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GEOLOGY

New Data on Bottom Geomorphology of the Sea of Azov

Academician of the RAS G. G. Matishov

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In marine basins, sedimentation and zoobenthos distribution are determined by their bottom topography and bathymetry [1. 3, 4]. Only general information is available for shelf geomorphology of the Sea of Azov. Because of the absence of detailed bathymetric maps (with isobaths of 1 or 0.5 m), the analysis of recent sediments and benthic communities was carried out without the consideration of bottom topography, resulting in distortion of real sedimentation patterns [5–7]. In this connection, the Azov Branch of the Murmansk Marine Biological Institute (Kola Scientific Center) and Southern Scientific Center of the Russian Academy of Sciences carried out detailed investigations of the bottom topography and sediments in the Sea of Azov.

These works resulted in the compilation of 20 large-scale bathymetric maps. They are based on our geomorphological materials and navigation maps. In all these maps, bathymetry is shown with a spacing of 1 m, and some areas are outlined with a spacing of 0.5 m (Fig. 1). The locations of echo sounding profiles and sampling sites are based on GPS measurements.

Sampling of bottom loose sediments at the shelf of the Sea of Azov was strictly correlated with its bottom topography. They were sampled by the 2-m-long gravity corer and van-Veen grab sampler. The samples were divided into the following grain size fractions (mm): sand (1.0–0.5, 0.5–0.25, 0.25–0.1), silt (0.1–0.05, 0.05–0.01), and pelite (0.01–0.005, 0.005–0.001). Sediments with a <0.01-mm-fraction content exceeding 70–90% were attributed to the clayey mud type.

The Sea of Azov is a shallow shelf basin of the estuarine type. Steep shores (up to 10–25 m high) separate the shelf from Chernozem steppe plains with its semi-arid climate. The inner Sea of Azov shelf is outlined by the 10-m isobath (Fig. 2). As is known, sand spits, nehrungs, bars, deltas, estuaries, and bights are widespread in this zone with high-energy hydrodynamics [2]. Large spits composed of quartz sand and coquina detritus are represented by structures of the Azov type: the Biryuch'ya (including the Fedot'eva Spit and Biryuchii Island), Obitochnaya, Berdyanskaya, Belosaraiskaya, Krivaya, and Begletskaya spits. Their length decreases successively from 40 to 30, 18, 13, 6, and 4 km with decreasing fetch of eastern waves. The Yasenskii, Temryukskii, Kazantinskii, Arabatskii. Obitochnyi, Berdyanskii, and Belosaraiskii (including the Taran'ya Bight) bays with depths ranging from 6 to 10 m are located between spits and cusps.

The spits of the eastern coast (Pavlochakovskaya, Chumburskaya, Dolgaya or Dolzhanskaya, and Kamyshevatskaya) are shorter (3, 4, 14, and 7 km, respectively). All of them are composed of coastal bars successively adjoining the shore. The spits are almost entirely composed of coquina material dominated by fragments of *Cardium edule* shells. All these coastal structures are usually low (1.0–1.5 masl) with separate areas of the Eiskaya and Pavlochakovskaya spits being 2.0–2.5 m high.

Narrow nehrungs separate from the sea a system of estuaries located along the eastern (Akhtanizovskii, Kurchanskii, Akhtarskii, Beisugskii, and Eiskii) and northern (Miusskii, Molochnyi, and Utlyukskii) coasts. The length of estuaries varies from 20 to 40 km. Water depth in these estuaries along their deepest axial parts ranges from 1.5 to 3.5 m. They are connected with the sea via relatively deep (4–9 m) channels (straits). The Beisugskii Estuary is connected with the sea through a narrow strait in the Yasenskaya Nehrung.

A spacious depression in the Taganrogskii Bay is located west of the Don River delta (Figs. 3, 4). The area between Zaimo-Obryv and Pavlo-Ochakovo is occupied by a flat depression (1.5–2.7 m deep and 2–4 km wide) that extends along the shoreline and joins the Kagal'nik River mouth (Fig. 3). The underwater part of the Don River prodelta hosts numerous flooded chan-

Southern Scientific Center, Russian Academy of Sciences, Rostov-on-Don, Russia

Murmansk Marine Biological Institute, Kola Scientific Center, Russian Academy of Sciences, ul. Vladimirskaya 17, Murmansk, 183010 Russia; e-mail: matishov@mmbi.info

