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GEOGRAPHY

Results of Spore-and-Pollen and Diatom Analyses of Columns on the Shelf of the Sea of Azov

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Investigation of diatoms, pollen, and spores is of great importance in the study of present-day and buried marine sediments. Based on diatom and palynological analyses, some problems of the stratigraphy of bottom sediments are refined and physiographic conditions existing during sedimentation are elucidated. Diatoms, pollen, and spores are major bioindicators of the Holocene and Pleistocene climate [8, 10]. Along with the terrigenous factor, sea organisms are of key importance in sedimentogenesis of the Sea of Azov [9, 14]. The effect of plankton and zoobenthos resides in filtration or adsorption of the pelagic and near-bottom suspension. Coquina makes up many beach ridges, banks, and bars extending for tens of kilometers into the Sea of Azov. Subordinate suppliers of sediments are represented by eolian transport of the material from the steppe zone and submarine mud volcanism developed in the southern part of the sea. The Azov ecosystem also accumulates spores and pollen of cultivated plants, as well as a wide spectrum of pollutants, including agricultural pesticides, oil hydrocarbons, heavy metals, and others.

Two columns (up to 1 m thick) obtained in the cruise of the R/V *Primorets* in 2004–2005 provided the material for this work. Bottom sediments were sampled with a corer. The columns were described according to the lithology of sediments and samples collected layer-by-layer were placed into sealed packages. A column of bottom sediments was selected for the spore-and-pollen analysis from a depth of 8 m with a 1- to 2-cm sampling interval in the axial zone of Taganrog Bay north of Eisk (Fig. 1). A sediment column for studying distribution of diatoms was recovered from the central part of Temryuk Bay at a depth of 12.3 m. Diatoms, spores, and pollen were analyzed according to standard procedures [3, 4].

Bottom sediments comprise diatom valves. Their content in the total material deposited on the bottom of the Sea of Azov is insignificant (0.2–2.0%) [15], but their study is highly informative. Diatom analysis, elaborated as early as the mid-19th century, is still applied successfully to date [4]. The distribution of fossil diatoms from Neogene sediments in the regions of the Azov and Black seas has been studied in detail [5, 7, 11]. However, information on diatoms from Holocene sediments is still absent.

Palynological studies of bottom sediments from the Sea of Azov carried out to date characterize mainly the upper part of neo-Azovian sediments [2, 12, 15]. The composition of spore-and-pollen spectra of surface-water samples of the sea basin showed that the ratio of basic components of the spectra does not depend on the distance from the shore.

This work discusses for the first time the distribution of diatoms, pollen, and spores in Holocene sediments of the Sea of Azov.

Diatom analysis. The greatest diatom species diversity in the section of mud sediments from Temryuk Bay (table) was recorded in the surface horizon (0–10 cm) of dark gray ooze. The sediments comprise recent plankton diatoms (mainly from the *Coscinodiscus* and *Thalassiosira* genera). Predominance of any species is not characteristic (table).

In addition to plankton diatoms, the horizons of 0–5 cm and 5–10 cm contain benthonic species, such as *Gyrosigma acuminatum* var. *gallica* Grun., *Rhopalodia musculus* (Kütz.) Müll., and *Diploneis bombus* Ehr., which could be delivered to bottom sediments of this region from the coastal zone with discharges of the Kuban River.

Judging from the lithology and species composition of diatoms, the horizon of 5–35 cm is not uniform. The bed of 10–35 cm is dominated by *Actynoptychus senarius* (Ehr.) Ehr. (table).

