28], at 40 m. Traces of mangyshlak regression in the form of submerged shorelines were established on the Caspian shelf at elevations of ~–40.5, –35.5, –31.5, and –29.5 m abs. elev., as well as at –58.0, –50.5, –44.5, and –37.5 m [34]; on the Dagestan shelf, such elevations were –55.0, –48.0, –50.0, –42.0, and –43.0 m abs. elev. [5].

The regression was of a complex character, having left its traces (accumulative bars, erosion incisions, and coarse deposits) at depths of 20–22 to 70–80 m below the current sea level [17]. A belt of the current bed 10–15 km in width along the western Caspian coast became dry. The Dagestan shelf at a depth of 20–25 m was found to contain large accumulative formations like Derbentskaya Bank [23], a long (20 km) ridge 3–4 km from the shore with gentle slopes 0.5–1.0 km in width. The contours of the bank coincide with the –20-m isobaths. Individual accumulative forms were also found in other parts of Dagestan shelf, where they mark sea level at those depths, though their size is lesser. In this period, the entire Northern Caspian was dry, separated by paleobranches of the Volga, Terek, Kuma, and Sulak. Further eastward, a large lake existed on the dry lowland bed with the paleo-Ural and paleo-Emba flowing into it. Vast areas of Turkmen shelf became dry, the mouth of the Uzboi lying at its edge. The new dry areas shows the active accumulation of various subaeral sediments, mostly eolian sands with a very homogenous mineralogical composition (quartz, feldspars, and mica), as well as alluvial aleurolites, floodplain and lacustrine clays.

Shallow-water mangyshlak deposits are widespread in some shelf areas, where marine conditions persisted. On the Dagestan shelf, they were identified at depths of 20–22 m, where they overlay, with erosion, khvalynskie deposits and form morphologically well-defined accumulative bars—relicts of an ancient shoreline. By their composition, these are shallow-water facies—dark shelly ground and shelly detritus with pebble and gravel. The shells were found to contain Didacna baeri, D. barbotdemarnyi, D. longipes, Dreissena elata, etc. The deposits on the Mangyshlak threshold consist of coarse aleurolite and yellow or gray sand with oolites and shells of mollusks Didacna trigonoides, D. barbotdemarnyi, Hypanis plicatus, etc. Overall, the deposits of Mangyshlak regression typically contain shelf facies of relatively coarse-grain composition with higher carbonate content, low organic matter, brown color, and rhythmic lamination [17].

On the eastern shelf, marine mangyshlak layers were found on the depth of 25–50 m, where they overlay, with erosion, khvalynian deposits, identified by fauna. By their composition, these are sand–shelly shallow-water deposits, containing a complex of mollusks with a predominant form Didacna subcatillus, numerous Dreissena polymorpha, Dr. rostriforvis, Hypanis caspia, and solitary Didacna delenda, D. praetrigonoides, D. baeri. The Mangyshlak layers contain both novokaspian and khvalynian forms of Didacna protracta and D. parallella, indicating to some freshening of the sea. In this case, depending on the geomorphological situation, the salinity of the sea could be either higher or lower than its current value. Thus, the faunistic complex that existed on the shelf of the mangyshlak threshold during the regression was of more freshwater type than that existing now at the same depth. This can be explained by the fact that the Volga delta seemingly shifted southward, following the retreating shoreline, to occupy a lower position and to produce a freshening effect on the zone of Mangyshlak threshold.

Judging by palinological data, i.e., the absolute predominance of xerophytes Chenopodiacea and Artemisia among the pollen of grass and bryshwood [6], the climate of mangyshlak regression was strongly arid. Semidesert and desert landscapes with abundant areas occupied by halophytic vegetation dominated on the eastern shore of the sea. Widespread on the western coast were dry desert steppe with the predominance of xerophytes, herbs, and separate areas of forest communities. In the Northern Caspian region, tree vegetation existed in river valleys and on the shores of lakes and limans.

Izberbashskaya Regression

The izberbashskaya regression separates the dagestanskaya (gousanskaya) and the novokaspiiskaya transgression of the Caspian. Earlier, according to [5], the gousanskaya transgression referred to the initial stage of the novokaspiiskaya period; however, the absence of the governing novokaspian form Cerastoderma glaucum (Cardium edule) in its sediments allows it to be identified as a separate—dagestanskaya—transgression of the Caspian.