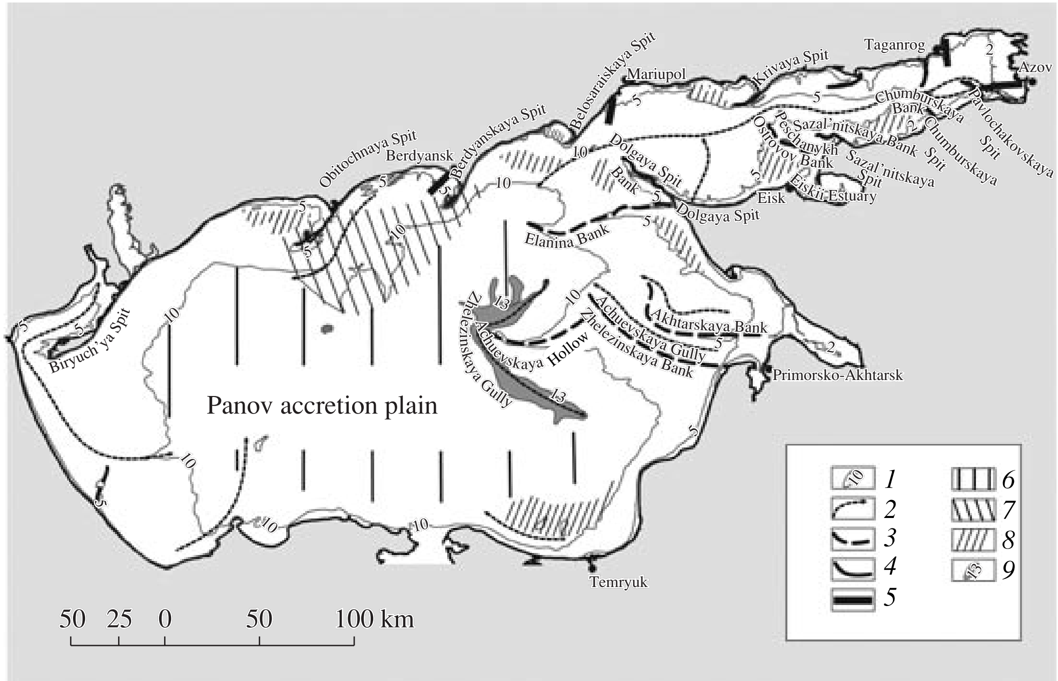

Fig. 1. Major geomorphological elements of the Sea of Azov shelf. (*1*) Isobaths 2, 5, 10, and 13 m; (*2*) large gullies and depressions; (*3*) large ridges and hills; (*4*) sandy ridges (underwater continuations of spits); (*5*) artificial navigable canals; (*6*) accumulation (clayey–muddy) plain; (*7*) development zone of swells and ridges; (*8*) abrasion (abrasion–accumulation) terraces; (*9*) deep area of the shelf (13.0–13.5 m).

nels with bottom sediments containing hydrotroillite. All these channels are connected with river delta valleys and are approximately 1–2 m deep. In a narrow (up to 3 m) zone extending along the Don River delta, bottom sediments have a specific odor of hydrogen sulfide, which suppresses zoobenthos activity.

A flat-slope depression extending along the axial part of the Taganrogskii Bay is its most remarkable geomorphologic element. The bay bottom is slightly inclined toward the depression. Small flat depressions extend from the south coast. The axial flat depression extends from the Don River prodelta for 150 km up to the Panov underwater plain in the open part of the Sea of Azov (Figs. 1, 2). The depth of the axial depression increases southwestward from 5 to 10 m. This depression is characterized by one of the lowest sedimentation levels in the Azov shelf. It is conceivable that this area corresponds to the Don River paleochannel formed during the Late Quaternary regression.

It is remarkable that the Dolgaya, Sazal'ninskaya, Dolgen'kaya, Chumburskaya, Pavlochakovskaya, Petrushina, and Begletskaya spits continue seaward to the Taganrogskii Bay. Their continuations extend for 8–11 to 20 km as loop-shaped shoals oriented along the direction of tidal currents. The shoals are longer as compared with the parental spits. These relatively narrow (up to 1–2 km) accumulative swells formed at depths of 3–5 m. The underwater parts of the spits are composed of sandy and sandy–coquina material. These shoals are 0.5 to 1.5 m deep. The underwater swell of the Pavlochakovskaya Spit extends northward for 9 km. It is cut by the Azov–Don navigable canal (70–80 m wide and 5 m deep) approximately in the middle zone.