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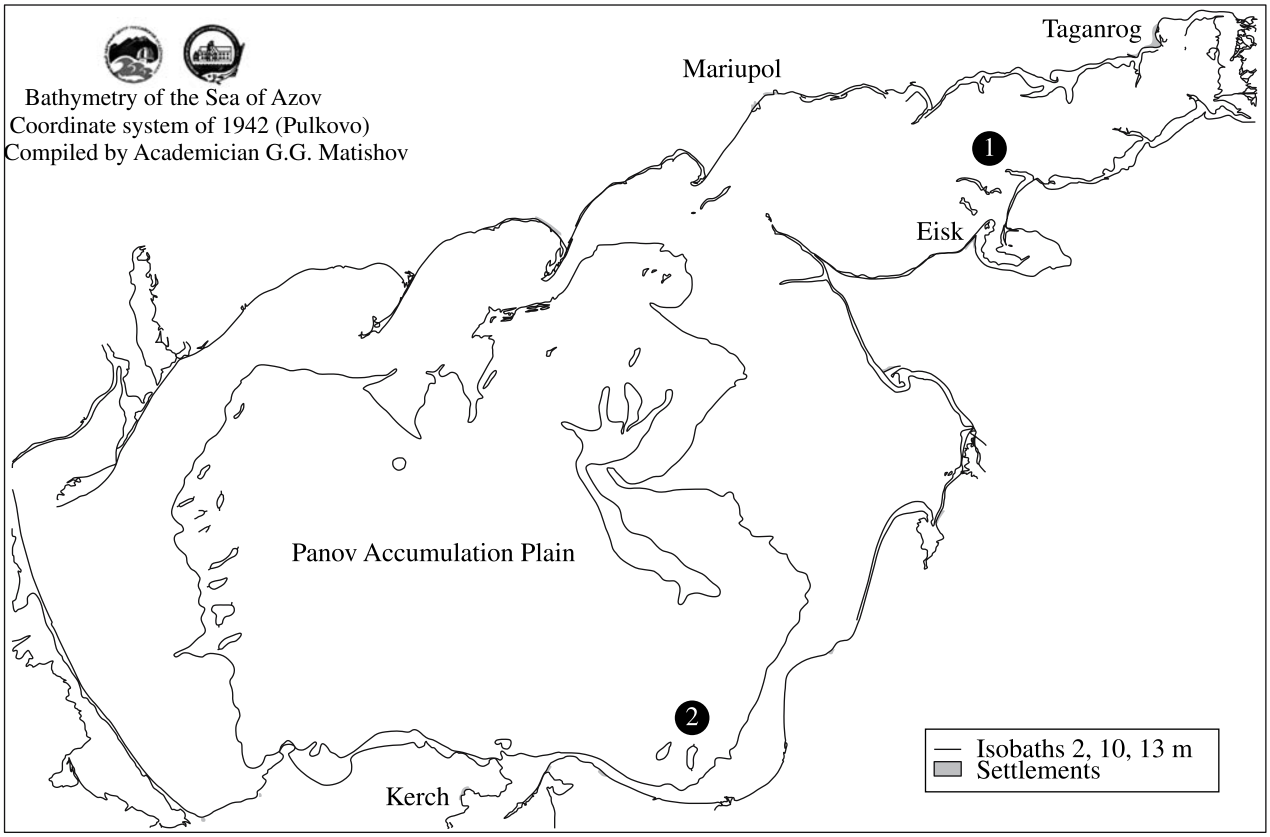

Fig. 1. Bathymetric map of the Sea of Azov with sites of core sampling for (*1*) palynological and (*2*) diatom analyses.

The next horizon (35–48 cm) comprises abundant (more than 50%) intact mollusk shells of *Cerastoderma*. *Abra* and shell detritus are less common. A mass development of *A. senarius* (= *A. undulatus* Ehr.) was recorded in the horizon. This horizon also includes the extinct variety *A. undulatus* var. *tamanica* Jouse and species/variety transitional forms. Such phenomena of mass development of species and its varieties can indicate specific hydrodynamic conditions in the coastal shoal of the basin for a long period of time. According to [4], the *A. senarius* species (Fig. 2) dwells in the sublittoral zone and appears in plankton accidentally. In the present-day Sea of Azov, the species is very rare and found only in plankton.

A closer examination of diatoms in the lithological bed at 48–95 cm showed that horizons 48–64, 64–74, 74–84, and 84–95 cm have a uniform composition of the diatom flora, indicating similar conditions during sediment deposition in this bed. However, the assemblage of two mass species (*Actinocyclus octonarius* Ehr., *Actinophychus senarius*) is dominated by *A. octonarius* in deeper horizons. It should be noted that *A. octonarius* (Fig. 2) is a brackish water marine species usually found in littoral desalinated areas of mildly warm seas. This species was sporadically found in the Sea of Azov in summer and autumn periods at a salinity of 11–13‰.

