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A Global Synthesis with implications
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Sea-level Changes in the North Black Sea and the Sea of Azov During the Latest Pleistocene and Holocene

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Abstract

The Black Sea and the Sea of Azov are similar in their strong dependence upon the limited water exchange with the World Ocean but differ in geological history and present tectonic situation. Comparison of these seas represents an opportunity for analysis of coastal evolutionary processes under sea-level changes during the Latest Pleistocene and Holocene. Existing data were critically analyzed and compared with the results of geological, geomorphological and palaeohydrological studies obtained by the present author during the past two decades.

Glacioeustatic processes played a major role in changes in relative sea level on most coasts of both areas. However, in several coastal stretches other factors overwhelm glacioeustasy during some time intervals. The Black Sea history changed drastically in the early Holocene with the intrusion of water from the Mediterranean that was not drastic. According to our data, there is no any room for the hypothesis of the sea-level rise by over 100 m nearly 7.5 Kyrs BP. The Sea of Azov began its history as a sea possibly nearly 7 millennia ago. The history of these seas were determined by the water exchange with the Mediterranean via the shallow Bosporus Strait and river discharge variations caused by climatic changes on the Russian Plain.

Fluctuations of the relative sea level in the Black Sea and the Sea of Azov were possibly in the order of 5-7 m. After the intrusion of Mediterranean waters in the early Holocene, three primary transgressive cycles occurred (Drevnechernomorian, Novochernomorian, and Nymphean). Fluctuations of relative sea level during middle and late Holocene were possibly in the order of several metres (from plus 2-3 m to minus 2-3 m in the Black Sea and to minus 5-7 m in the Sea of Azov). Lower estimates of regressive stages for the Black Sea are principally based on archaeological data on ancient settlements in tectonically

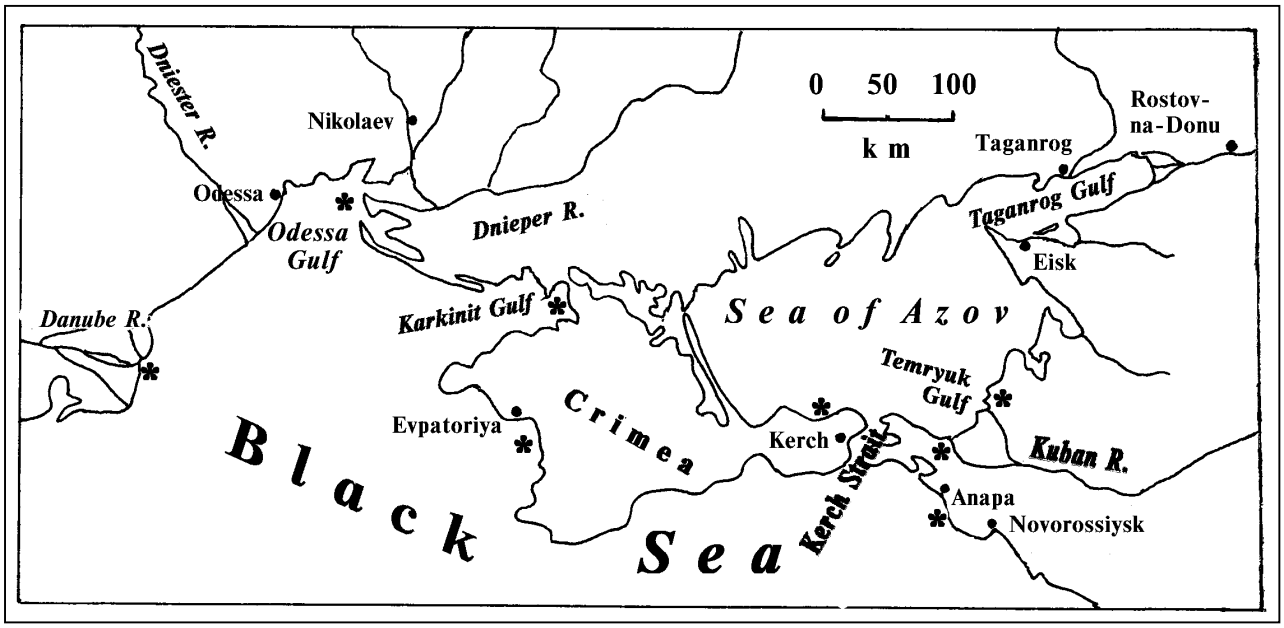

Figure 1. General scheme of the North Black Sea and the Sea of Azov: Areas of detailed Holocene sea-level studies are shown by asterisks

submerging deltaic areas and can not be regarded as reliable.