Northwest of Shabel'skii and Eisk, the spacious shoal (up to 35 km across and 5–6 m deep) incorporates two extended morphological structures (Sazal'nikskaya and Peschanykh Ostrovov shoals). Water depth above these structures ranges from 0.2–0.8 to 1–2 m. The Peschanykh Ostrovov shoal outlined by the 4-m isobath extends westward for 22 km (Fig. 3). The flat underwater Peschanykh Ostrovov swell is isolated from coastal cusps.

The longest Dolgaya Spit is outlined by the isobath of 1–2 m. The width of this spit decreases from 6 to 2 km in the northwest direction. Its flat shoal incorporates a number of sandy islands. The total length of the spit–underwater shoal exceeds 60 km. This accumulative structure is supplied with sediments delivered from both sides under the influence of two systems of wave currents probably characterized by equal energy and recurrence frequency. The Dolgaya Spit separates the Taganrogskii Bay from the major part of the sea (Fig. 3).

The 100-km-wide coastal shelf, which is located west of Primorsko-Akhtarsk, and the Dolzhanskaya Spit is characterized by several remarkable geomorphological features. It hosts numerous large underwater swells approximately 35–40 km long. The Elenenin, Zhelezinskaya, Akhtarskaya, and Achuevskaya banks

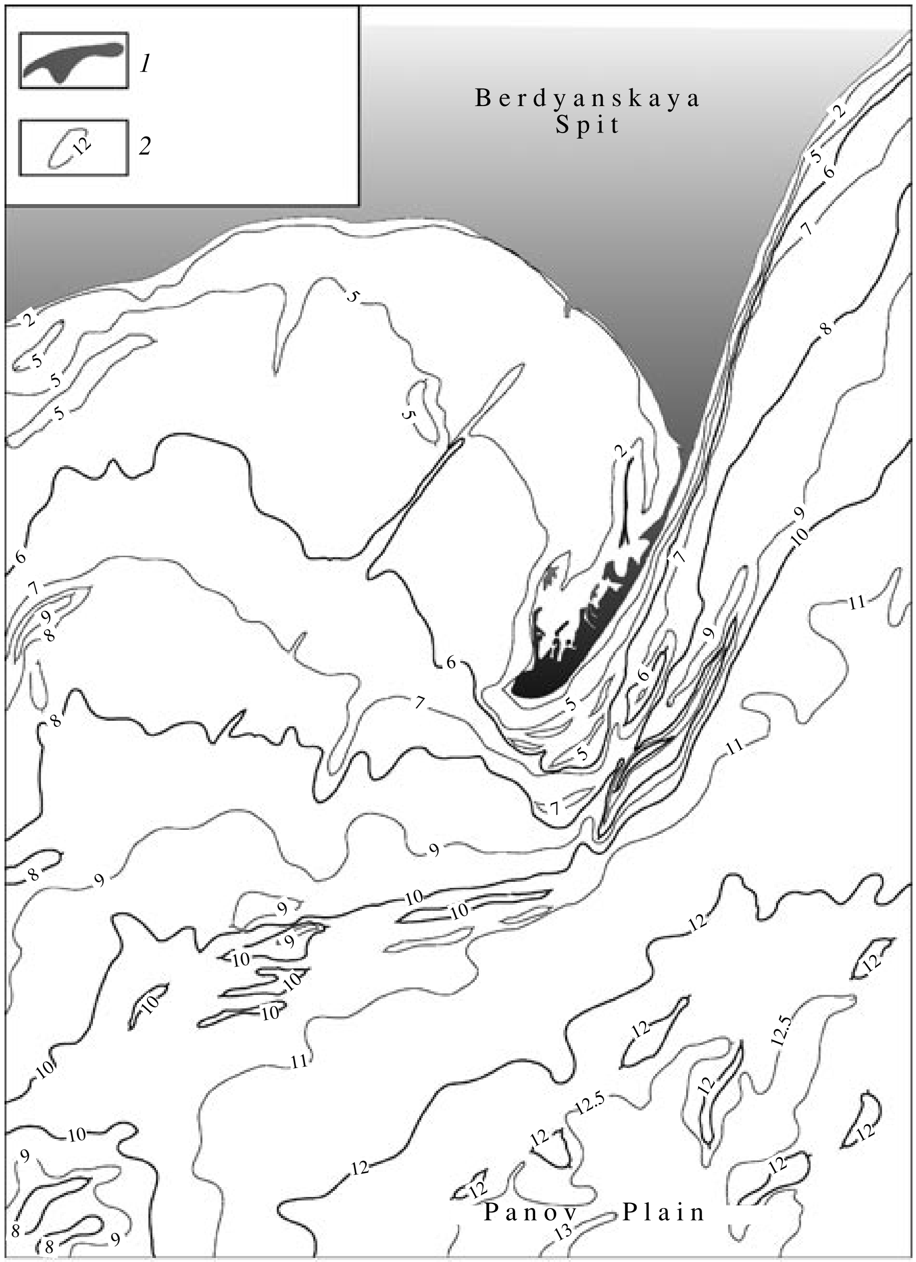

Fig. 2. Bottom topography in the Berdyanskaya Spit area. (*1*) Coastal zone; (*2*) isobaths (m).

are up to 35–50 km long (Figs. 1, 2). The banks are typical shelf structures isolated from coastal cusps. Depths of bank summits (from 1–2 to 3–7 m) are minimal above the Elenenin Bank. The relative depth of banks above the surrounding depressions ranges from 2 to 5 m. Their summits and slopes are covered by coquina with sandy–silty matrix.

