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GEOGRAPHY

Holocene Marine Sediments on the Iranian Coast of the Caspian Sea

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Holocene marine sediments on the Iranian coast of the Caspian Sea are poorly studied. Descriptions of reference sections and their biostratigraphic substantiation are lacking in Russian publications. Owing to the kind assistance of organizing bodies of the International Conference "Rapid Sea Level Change: A Caspian Perspective" (Resht, May 2005) and our Iranian colleagues, we had the opportunity to visit and examine several sections of the Neocaspian sediments. We were also able to take several samples of molluscan shells. They were subsequently classified and dated by the radiocarbon method.

The Iranian coast extends over more than 600 km along the South Caspian Lowland and includes the western Gilyan, central Mazandar, and eastern Golestan segments. The lowland is bordered by the Elburz mountains to the south. The lowland is filled with several hundred meters of loose Upper Pliocene–Pleistocene sands and pebbles derived from the Elburz Mountains. Its surface is covered by flat terraces slightly inclined toward the seashore. The lowest terrace (0.3–1.5 km wide), separated from the sea by the present-day beach, is from the Holocene [1, 2]. The terrace includes accumulative levels at approximately 1–2 (terrace recorded in 1929), 4, and 6 m. In the western and eastern segments of the coast, the terrace represents extended sandbars that separate large lagoons, such as Lake Anzali and Gorgan Bay, from the sea. In the central segment of the coast, the Neocaspian terrace separates from the Caspian Sea a spacious accumulative plain (from –23 to –16 m) composed of different terrestrial and aqueous sediments. According to [1], the Neocaspian terrace is a coastal bar formed by the transverse displacement of marine sediments that border the swampy part of the South Caspian Lowland in the south.

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The examined sections characterize the structure of different Holocene terraces and provide information on their formation history.

The rear (lagoonal) section of the Holocene sandbar (0.2–0.5 km wide), which separates Lake Anzali from the Caspian Sea in the Sangashin area (Fig. 1, point 1), consists of the following beds exposed in the channel wall (Fig. 2a):

(1) Dark gray to gray, inequigranular, largely coarse-grained sand with an abundance of variably rounded pebbles and gravel in some beds. The fine-grained brown sand in the upper part of the bed contains traces of soil formation. The base of the bed includes a coquina lens composed of dominant *Cerastoderma glaucum* Poir. (frequently represented by intact shells) and subordinate *Didacna pyrmidata* Grimm. and *D. crassa* Eichw. Some shells of these species are found in the entire bed. The lower boundary is lithologically sharp and uneven. The thickness is 1.7 m. These marine sediments with their upper part subjected to soil-forming processes accumulated in dynamic beach settings.

(2) Brown-gray, dark gray, and yellow-brown, fine-grained sand with small ferruginated spots developed after fossil plant remains. The thickness is 0.1 m. The lower boundary is uneven. The bed represents lagoonal sediments reworked by hydromorphic soil-forming processes.

(3) Brown coquina with fine-grained cement and ferruginated spots. The molluscan assemblage consists of dominant *Dreissena polymorpha* Pall., common *Cerastoderma glaucum* Poir., subordinate dwarfish *Didacna crassa* Eichw., *Monodacna caspia* Eichw., and *Theodoxus pallasi* Grimm. The thickness is 0.1 m. The lower boundary of the bed is uneven. The coquina represents sediments of a shallow freshened well-heated lagoon intermittently connected with the sea. *Cerastoderma glaucum* shells yielded a radiocarbon age of 570 ± 50 yr (GIN-13294).