The izberbashskaya regression took place in interval 4.3–3.9 thous. years ago. It was mentioned by some researchers [13, 29]; however, documentary signs of its manifestations are few. They can include findings of a sand layer with detritus and shells of mollusks Didacna sp., Monodacna caspia, Adacna vitrea, dated at 3.8 ± 0.6 thous. years, on the submarine slope of the Southern Mangyshlak at a depth of 32 m [5]. According to drilling records [40], a stratum of shallow bay sediments lies between two layers of marine deposits (the top among them dated at 4.9–4.8 thous. years ago), suggesting a drop in the Caspian level. It seems to have been relatively small (not exceeding 10–22 m) with only the top part of the Caspian shelf becoming dry; the signs of continental processes were destroyed during the subsequent transgressive phases of the novokaspian sea. There is a possibility that the inundated shorelines at the elevations of –31 to –47 m abs. elev. are partially referred to the persisting signs of the izerbashskaya regression [7, 29].

In addition to the izerbashskaya regression, two small level drops (aleksandrbaiskaya and derbentskaya regressions), separating layers of the verkhnekaspiiskie deposits, were identified in the late Holocene in the period of novokaspiiskaya transgression [5].

DISCUSSION OF RESULTS

During regression periods of GC, large-scale natural processes were taking place on its shelf, and nearby inundated areas, including sea level drops and drying of vast seabed areas; changes of landscapes and processes of relief-formation and sedimentation; shallowing and changes in water salt composition and the fauna in the areas remaining under water (table).

The GC regressions considered in the study refer to different hierarchical states of its basins. The largest and longest are the balakhanskaya, domashkinskaya, and tyurkyanskaya regressions, which separate the major macrotransgressions of the Caspian—the akchagyl'skaya, apsheronskaya, and kaspiiskaya (Pleistocene). The singil'skaya, atel'skaya, and mangyshlakskaya regressions, which separate the Caspian water bodies in Pleistocene—bakinskii, khazarskii, khvalynskii, and novokaspiiskii basins—show less considerable rythmics. The periods of existence of those water bodies featured regressive rythmics of smaller scale and shorter periods, including venedskaya, chernoyarskaya, enotaevskaya, and izerbashskaya with level drops of a few tens of meters, drying of the upper part of the shelf, and stadial separation of transgressions.

Sea level drop and drying of vast seabed areas had different depth, duration, and drying area. Signs of level drop can be seen in the elements of underwater relief (accumulative and abrasion forms), lithofacial composition of bottom sediments—an increase in the concentrations of coastal beach facies and their coarseness, the wide occurrence of subaeral (eolian) and aqueous terrestrial (lacustrine, alluvial) formations, the presence of signs of soil formatioin, changes in the composition of biological complexes (mollusks and microfauna, diatoms, etc.).

The deepest drops of the Caspian level, reaching 100–120 m and more, took place in the tyurkanskaya, atel'skaya, and mangyshlakskaya periods, when the Caspian shelf may have dried, and the area of persisting water bodies decreased to 200 thous. km^2. A relatively small drop in the Caspian level (10–30 m) took place during the short chernoyarskaya regression and the long domashkinskaya period. Its regressive state was reliably established only for the marginal parts of the boundary akchagal–apsheronskii water body (the Middle Volga and areas west of the Urals and the Aral Sea, etc.).

In regression periods, the Caspian level varied mostly between –30 and –50 m abs. elevation, rarely falling below –100 m. Transgression periods in the basin were commonly 3–4 times longer than regression periods. This can be derived from both geochronological data and from the analysis of the thickness of ancient Caspian deposits. The total thickness of ancient Caspian deposits in tectonic depressions of Western Tukmenia and Azerbaijan may exceed 1000 m. The results of elementary calculation of their formation time, corrected with the use of data of modern sedimentation in the Caspian suggest that the accumulation of deposits continued for the major portion of Pleistocene.