The Zhelezinskaya and Akhtarskaya banks are separated by the narrow Achuevskaya flat depression 8–10 m deep (Fig. 2). In the west, they are bordered by the closed Zhelezinskaya Depression (13.0–13.5 m deep, 80 km long, and 4–12 m wide). The depression, the deepest one in the Sea of Azov shelf, is filled with muddy sediments.

The underwater shoals (Zhelezinskaya and other banks) are likely characterized by a long subaerial development history (including the Holocene) and complicated initial geomorphologic settings. The formation of the bottom morphostructure was determined by the geotectonic background. The morphological sculptures are related to abrasion–accumulation, erosion, and sedimentation processes.

The bottom geomorphology over a distance of 20–30 km at the northern coastal shelf is determined by a

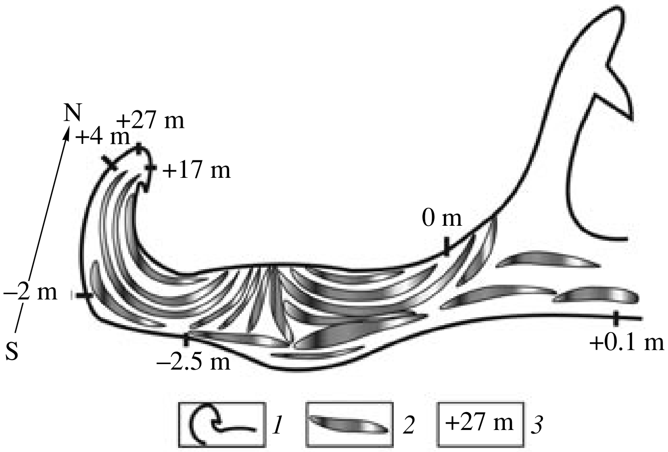

Fig. 3. Schematic location of coastal swells in the Obitochnaya Spit (distal part, July 1964). (*1*) Storm-related swell; (*2*) old storm-related swells; (*3*) shore erosion during the 3-days-long storm period.

system of narrow swells and ridges 0.2–0.8 km wide, 2–9 km long, and 1.5–3.5 m high (Figs. 1, 2). Their formation was evidently promoted by an intricate interaction of wind-driven, tidal, and alongshore currents. It is clear that sandy spits and underwater ridges are of similar origin. The sandy ridges and swells are most widespread south of the Obitochnaya Spit. As much as ten near-parallel positive structures (up to 4–6 m high and 3–6 m deep) diverge from the coast toward the sea. They are largely composed of coarse-grained sands (up to 75%) with subordinate silty sands in intervenient depressions 9–11 m deep.

South of the Belosaraiskaya Spit, narrow (up to 0.7 km) sandy ridges (~4 km long and 2–3 m high) are developed at depths of 5–8 m. Their formation is probably related to the activity of alongshore currents.