The species mentioned above (except for *A. undulatus* var. *tamanica*) are found in present-day phytoplankton of the Sea of Azov. Some species (*Coscinodiscus granii, C. oscinodiscus jonesianus, Thalassiosira baltica, T. aculeata, T. eccentrica*) reach their mass development. Although *A. octonarius* and *A. senarius* are found occasionally in plankton of the Sea of Azov, they do not reach mass development as in bottom sediments at horizons deeper than 10 cm.

Mass development of *A. octonarius* in the Kerch–Taman region was established in the terminal Miocene [1], indicating the redeposition of valves of this species in bottom sediments.

Spore-and-pollen analysis. In terms of lithology, the sediments recovered are represented by dark gray ooze. Down the column (from 10 cm), the sediments become more consolidated and comprise shells. The palynological study of the sedimentary section penetrated in the axial zone of Taganrog Bay showed that spore-and-pollen spectra in the whole column exhibit a great similarity (Fig. 3). They are characterized by a low content of the arboreal pollen (10–15%), and its content increases to 50% only at the depth of 62–66 cm. Constant components in this group are pine, birch, oak, elm, nut-tree, and hornbeam. The pollen of walnut, linden, and beech are periodically encountered. Cornelian cherry and willow are also found.

Description of the column of bottom sediments from Temryuk Bay

	Lithology	Beds, cm	Diatom species	
			mass	sporadic
	Clayey ooze dark gray (with green shade) liquid. *Ceratoderma*, *Mya*, and *Abra* valves are present.	0–5	*Coscinodiscus granii* Gough., *Coscinodiscus gigas* Ehr., *Thalassiosira baltica* (Grun.) Ostf, *Thalassiosira aculeata* Pr.-Lavr., *Thalassiosira eccentrica* (Ehr.) Cl., *Biddulphia mobiliensis* Bailey, *Thalassiosira nitzschioides* Grun., spores *Chaetoceros* spp.	*Gyrosigma acuminatum* var. *gallica* Grun.; *Actinoptychus senarius* (Ehr.) Ehr.; *Cyclotella tuberculata* Makar. et Log.; *Skeletonema costatum* (Grev.) Cleve; valve debris: *Pseudosolenia calcaravis* (Schultze) Sundstrom; *Ditylum brightwelli* (West) Grun.; *Coscinodiscus radiatus* Ehr.
	Clayey ooze dark gray viscous. Intact *Ceratoderma* valves within the interval of 5–10 cm. Shell detritus and sludge throughout the whole bed.	5–10	*Coscinodiscus jonesianus* (Grev) Ostf, *Thalassiosira eccentrica* (Ehr.) Cl., *Thalassiosira baltica* (Grun.) Ostf, spores *Chaetoceros* spp., valve debris of *Actinocyclus octonarius* Ehr.	*Actinoptychus senarius* (Ehr.) Ehr.; *A. undulatus* var. *tamanica* Jouse; *Rhopalodia musculus* (Kutz.) Mull.; *Diploneis bombus* Ehr.; valve debris: *Coscinodiscus radiatus* Ehr. and *Actinocyclus octonarius* Ehr.
		10–35	*Actinoptychus senarius* (Ehr.) Ehr., *Thalassiosira eccentrica* (Ehr.) Cl.	*Ditylum brightwelli* (West) Grun., *Thalassiosira* sp.; valve debris: *Coscinodiscus radiatus* Ehr., *Actinocyclus octonarius* Ehr.
	Shell ooze. Both intact shells and shell detritus are present. The content of shells exceeds 50%; *Cerastoderma* is common, *Abra* is minor.	35–48	*Actinoptychus senarius* (Ehr.) Ehr., *A. undulatus* var. *tamanica* Jouse	*Thalassiosira eccentrica* (Ehr.) Cl., *Coscinodiscus radiatus* Ehr., valve debris: *Actinocyclus octonarius* Ehr.
	Viscous dense **dark gray clayey ooze**. Intact shells are found within 64--74 cm; shell detritus and sludge, within 90--95 cm.	48–64	*Actinocyclus octonarius* Ehr., *Actinoptychus senarius* (Ehr.) Ehr., *Thalassiosira eccentrica* (Ehr.) Cl.	*Actinoptychus senarius* (Ehr.) Ehr., *Thalassiosira eccentrica* (Ehr.) Cl., *Thalassiosira parva* Pr.-Lavr., *Actinoptychus senarius* (Ehr.) Ehr., *Thalassiosira parva* Pr.-Lavr.
		64–74	*Actinocyclus octonarius* Ehr., *Actinoptychus senarius* (Ehr.) Ehr., *Thalassiosira eccentrica* (Ehr.) Cl.	
		74–84	*Actinocyclus octonarius* Ehr.	
		84–95	*Actinocyclus octonarius* Ehr.	