In regression periods, changes were taking place in the salinity of GC and its temperature regime, which caused changes in the fauna. Small freshening was common with salinity drops not exceeding a few parts per thousand. Such changes in mineralization can be different in different parts of the basin. Thus, the salinity in the Northern Caspian depends on water exchanges with the Middle Caspian and from the runoff of the Volga and other rivers. In regression periods, this exchange was minimal, which, in combination with river inflow, caused water freshening in the Northern Caspian by the runoff of the Volga and other rivers.

Changes in the salinity in transgression–regression periods in the Middle and Southern Caspian were insignificant (within a few parts per thousand), and the salinity was close to that in the modern Caspian (~13‰). Those parts of the sea also showed a small increase in the salinity, which may be due to the effect of evaporation and the absence of runoff into Kara Bogaz Gol bay [29]; this could also be caused by climate warming in this part of the Caspian region.

The temperature regime of water bodies became less contrast and more warm because of a considerable drop of their area, mostly due to their northern parts.

The periods of low level in the Caspian are periods of considerable changes in its benthos, in particular, mollusk complex. Thus, during the domashkinskaya regression, caused by the cessation of the input of seawater, the akchagylskaya fauna died out while freshwater mollusks (Limnaea, Streptocerella, Theodoxus, Dreissena, Corbicula) and first apsheron forms tolerant to freshening (Apsheronia, Monodacna) became widespread. The apsheronskaya fauna disappears in the tyurkanskaya period, and rare Caspian didacnas appear in the end of this period.

The regression periods of the Pleistocene Caspian show incessant changes of the complexes of catilloid, crassoid, and trigonoid didacnas [38]. Appreciable changes were found in the microfauna and diatom flora. Two regression phases were identified in the Late Holocene in core samples from Krasnovodskii Bay by the ratio of three species of foraminifera–elphidides (Elphidium shochinae, E. caspinus, and Mayrella brotzkajae) [30]. Three diatom complexes were determined in wells from the Northern Caspian, showing beds of freshened deposits in the section [9].

In regression periods, the dried areas showed a complete change of landscapes, major relief-formation and sedimentation processes, which was most significant on the vast dried area of the Northern Caspian and the nearby dried lowland areas. Here, the aqual landscape of Caspian shallows was replaced by vast lowland dry semidesert steppes, cut by river valleys. Sea level drop caused erosion incision, elongation of major river valleys, and active protrusion of deltas. Eolian relief forms became widespread on flat water divides. The narrow dried shelf of Caspian depressions showed active formation of the relief of denudation plains with systems of ridge and step-wise forms of erosion and abrasion origin, cut by a series of deep watercourses, relating to the low level of the Caspian. The talassogenous factors of relief formation, associated with seawater dynamics, persisted on the still submerged parts of the shelf, and the active formation of barrier bars, bench, and abrasion and accumulation terraces continued in the surf zone.

Continental sediments of variegated facial composition were accumulating on the dried shallow areas. Eolian, lacustrine–floodplain, lacustrine–lagoon, and channel deposits were found in the Northern Caspian. Eolian sediments are represented by quartz–feldspar sands with traces of wind sorting; lacustrine–floodplain sediments, by variegated aleurites with hydrogen sulfide odor; lacustrine–lagoon, by hydromicaceous–chlorite clays with gypsums, calcite, and dolomite; and channel facies, by sands of quartz-glauconite composition. Unlike marine montmorillonite clays, the clay composition of continental facies of the shelf is different: here, alluvial deposits accumulated hydromica, caolinite, and halloysite; while lacustrine and eolian deposits, montmorillonite, palygorskite, and chlorite. The top of the deposits, which were long subject to exogenous impact, show signs of various soil formation processes. Eolian accumulations dominate among terrestrial deposits of the eastern and southern shelves and dried coasts.

Regression marine sediments on the shelf, unlike the transgression deposits overlying and underlying them, are coarser and reflect the dynamic conditions of their accumulation in the shallower sea.