(4) Dark gray, inequigranular, largely medium- to fine-grained sand with ferruginated spots in the upper

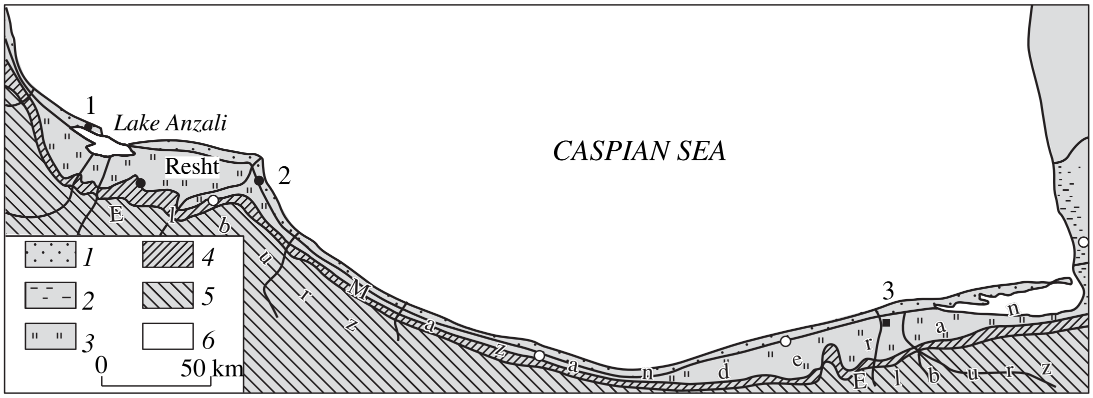

Fig. 1. Location of Holocene sections on the Iranian coast of the Caspian Sea.
(*1*) Neocaspian terrace with the present-day beach; (*2*) drained shores; (*3*) late Khvalynian fluvial–proluvial–marine plain; (*4*) piedmonts dominated by early Khvalynian terraces; (*5*) mountainous relief; (*6*) examined sections.

(a)

Column	Bed	Thickness, m	Species	Date, yr.	Sedimentation cycles	Genesis of sediments
	1	1.7	*Cerastoderma glaucum* *Didacna pyramidata* *D. crassa* ***Cerastoderma glaucum***		I	Marine sediments of deep beach subjected to soil-forming processes
	2	0.1			II	Lagoonal sediments with evidence of hydromorphic soil formation
	3	0.1	***Dreissena polymorpha***, *Cerastoderma glaucum, Didacna crassa, Monodacna caspia, Theodoxus pallasi*	570±50		Sediments of shallow freshened l agoonal settings with intermittent seawater influx
	4	1.5			III	Coastal-marine sediments

(б)

Column	Bed	Thickness, m	Species	Sedimentation cycles	Genesis of sediments
	1	1.0		I	Coastal-marine sediments of dynamic settings
	2	3.0	*Cerastoderma glaucum*	III	

(г)

Column	Bed	Thickness, m	Species	Genesis of sediments
	1	0.8		Sediments of freshwater settings (floods, channels, and others) differently reworked by soil-forming processes
	2	0.6	*Valvata sp., Limnea sp.*	
	3	0.1		
	4	0.3		
	5	0.5	*Valvata sp.*	
	6	0.8		
	7	0.6		
	8	0.7		

(в)

Column	Bed	Thickness, m	Species	Date, yr.	Genesis of sediments
	1	1.0	*Cerastoderma glaucum* *Didacna crassa* *D. pyramidata,* *D. trigonoides,* *Adacna laeviuscula*	340±60	Marine shallow-water sediments

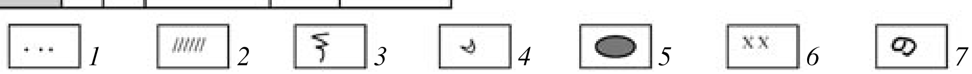

Fig. 2. Holocene sections. (*1*) Sand; (*2*) sandy loam; (*3*) recent soil; (*4*) Caspian molluscan shells; (*5*) pebble and gravel; (*6*) fossil soil; (*7*) shells of freshwater mollusks.