In addition to gentle morphologic structures, the coastal shelf of the Sea of Azov (up to 6–11 m deep) hosts flat underwater terraces representing abrasion and abrasion–accumulation structures (Figs. 2, 3), which were probably produced by the Holocene transgression. West of the Dolgaya Spit, the terrace is located between the 6- and 8-m isobaths. A similar 10-km-wide terrace is observed at a depth of 4 m west of the Chumbur-kosa and Port-Katon localities. In the Taran'ya Bay, a 4-km-wide terrace is mapped at depths of 4–5 m. A wider (6–7 km) terrace is outlined at depths of 8–9 m south of the Belosaraiskii and Obitochnyi bays. A flat (slope ~0.005–0.001) terrace extends in the Temryukskii Bay between the 10- and 12-m isobaths from the Kuban River delta to the north. The depth gradient of the terrace surface is as low as 10 cm per 1–2 km. Narrow abrasion terraces or benches are developed in the coastal zone, e.g., south of Port-Katon.

Biogenic processes related to the life activity of benthic communities play a significant role in the formation of geomorphology of the Sea of Azov shelf up to 8–10 km deep. It is remarkable that most of its constituting sediments (coquina, detritus, and shelly sand) are produced at the sea bottom. Banks with organogenic accumulations appear in areas with stable populations of molluscan communities (*Cardium, Mydia*, and others). The bottom is almost universally marked by various topographic microstructures (fucoids, furrows, burrows, and cones) related to the life activity of fossorial organisms.

The geomorphology of the Sea of Azov coastal zone is formed under the influence of both natural and man-caused factors. The most remarkable among the artificial structures are numerous embankments along underwater dumps and marine navigable canals. The longest (up to 20–30 km) and deepest (5–9 m) underwater canals extend to the Azov, Taganrog, Mariupol, and Berdyansk harbors (Figs. 2, 3). On both sides, the canals are bordered by flat dumps. The canals are ~4–5 m deeper than the adjacent shelf. The free water exchange allows Black Sea species and benthic fauna in the central part of the Sea of Azov shelf to pass into its coastal zone. Such a geoecological situation determines the specific composition of biogeocoenoses.

The central part of the shelf (10–13 m deep) is occupied by a spacious (5000 km^2) accumulative clayey–muddy plain with a gently undulating surface. We propose to name this area the Panov underwater plain (Fig. 2). It is as long as 120–140 km. The plain surface is slightly inclined toward the Zhelezinskaya and other depressions located at depths of 13.0–13.5 m. In the northern hilly part of the plain, flat rises are outlined by the 10-m isobath. The internal part of the plain hosts up to 15 gently sloping hills (5–20 km across, 40–60 m high) located at a depth of up to 12 m.

In many areas of the Panov Plain, the bottom topography is complicated by flat hills, furrows, depressions, small deeps, and so on. Their relative depth varies from 30 to 80 cm above the seafloor. The origin of such structures can be related to the activity of bottom currents, storm waves, subsidences, mud volcanism, gas hydrate seepage, or slumping of liquid clayey and fine silty mud downward the slope. The influence of tectonic movements on the bottom surface cannot be ruled out as well.

Recent sediments of the Panov underwater plain typically contain an admixture of organogenic sandy particles. In clayey and fine silty mud, the share of sandy fraction ranges from 0.3 to 2.5%. However, the sandy fraction can increases near the shore to 7–17%. The dispersal of sandy particles over the Sea of Azov shelf is probably related to storm winds and currents, as well as to sea-ice rafting.

Thus, the Sea of Azov shelf is characterized by the following main morphological types: sandy and sandy–shelly ridges and other structures formed by eolian cur-