Various climatic events took place in the periods of regressions in the Caspian domain and nearby glacial regions of the East European Plain. The available documentary material is yet not enough for detail correction of the climate history of those regions in Late Pleistocene–Middle Pleistocene. It can be supposed that, on a large scale, the main regression periods coincided with interglacial periods in the northern and central East European Plain (petropavlovskoe, likhvinskoe, mikulinskoe, and Holocene). However, this explanation is not exhaustive, at least because the number of regression rhythms of the Caspian known by now is less than the number of glacial–interglacial periods on the East European Plain. A series of successive large-scale natural events, which coincided with the glacial rhythms of the East European Plain, were established on the Caspian shelf in the period of the most recent glacial cycle (Late Wurm, Late Valdai, 23–10 thous. years ago). In the first half of the late glacial period, atel'skaya regression took place on the Caspian, whose shelf fully lied within the zone of subaerial processes; hence, it was completely dried. The end of the regression coincided with the maximal (ostashkovskaya) stage of glaciations in the East European Plain with extremely severe continental climate. Judging by radiocarbon data, the enotevskaya regression (9.5–8.6 thous. years ago) coincides with cold epochs of the early Holocene on the East European Plain; while the mangyshlakskaya and izerbashskaya regressions coincide with warm atlantic and cool subboreal periods of Holocene, respectively.

It appears obvious that the modern Caspian Sea is a water body at a regression stage. Its beginning refers to the second half of the khvalynskaya period, the very end of the Pleictocene–Late Holocene, when the retreating sea passed through the zero absolute elevatioin. In this case, the total drop of the Holocene level was complicated by rises of low hierarchic states (oscillations, convulsions). At the same time, the Great Caspian as a whole shows higher sea level standing. The time ratios of transgressions and regressions of the Caspian can be expressed as 3 : 1 or 4 : 1.

CONCLUSIONS

The history of the Great Caspian shows various level variations, where, parallel to long transgressions, various-scale regressions took place, including balakhanskaya, domashkinskaya, tyurkanskaya, venedskaya, chernoyarskaya, atel'skaya, enotaevskaya, mangyshlakskaya, and izerbashskaya. The largest among them are the balakhanskaya, domashkinskaya, and tyurkanskaya, which separate the major Caspian transgressions—ackhagylskaya, apsheronskaya, and kaspiiskaya. During the regression periods of the Great Caspian, large-scale natural processes were taking place on its shelf, coasts, and nearby inundate areas; these included sea level drop and drying of vast seabed areas, changes of landscapes and processes of relief-formation and sedimentation; the remaining water areas showed shallowing, changes of water salt composition, and the inhabiting fauna.

Various climate events took place during regressions on nearby continental territories; the main regression periods can be supposed to coincide with interglacial periods of the northern and central East European Plain.

A relic of the Great Caspian—the modern Caspian Sea—is in a regression state, complicated by a small level rise.

ACKNOWLEDGMENTS

The author is grateful to L.M. Shipilova, R.R. Makshaev, and E.E. Taldenkova (Moscow State University) for their help in the preparation of this article.

This study was supported by the Russian Foundation for Basic Research, project nos. 13-05-00086, 13-05-00625, 14-05-00227.