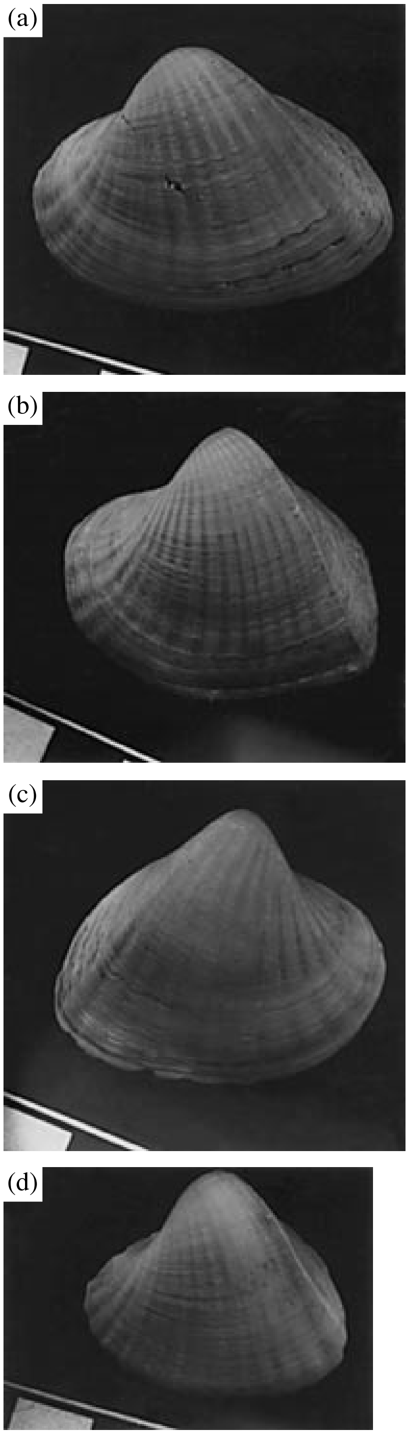

Fig. 3. *Didacna* species from Neocaspian sediments on the Iranian coast of the Caspian Sea. (a) *Didacna crassa*; (b) *D. praetrigonoides*; (c) *D. trigonoides*; (d) *D. pyramidata*.

part of the bed and an admixture of gravel and rare pebble, which forms an interbed at the base. The thickness is 1.5 m. The sediments are coastal-marine in origin.

The section structure implies that the rear part of the Holocene sandbar is composed of sediments accumulated during three sedimentation cycles. The upper (bed 1) and lower (bed 4) cycles are coastal-marine sediments accumulated in settings with normal Caspian salinity (12–13‰). This is evident from the prevalence of *Cerastoderma glaucum*. The beds are separated by sediments formed in a lagoon with intermittently freshened (co-occurrence of marine euryhaline, as well as brackish and freshwater molluscan species) and desiccated (signs of hydromorphic soil formation) environments.

The northern quarry demonstrates the maritime part of the sandbar composed of the following beds (Fig. 2b, from top to bottom):

(1) Gray to dark gray, inequigranular, mostly medium-grained sand with horizontal intercalations of fine- or coarse-grained sand and signs of soil formation in its uppermost part. The thickness is 1.0 m. Transition to underlying sediments is gradual.

(2) Inequigranular, largely coarse-grained, oblique- and cross-bedded sand with the beds inclined toward the rear part of the sandbar. The bed contains numerous pebbles of different sizes and rare fragments of *Cerastoderma glaucum* Poir. shells. The thickness is 3.0 m.

In contrast to the previous exposure, the quarry section includes two members of coarse-grained sediments accumulated in dynamic coastal settings. They probably correspond to the first and third cycles of the rear part of the sandbar. Lagoonal sediments of the second cycle are missing. It is remarkable that sediments of the present-day beach are finer-grained as compared with pebbly sediments exposed in the quarry. The well-sorted fine-grained sand includes the dominant *Cerastoderma glaucum* Poir. and the rare fragile *Adacna vitrea* Eichw. and *Ad. laeviuscula* Eichw. This suggests substantially more dynamic and deeper sedimentation settings.

The prospect hole in the Sefidrud River delta recovered a section of the Neocaspian terrace (Fig. 1, point 2; Fig. 2c) composed of gray to dark gray well-sorted fine-grained and horizontally laminated sand with signs of soil formation. These marine shallow-water sediments yield abundant *Cerastoderma glaucum* Poir., *Didacna crassa* Eichw. accompanied by rarer *D. pyramidata* (Grimm.), *D. trigonoides* Pall., and occasional *Adacna laeviuscula* Eichw. The thickness is 1.0 m. The radiocarbon age of *Cerastoderma* shells is estimated at 340 ± 60 yr (GIN-1395).