The group of herbaceous pollen is characterized by a great diversity. Absolute dominants of spore-and-pollen spectra are the pollen of wormwood *Artemisia* (30–40%) and Chenopodiaceae (25–42%), which are components of southern steppes, and gramineous plants (Poaceae, up to 20%). The assemblage also includes the following subordinate (but constant) members: the pollen of plants characteristic of steppe and meadow communities (representatives of widespread families), such as Polygonaceae, Fabaceae, Rosaceae, Lamiaceae, Brassicaceae, Cichoriaceae, and others. Worthy of note is the presence of the pollen of representative species of south steppe communities (*Ephedra*, species of the Plumbaginaceae family) and meadow–steppe ecotopes (*Polygonum bistorta, Plantago lanceolata, Linum, Convolvulus, Centaurea, Malva*).

Palynological data indicate that the upper 0.5-m bed of oozy sediments in Taganrog Bay comprises traces of agricultural impact. A constant component of the spectra under discussion is the pollen of cultivated gramineous plants. They occur continuously beginning from the depth of 55 cm. The content of pollen of cultivated gramineous plants slightly increases within the interval of 50–40 cm and above 20 cm. The pollen of hemp (*Cannabis*) and buckwheat (*Fagopyrum saggitatum*), the frequency of occurrence of which increases in the upper 20 cm of the profile, should be mentioned as indicators of anthropogenic influence. The pollen of dock (*Rumex*) and *Cichorium* and Hepaticae spores reflect the development of the assemblages on disturbed soils.

Despite such a monotonous nature of spore-and-pollen spectra, the section can be divided into three spore-and-pollen zones. They also differ in the soil consistence, amount of shell admixture, and sediment color.

Zone 1 (a short interval below 66 cm) and *Zone 3* (62–0 cm) are identical in the composition and ratio of basic components of the spectra. During the formation of these sediments, southern steppe communities were developed in the adjacent territory. The influence of