REFERENCES

1. Ali-Zade, A.A., *Akchagyl Turkmenistana* (Akchagyl Period in Turkmenistan), Moscow: Gos. nauch.-tekhn. izd-vo lit. po geologii i okhrane nedr, 1961, vol. 1.
2. Ali-Zade, K.L., Vekilov, V.G., Asadullaev, E.M., et al., Stratigraphy of marine anthropogenic (Quaternary) deposits in Azerbaijan, in *Geologiya chetvertichnogo perioda* (Quaternary Geology), Yerevan: Izd. AN SSSR, 1977, pp. 61–67.
3. Andrusov, N.I., Development history of the Caspian Sea and its inhabitats, *Izv. RGO*, 1888, vol. 24, nos. 1–2, pp. 91–114.
4. Bludorova, E.A., Vasil'ev, Yu.M., Zhidovinov, N.Ya., et al., Apsheron period of East European Plain, *Byul. Komis. Izuch. Chetv. Per.*, 1983, no. 52, pp. 3–16.
5. Varushchenko, S.I., Varushchenko, A.R., and Klige, R.K., *Izmenenie rezhima Kaspiiskogo morya v besstochnykh vodoemakh v paleovremeni* (Variations of Caspian Sea Regime in Drainless Water Bodies in Paleotime), Moscow: Nauka, 1987.
6. Vronskii, V.A., Paleoclimates of USSR southern seas in the Holocene (based on palinological data), in *Paleoklimaty Golotsena Evropy i territorii SSSR* (Holocene Paleoclimates in Europe and the USSR), 1988, pp. 150–157.
7. Goretskii, G.I., *Formirovanie doliny r. Volga v rannem i srednem antropogene* (Volga Valley Formation in the Early and Middle Anthropogene), Moscow: Nauka, 1966.
8. Gurarii, G.Z., Alekseev, M.N., and Vangengeim, E.M., *Skhema korrelyatsii antropogenovykh otlozhenii Severnoi Evrazii* (Scheme of Correlation of Anthropogene Deposits in Northern Eurasia), Moscow: Nauka, 1965.
9. Zhakovshchikova, T.K., Diatom algae in core samples from Caspian bottom deposits, *Dokl. Akad. Nauk SSSR*, 1970, vol. 190, no. 4, pp. 915–918.
10. Zhidovinov, N.Ya., Sedaikin, V.N., Troyanovskii, S.V., et al., Results of studying Neogene and Quaternary deposits in Astrakhan Parametric Well, in *Pliotsen i pleistotsen Volgo-Ural'skoi oblasti* (Pliocene and Pleistocene of the Volga–Ural History of the Caspian Depression), Moscow: Nauka, 1981, pp. 123–127.
11. Zhukov, M.M., Pliocene and Quaternary history of the Caspian Depression, in *Problemy Zap. Kazakhstana* (Problems of Western Kazakhstan), Moscow, 1945, vol. 2.
12. Zubakov, V.A. and Kochegura, V.V., Chronology of the recent stage of USSR geological history, in *Khronologiya pleistotsena i klimatologicheskaya stratigrafiya* (Pleistocene Chronology and Climatological Stratigraphy), Leningrad: VGO, 1973, pp. 15–27.

13. Karpychev, Yu.A., Radiocarbon dating of regressive stages of the Caspian Sea, *Water Resour.*, 1998, vol. 25, no. 3, pp. 249–253.

14. Kovalevskii, S.A., Great Akchagyl transgression and its contribution to the formation of production strata, *Izv. Az FAN SSSR*, 1944, no. 5, pp. 53–64.

15. Leont'ev, O.K. and Fedorov, I.A., History of the Caspian Sea in Late and Post-Kvalynian Time, *Izv. Akad. Nauk SSSR, Ser. Geogr.*, 1953, vol. 4, pp. 64–74.

16. Lokhin, M.Yu. and Maev, E.G., Late Pleistocene deltas on the shelf of the northern Middle Caspian, *Vestn. Mosk. Univ., Ser. 5, Geogr.*, 1990, no. 3, pp. 34–39.

17. Maev, E.G., Caspian Sea Regressions, *Geomorfologiya*, 1994, no. 2, pp. 94–101.

18. Mal'gina, E.A., Paleogeographic conditions in Western Turkmenia in Late Pleistocene and Early Quaternary (by data of spore–pollen analysis), *Extended Abstract of Cand. Sci. (Geol.-Miner.) Dissertation*, Moscow: IG AN SSSR, 1964.

19. Menabde, I.V., Svitoch, A.A., and Yanina, T.A., Changes in Caspian Sea salinity in the Pleistocene, *Vodn. Resur.*, 1992, no. 5, pp. 57–69.

20. Milanovskii, E.E., Paleogeography of the Caspian Basin in the middle and early Late Pleistocene (balakhanskii and akchygal'skii periods), *Byul. MOIP., Otd. Geol.,* 1963, vol. 38, no. 3, pp. 77–86.

21. Molod'kov, A.N. and Bolikhovskaya, N.S., Climate–chronostratigraphic scheme of Neopleistocene in Northern Eurasia, in *Problemy paleogeografii i stratigrafii pleistotsena* (Problems of Paleogeography and Stratigraphy of Pleistocene), no. 3, Moscow: Rossel'khozakademiya, 2011, pp. 44–77.

22. Moskvitin, A.I., Pleistocene of the Lower Volga Region, in *Tr. Geol. Inst. AN SSSR* (Trans. Geol. Inst. USSR AS), Moscow: Izd. AN SSSR, 1962, issue 64.

23. Musatov, V.A., Ancient shorelines on the shelf of Dagestan coast of the Caspian, in *Kolebaniya uvlazhnennosti Aralo-Kaspiiskogo regiona v golotsene* (Moistening Variations in Aral–Caspian Region in Holocene), Moscow: Nauka, 1980, pp. 45–52.