The section of the low maritime lowland separated from the sea by the sandbar (Fig. 1, point 3; Fig. 2d) is exposed in the channel wall (from top to bottom):

(1) Pale yellow to gray sandy loam with vague signs of soil formation at the top and sharp lower boundary. The bed represents flood warp. The thickness is 0.8 m.

(2) Dark brown compact sandy loam with rare small freshwater gastropods *Valvata* sp. (dominant) and *Limnaea* sp. (occasional), signs of hydromorphic soil formation as a bluish gray interbed in the middle part, and uneven lower boundary. The thickness is 0.6 m.

(3) Dark gray to black sandy loam with small gastropod shells and gradual lower boundary. The bed represents hydromorphic soil. The thickness is 0.1 m.

(4) Gray-brown muddy compact sandy loam with ferruginated incrustation and sharp lower boundary. The thickness is 0.3 m.

(5) Dark gray to black (in the upper part) and gray to brown-gray (in the lower part) muddy, locally enriched in sand sandy loam with numerous small *Valvata* sp. shells and gradual lower boundary. Buried automorphic (?) soil. The thickness is 0.2 m.

(6) Brown-gray muddy and sandy loam with ferruginated spots and sharp lower boundary. The thickness is 0.8 m.

(7) Laminated sandy loam with intercalations of gray-yellow sand and gradual transition to underlying sediments. The thickness is 0.6 m.

(8) Yellow-brown (bluish gray at the base) sandy loam with small gastropod shells in the upper part. The apparent thickness is 0.7 m.

According to the Iranian geologists who guided the excursion, *Didacna* shells from sediments located below the present-day brink yielded a radiocarbon age of approximately 2500 yr. The exposed sediments constitute a relatively thick (6 m) sequence of diverse subaerial sediments deposited in river floods, channels, and freshwater lagoons and lakes subsequently reworked to a variable extent by soil-forming processes. This is evident from the development of three or four soil horizons. The exposed part of the section lacks marine and channel sediments. It demonstrates a transition from marine (below the brink) and lagoonal–lacustrine sedimentation to intermittent sedimentation in flood settings with periodic draining and reworking of the uppermost parts of the beds by soil-forming processes. Judging from traces of soil formation, the most prolonged draining corresponded to deposition of beds 2 and 5. As a whole, the section is characterized by high sedimentation rates (approximately 0.5 cm/yr). The Iranian researchers also noted high Holocene sedimentation rates (2–8 mm/yr) [2].

The analysis of exposed sections allows us to draw the following conclusions:

(1) Holocene sections in the coastal part of the South Caspian Lowland can be divided into three types corresponding to different geomorphologic elements of the coeval surface: sandbars, Neocaspian terrace, and wash lowland plain. The sediments constituting the sandbar, which separates Lake Anzali from the Caspian Sea, are represented by two beds of marine sediments divided by lagoonal sediments in the rear part of the sandbar. The terrace that separates the lowland plain from the sea is entirely composed of marine sediments, while the surficial part of the southern wash plain consists of subaerial sediments with traces of hydromorphic soil formation. The first two types of Holocene marine sections are also observed in other areas of the Caspian Sea coast (particularly in the Dagestan coast), which are geomorphologically similar to the Iranian segment. The third type (marine terrace), which borders the spacious lowland plain of sediments derived from the Elburz, is developed only on the Iranian coast of the Caspian Sea.

(2) If radiocarbon dates are correct, the exposed Holocene sediments are very young and belong to one of the last positive oscillations of the Neocaspian transgression. If we take into consideration the radiocarbon dating obtained for the lowland plain section, it is conceivable that ages based on *Cerastoderma glaucum* shells are substantially younger and relevant sediments can be referred to the Neocaspian transgression maximum (Turalin phase).

(3) Relative to coeval counterparts in other areas of the Caspian coast (Fig. 3), the Neocaspian molluscan assemblages are characterized by the dominant role of not only the Black Sea invader *Cerastoderma glaucum* but also crassoid *Didacna* species and a low share of slightly brackish water forms.

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