Palaeohydrological analysis gives us an independent support to the hypothesis of the preservation of significant differences in water level between the Black Sea and the Mediterranean. An existence of intensive, of the order of 15-25 m or even more, sea-level fluctuations in the Black Sea during the middle and late Holocene is rejected by this analysis.

The Black Sea possibly became an enclosed water basin (like the Caspian Sea) during the Pleistocene glacioeustatic regressions when the Black Sea/Mediterranean sill was drowned. However, a strong possibility exists that the altitude of the Bosporus bottom varied significantly during the Pleistocene because of tectonic movements, sedimentation, and erosion (Avenarius, 1979; Shcherbakov, 1983). This could add complexity to the pattern of sea-level changes in the Black Sea. The Sea of Azov is really a large gulf of the Black Sea and depends largely from water exchange with it via shallow Kerch Strait and water discharge from the Don River.

The idea of the "Noah's Flood" in the Black Sea resulting from the intrusion of the Mediterranean waters nearly 7.5 Kyrs BP (Ryan et al., 1997; Ryan and Pitman, 1998; Gorur et al., 2001) additionally heated the discussion on sea-level changes in the Black Sea.

The presentation summarises results of the present author as well as other scientists achieved during the past two decades. These results are described in detail in other publications (Kaplin and Selivanov, 1999, 2000, 2003; Selivanov, 1996; Svitoch et al., 1998). The general position of the region examined here and key areas for obtaining of sea-level curves are shown in Fig. 1.

Our studies distinguished five primary coastal complexes on the Black Sea and the Sea of Azov:

(1) a submerged coastal complex at minus 8.6-9.9 m dated from 7380 a BP (Vityazevian stage);
(2) a submerged coastal complex at minus 3-5 m. It is preliminarily correlated with the Kalamitian stage of the Black Sea (approx. 6-7 ka BP). However, direct radiocarbon assays have not been obtained yet. The maximum inundation of the coastal area, up to 43 km in width, occurred during this period;
(3) an emerged coastal complex at plus 0.5-2.5 m with ages from 5.7 to 4.5 ka BP (Dzhemetian stage). The mollusc fauna of this period iindicates the highest salinity during the Holocene. This fact confirms the most intensive water exchange with the Black Sea possibly resulting from the highest sea level during the Holocene;
(4) an emerged coastal complex at 0-plus 1.5 m aged from 2.2-1.7 ka BP (Nymphean stage). This complex is similar in morphology and altitudes to the previous one but is clearly differentiated from it by its position nearly 8-10 km to the west;
(5) the present coastal barriers with elevations of up to 1.5 m above MSL.

In general, landward migration of the shoreline occurred until the Middle Atlantic period (Kalamitian stage) and changed to its seaward migration since that time.

This phenomenon is typical for many coasts of the World it is possibly resulted from decceleration of sea-level rise during that period (Selivanov, 1996). Bearing data on these complexes in mind, relative sea-level position in the area during the Holocene transgressive stages were estimated. It should be noted that complexes (4) and, possibly, (3) may have been partially modified in recent times by storm surges exceeding 3 m according to direct observations. It is reasonable also to allow for tectonic subsidence of the deltaic area. According to direct observations, rates of subsidence in the 20th century in the central part of the Kuban delta is nearly 4.5 mm/a and 3 mm/a in peripherical parts.

A correction of 4.5 mm/a to the altitudinal position of respective sea-level indicators is included. Anyway, such a correction should be regarded as an extreme one because mean rates of tectonic movements usually decrease drastically with the increasing time interval from decades to millennia (Selivanov, 1996). Additionally, changes in the sedimentary budget of particular deltaic areas due to migration of channels or position of barrier forms can not be excluded. In any case, correlation of transgressive phases with the Early Atlantic, Late Atlantic and Middle Subatlantic is obvious.

No direct indicators of low sea levels during the Holocene regressive stages are available. However, beds of lagoon silts and gyttja are situated not lower than minus 2-2,5 m. This level can be possibly regarded as the "base" for a minimum sea-level position during the middle and late Holocene regressive stages. Anyway, the tectonically subsiding Sea of Azov has a series of the recently submerged and partially destructed coastal depositional features at the depths of 5-7 m. They are dated from the late Middle Holocene (5-6 ka BP). The next generation of similar features evolved during the Late Holocene sea-level rise. Most of the presently degrading coastal depositional features in the Sea of Azov are the remnants of those. Both the Black Sea and the Sea of Azov are typical of limited water exchange with the ocean.