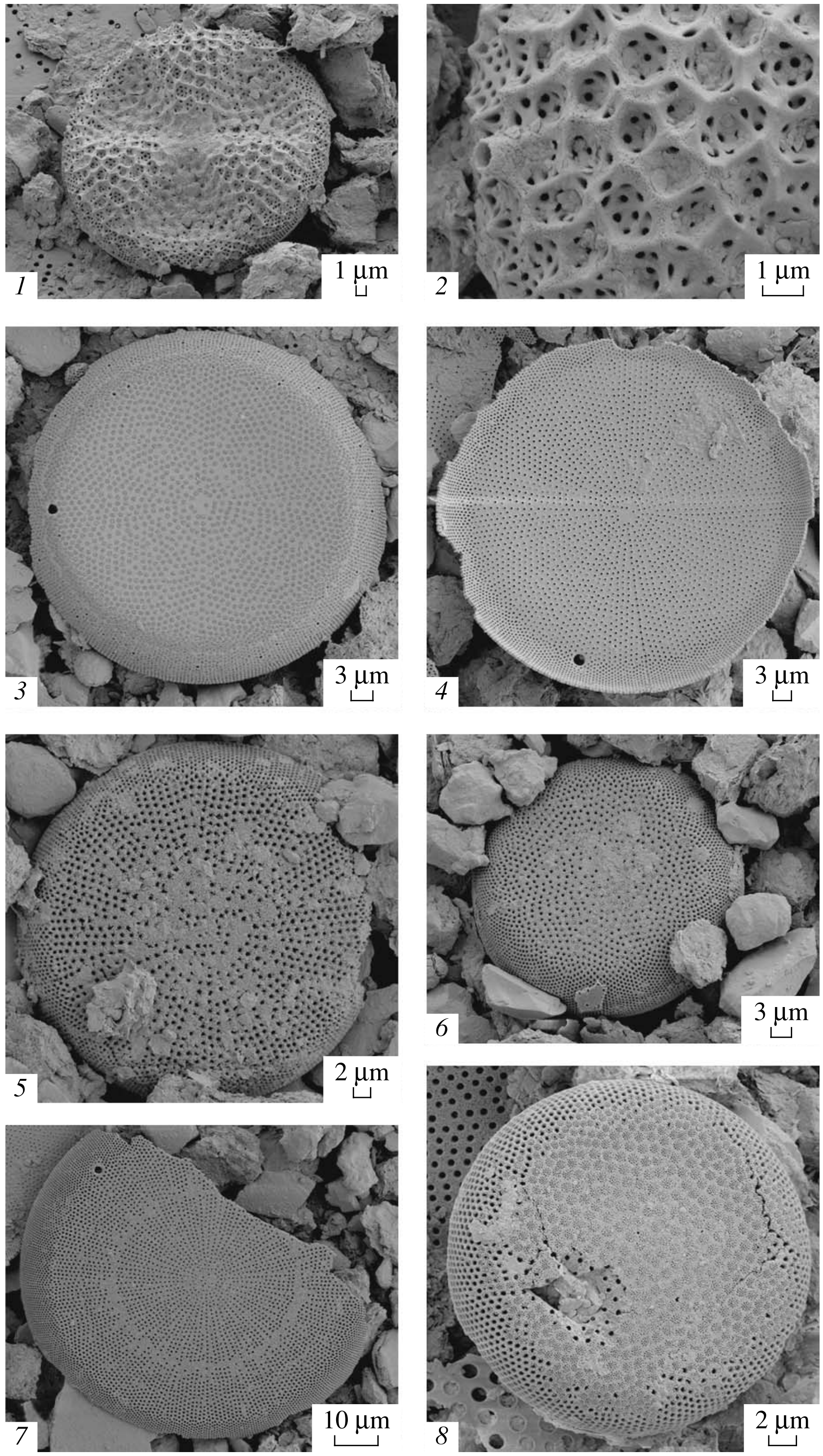

Fig. 2. Dominant diatom species: (*1*, *2*) *Actinoptychus senarius* (Ehr.) Ehr.; (*3–8*) a type form and varieties of *Actinocyclus octonarius* Ehr.

human economic activity gradually increased. It was more prominent during the formation of the upper 20-cm layer of the section, i.e., at the present time.

Zone 2 (66–62 cm) is characterized by a higher content of arboreal pollen (mainly oak, elm, alder, and nut-tree). At the same time, the amount of the wormwood and Chenopodiaceae pollen decreases. The content of meadow herbs (Fabaceae, Caryophyllaceae, and Rosaceae) increases slightly. It is likely that the forest–steppe boundary moved southward during the accumu-