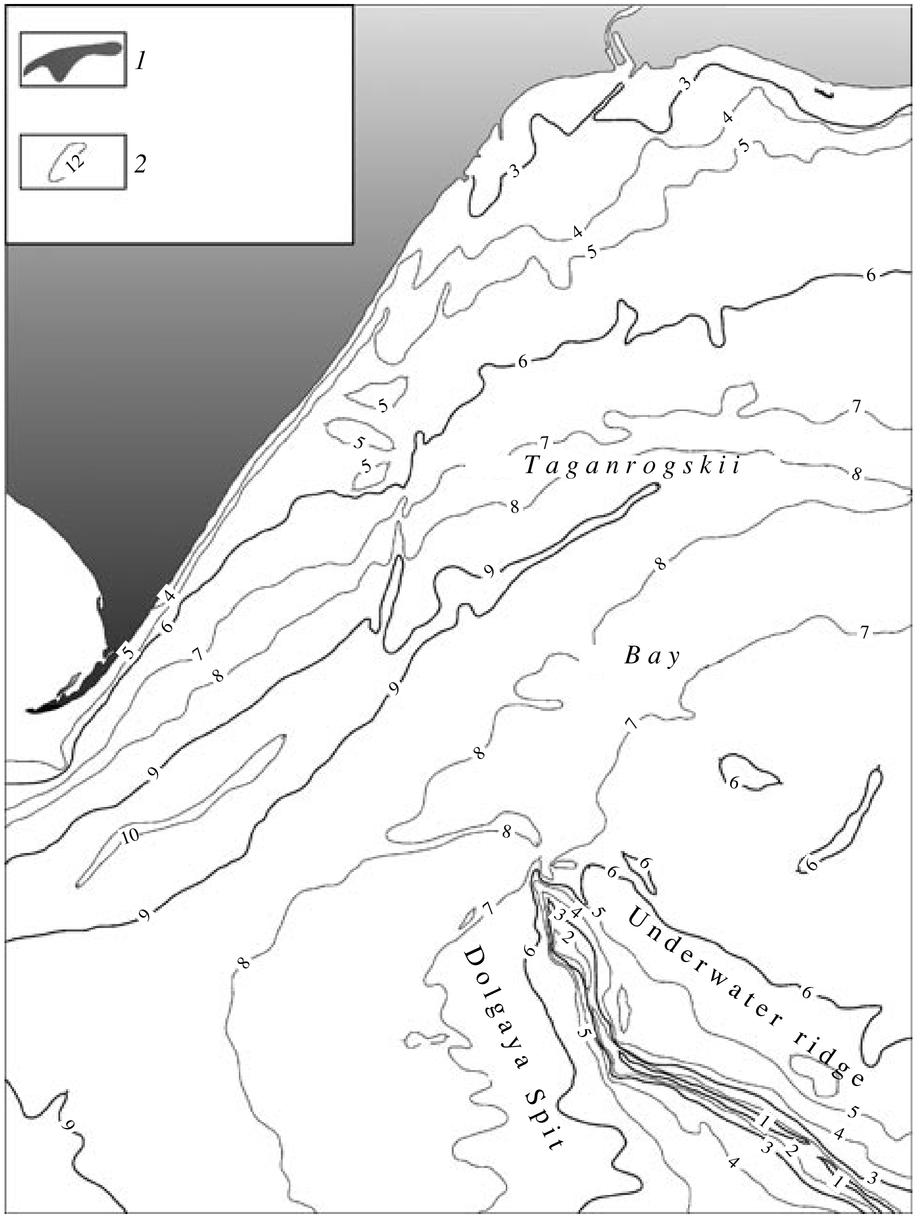

Fig. 4. Bottom topography of the axial gully-shaped valley in the Taganrogskii Bay (between the Belosaraiskaya and Dolgaya spits). (*1*) Shore; (*2*) isobaths (m).

rents; abrasion and abrasion–accumulation terraces at depths of 4–9 m; accumulation (clayey–muddy) plains; and flat erosion depressions. Of course, the origin of these geomorphologic structures is more complicated and requires special studies.

In several cases, the formation of geomorphological elements of the Sea of Azov shelf was determined by tectonic movements. For example, the system of the Achuevskaya, Zhelezinskaya, and Akhtarskaya banks is confined to the Azov Swell arch. In contrast, the Panov accumulation plain is heterogeneous with respect to its tectonic structure. Its surface formed in the zone of the Indol–Kuban Trough, South Azov Scarp, and Azov Swell.

As is known, the Novoeuxinian regressive phase (approximately 18 ka ago) resulted in draining of the Sea of Azov [5]. The majority of its space was occupied by the lacustrine–fluvial plain crosscut by paleovalleys of rivers of the Azov steppe region. All these small rivers represented tributaries of the paleo-Don. The present-day geomorphology was developed during the Holocene under the influence of both hydrodynamic–sedimentary and neotectonic processes. The new geomorphological data are important for specifying the lithological–zoogeographic features and for investigating the hydrodynamic and ecosystem models of the Sea of Azov.

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