24. Naidin, D.P. and Naidina, O.D., On the so-called Great Akchagyl Transgression, *Izv. Vysshikh ucheb. zavedenii. Geologiya i razvedka*, 1992, no. 6, pp. 3–18.

25. Nevesskaya, L.A. and Trubikhin, V.M., History of the Caspian Basin and its mollusk fauna in Late Pliocene and Early Pleistocene, in *Antropogen Evrazii* (Eurasian Anthropogene), Moscow: Nauka, 1984, pp. 19–27.

26. Pravoslavlev, P.A., Materials for studying Lower Volga deposits, *Izv. Varshavskogo Univ.*, 1908, no. 2.

27. Putans, V.A., Sedimentary waves on the western slope of Derbent depression of the Caspian Sea, *Byull. MOIP*, 2012, vol. 87, no. 4, pp. 20–31.

28. Rikhter, V.G., New data on the ancient shorelines on the Caspian bed, *Izv. Akad. Nauk SSSR, Ser. Geol.*, 1954, no. 5, pp. 57–63.

29. Rychagov, G.I., *Pleistotsenovaya istoriya Kaspiiskogo morya* (Pleistocene history of the Caspian Sea), Moscow: Izd. MGU, 1997.

30. Svitoch, A.A., Caspian level variations in the Pleistocene (classification and a systematic description), in *Kaspiiskoe more: paleogeografiya i geomorfologiya* (Caspian Sea: Paleogeography and Geomorphology), Moscow: Nauka, 1991, pp. 5–100.

31. Svitoch, A.A. and Yanina, T.A., *Chetvertichnye otlozheniya poberezhii Kaspiiskogo morya* (Quaternary Deposits on Caspian Coasts), Moscow: RASKhN, 1997.

32. Sidnev, A.V., *Istoriya razvitiya geograficheskoi seti v Predural'e* (Development History of the Geographic Network West of the Urals), Moscow: Nauka, 1985.

33. Staroverov, V.N., Facial models and paleogeography of Pliocene in southeastern Russian Plate, *Extended Abstract of Cand. Sci. (Geol.-Miner.) Dissertation*, Voronezh: Voronezh. State Univ., 2005.

34. Trubikhin, V.M., *Paleomagnetizm i stratigrafiya akchagyl'skikh otlozhenii Zapadnoi Turkmenii* (Paleomagnetism and Stratigraphy of Akchagyl'skie Deposits in Western Turkmenia), Moscow: Nauka, 1977.

35. Fedorov, P.V., Stratigraphy of the Quaternary deposits and development history of the Caspian Sea, *Tr. Geologich. Inst. AN SSSR*, 1957, no. 10.

36. Filippova, N.Yu., *Palinologiya verkhnego pliotsena - srednego pleistotsena yuga Kaspiiskoi oblasti* (Palinology of the Upper Pliocene–Middle Pleistocene of the Southern Caspian Region), Moscow: GEOS, 1997.

37. Shnitnikov, A.A., *Zakonomernosti kolebaniya urovnya Kaspiiskogo morya v svyazi s izmenchivost'yu uvlazhneniya materikov Severnogo polushariya* (Regularities in Caspian Level Variations in the Context of Moistening of Continents of the Northern Hemisphere), Moscow: Izd. AN SSSR, 1957.

38. Yanina, T.A., *Didakny Ponto-Kaspiya* (Didacnas of Pont–Caspian), Smolensk: Madzhenta, 2005.

39. Aladin, N.V. and Plotnicov, I.S., *Radiocarbon Dating of Regressive Stages of the Caspian Sea ow changing of the Caspian Sea level makes influence on biodiversity of fishes and free-living aquatic invertebrates*, 4th Int. Conf. UNESCO Programme 481 Dating "Caspian Sea Level Change," Almaty, 2006, pp. 15–16.

40. Kroonenberg, S.B. and Hoogendorn, M.B., Field excursion Volga delta, *Field Excursion Volga Delta. An Analoque for Paleo-Volga Deposits*, Delft: University of Delft, 2008, pp. 1–39.

Translated by G. Krichevets