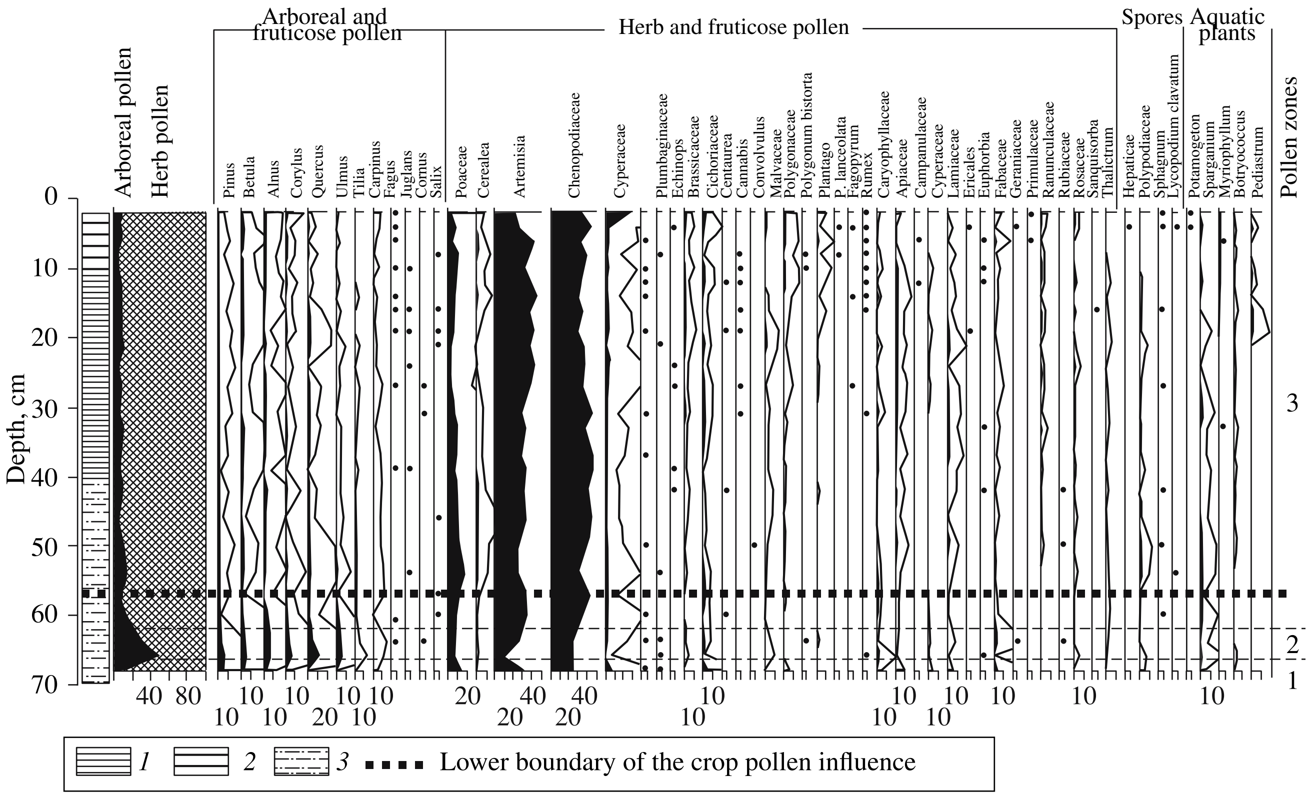

Fig. 3. Spore-and-pollen diagram for the section of bottom sediments from Taganrog Bay, Sea of Azov. Lithology: (*1*) clayey ooze; (*2*) silty–clayey and sandy sediment; (*3*) sand with coquina. Percentages of spectrum components are calculated from the pollen of arboreal and herb species. An additional contour shows the exaggerated content (by 10 times) of minor components.

lation of sediments, resulting in a higher proportion of the arboreal pollen share in the spectra. Meadow steppes were developed in the adjacent territory.

The lithological composition and palynological characteristics of sediments in the horizon of 62–66 cm (Fig. 3) are likely to reflect climatic changes related to increasing humidity at the beginning of neo-Azovian time. In any case, sediments of this level were probably accumulated prior to intense human impact on the basin ecosystem.

Results of the palynological analysis with a spacing of 1–2 cm in this section allowed us to examine variations in vegetation with a high time resolution. On the whole, the discussed spore-and-pollen spectra exhibit a high similarity both with marine bottom sediments [2] and Holocene continental sediments of the northeastern Azov region [13].

Thus, the analyzed diatom species composition and the proportions of basic components of spore-and-pollen spectra allow us to trace some biostratigraphic and paleogeographic regularities in the 1-m-thick sedimentary series of the Azov shelf. Shore abrasion, hydrochemical and hydrobiological processes, and bottom geomorphology undoubtedly play a crucial role in the terrigenous material transport to the Sea of Azov. The results of the palynological analysis show that bottom sediments down to the depth of 60 cm comprise spores and pollen of crops. The epoch of plant cultivation in the Azov region started about 2–4 ka ago. Since that time, the ecosystem of the Azov shelf has endured human impact.

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