However, the possibility for the existence of long-term differences in water level between the Black Sea and the Mediterranean and, moreover, the World Ocean is under serious question. The hypotheses of the preservation of significant differences in water level between the Black Sea and Mediterranean for several centuries and even millennia have already been mentioned.

To illustrate, Shcherbakov (1983) supposed that during regressive periods the transverse flow area of the Bosporus decreased to such an extent that 30-40-m difference established between the water levels in the Black Sea and the Sea of Marmara, the outflow from the Black Sea being retained during the whole regressive stages.

Oppositely, Fedorov (1985) believes that a unidirectional outflow from the Black Sea to the Sea of Marmara existed for several millennia, particularly in Late Pleistocene.

The mean width of the Bosporus is over 2 km now, whereas the the maximum width is 3.8 km and the minimum one is 700 m, its length being 30 km and the mean depth 45 m It may have been that the depth of the stream owing to the existence of rapids decreased to 5 m,

but it is hardly probable because the bottom of the Bosporus down to minus 100-120 m is composed of loose Quaternary sediments, which would have been intensively eroded under the water-level lowering and the resulting decrease in the transverse flow area. Making a comparison with the strait that connects the Kara Bogaz Gol Bay with the main water body of the Caspian Sea, it seems likely that the rate of bottom erosion is as high as several mm per year, i.e. comparable to the possible rate of the water-level fall.

Estimating the mean annual water flow from one basin to another from the well-known Chezy equation:

$$Q = cw \sqrt{(RI)},$$

where c is the dimensional coefficient equal to 20-50 for such a stream, w is the transverse flow area, R is its hydraulic radius, and I is the mean water surface slope.

Then, even if this extreme assumption of a decrease in depth to 5 m was true, for a difference in water levels equal to 30 m, the mean annual flow along the strait would be as high as several hundreds of km^3 per year and 100 km^3/year for the water-level difference of 5 m. Then, the realistic positive water budget of the Black Sea (which could not be higher than 100-150 km^3/year from palaeoclimatological data (Varushchenko et al., 1987), would have resulted in the equalizing of water levels between the neighbouring seas in several years or decades.

The prolonged existence of the unidirectional outflow from the Black Sea to the Sea of Marmara is improbable also from the salt budget of the Black Sea. The mean salinity of the Black Sea varied from the present or a slightly higher value during the transgressive stages (Nevesskaya, 1965) to 5 per mill or less during low stands of water level. In the event of the annual water flow along the Bosporus such a drastic change in water salinity would have occurred over several centuries.

Therefore, the unidirectional water exchange between the Black Sea and the Mediterranean would have inevitably ceased on a 100-1,000 a time scale. However, migration of the mollusc fauna could occur even during such a short time period in a geological sense. Moreover, water-level falls in the Black Sea to minus 25 m at 6.5-5.8 ka BP and to minus 8-12 m at 3-2 ka BP as proposed by several writers are improbable during the periods of water exchange with the Mediterranean and the ocean.

A hypothesis exists that significant sea-level fluctuations occurred during the middle and late Holocene.

The inadequate facial interpretations of sediments in bottom cores can be the principal reason for extreme estimates of sea-level fluctuations by Voskoboinikov et al. (1982).

The assumption that sea-level falls to 10-15 m during the Phanagorian transgression and to minus 2-5 m in the Medieval period as proposed by Balabanov and Izmailov (1988) possibly resulted from the unjustified comparison of terraces of questionable coastal genesis for the transgressive phases with bottom cores for the regressive stages. Pirazzoli (1991) reasonably suggested that several sea-level curves with fluctuations of over dozen metres possibly resulted from the unjustified comparison of ancient sea-level indicators from areas differing in tectonic regime.

Deep sea-level falls in the middle and late Holocene of the Black sea as indicated by data on submerged ancient towns (Fedorov, 1985; Shilik, 1997) obviously resulted from tectonic submergence of several coastal stretches.

To conclude, our studies do not leave any room for the global or regional events like “the Noah’s Flood”. However, smaller-scaled local events resulting from the tectonic and, possibly, hydrological changes really occurred during the Holocene.

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