Paleogeography of the northwestern Black Sea shelf during the last 12 ka

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Introduction

At present, the problem of Black Sea formation during the last 25–30 ka remains the focus of interest for geologists and geographers who have investigated this problem over many decades, and also for archaeologists and experts in social-economic and political studies. Forecasts of possible shoreline changes during the next 50–100 years are important and ongoing tasks, and successful solution of this problem is essential for preparation of long-lasting development strategies for sea transport and recreational zones, construction in the shore belt, as well as other important plans.

One possible solution to this problem is paleogeographic reconstruction based on multi-disciplinary study of different features of the bottom relief and sediments, as well as on faunal, floral, and pollen complexes from these sediments. Paleogeographic analysis enables a separation of continental and marine environments during different phases of sea transgression. It also enables an estimate of the possible limits of sea depth fluctuations within the coastal belt. Besides, it gives an opportunity to reconstruct landscape dynamics during a transgression (Dolukhanov et al., 2009), and thus, it provides grounds for establishing possible scenarios of environmental transformation in the Black Sea region during this century.

This presentation is aimed at paleogeographic reconstruction on the northwestern Black Sea shelf during the last 12 ka.

Methodology

Paleogeographic reconstruction was based on detailed surveys of the northwestern Black Sea shelf, conducted at scales of 1:200,000 and 1:50,000 by Prichernomorskoe State Regional Geological Survey (Avrametz et al., 2007; Podoplelov et al., 1973–1975; Sibirchenko et al., 1983).

The shelf surface has been subdivided using morphological and statistical analyses of sea-floor relief, lithological characteristics, statistical parameters of Holocene sediments, and locations of benthic biocenoses.

Using a GIS framework, we were able to correlate the paleo-relief surfaces with the corresponding shoreline positions, taking into account uncertainties resulting from the insufficient number of radiometric dates. In doing so, we assumed that the main features observed in modern sea-floor relief of the northwestern Black Sea shelf correspond to erosional denudation surfaces formed in the aftermath of the Post-Karangatian regression. Subsequent modifications were essentially due to sediment accumulation and, to a lesser degree, erosion. Hence, the statistically confirmed steep slopes may be considered reliable indicators of former shoreline positions (Larchenkov and Kadurin, 2006).

Analysis of stratigraphy, lithology, mineralogy, and sediment thickness from more than 400 vibracores along the northwestern shelf enabled us to identify the facies corresponding to various types of sedimentary environments. Based on these data, faunal complexes within the sediments and geomorphology of the study area have been used for reconstructing the marine and coastal environments, and general features of paleo-relief for the times of 12 ka BP, 9 ka BP, and 4 ka BP.

Results

The Quaternary sediments of the Pontic Lowland include eolian, proluvial, deluvial, eluvial-deluvial, alluvial, lake-alluvial, deltaic, and liman sequences. They cover watersheds and slopes of valleys, and they build low terraces of rivers and estuaries, deltas, beaches, spits, and sand-bars. Loess is widely distributed also.

Liman valleys are filled by Upper Quaternary and Holocene deposits, with a thickness up to 30–40 m. Black, dark-green, or grey-green colored clay and clayey-sand with shells of marine and freshwater mollusks are the most common sediments here (Gozhik et al., 1987).

Neoeuxinian alluvial, alluvial-deltaic, and liman deposits are everywhere on the recent shelf. Silt, sand, clay, and peat are common in the upper part of the sequences, but their bottom parts consist mostly of sand and gravel; here, silt is relatively rare, and pebbles are very seldom encountered (Avrametz et al., 2007; Podoplelov et al., 1973–1975).

Lacustrine Late Neoeuxinian sediments have not been found anywhere on the shelf above –36 m, but in deeper places, they cover all underlying deposits. The sediments consist mostly of sand, including shelly debris and silt, but clay can be found in rare locations all over the shelf.

Shell, shelly sand, and muddy shells are very common in Holocene sediments on the northwestern Black Sea shelf, however, mud dominates in sediments filling depressions in the sea bottom relief (Sibirchenko et al., 1983).The Holocene marine deposits on the shelf are subdivided into Drevnechernomorian, or Lower Chernomorian (Old Black Sea), and Novochernomorian, or Upper Chernomorian (New Black Sea), horizons. Drevnechernomorian sediments can be separated into Bugazian and Vityazevian sub-horizons. Bugazian formations on the main part of the shelf consist of shell and shelly debris with sand, silt, and clay layers. Sand deposits dominate near the Early Holocene seashore where their thickness can be up to 1.5–2 m. Vityazevian deposits, which conformably overlie the Pre-Holocene and Bugazian ones like a cover, consist mostly of mud. Sand is confined to a narrow belt along submerged shoreline areas and on spits. Novochernomorian sediments on the northwestern Black Sea shelf usually are subdivided into Kalamitian and Dzemetinian sub-horizons.

Kalamitian marine sediments consisting of oozes and shells are widespread on most shelf locations where they cover Lower Holocene deposits and, sometimes, Pre-Holocene and Pre-Quaternary ones. There are remnants of nearshore sand accumulation forms, which are evidence of post-Kalamitian sea-level decrease and erosion. This is a rather obvious sign of a hiatus at the end of Kalamitian time on the inner shelf.

Widely distributed marine Dzemetinian deposits consist mostly of oozes in the central parts of depressions, with shells and, rarely, sands and gravel. Usually Dzemetinian sediments consist of one layer, but occasionally they are two- or multilayered. They unconformably overlie eolian-deluvial, alluvial, lacustrine-alluvial sequences, and soils of the Lower, Middle, and the lower part of the Upper Holocene, and sometimes continental Upper Quaternary rocks.

It is necessary to emphasize that any active tectonic events, at least since the Pliocene are not fixed (Aksu et al., 2002; Larchenkov and Kadurin, 2005; Morgunov et al., 1981; Shcherbakov et al., 1975). This is very important and useful for paleogeographic reconstructions. Therefore, according to the geologic data, the depth levels determined here for ancient zones of land-sea transition can be considered sufficiently accurate as undisturbed paleo-sea levels (Larchenkov and Kadurin, 2008; Yanko-Hombach, 2006; Yanko-Hombach, 2007). However, there is complexity in that the Late Pleistocene and Holocene transgression occurred in pulsing transgressive-regressive stages. The coastline in the transgressive phase could be formed at a hypsometric level sometimes exceeding by 10–15 meters the sea level that was established in the regressive phase of the given stage (Ivanov and Kakaranza, 2006).

Discussion

Analysis of marine sediment lithology, paleorelief, and depositional environments on the northwestern Black Sea shelf were used for paleogeographic reconstructions for the time periods of 12 ka, 9 ka and 4 ka BP (Fig. 1).

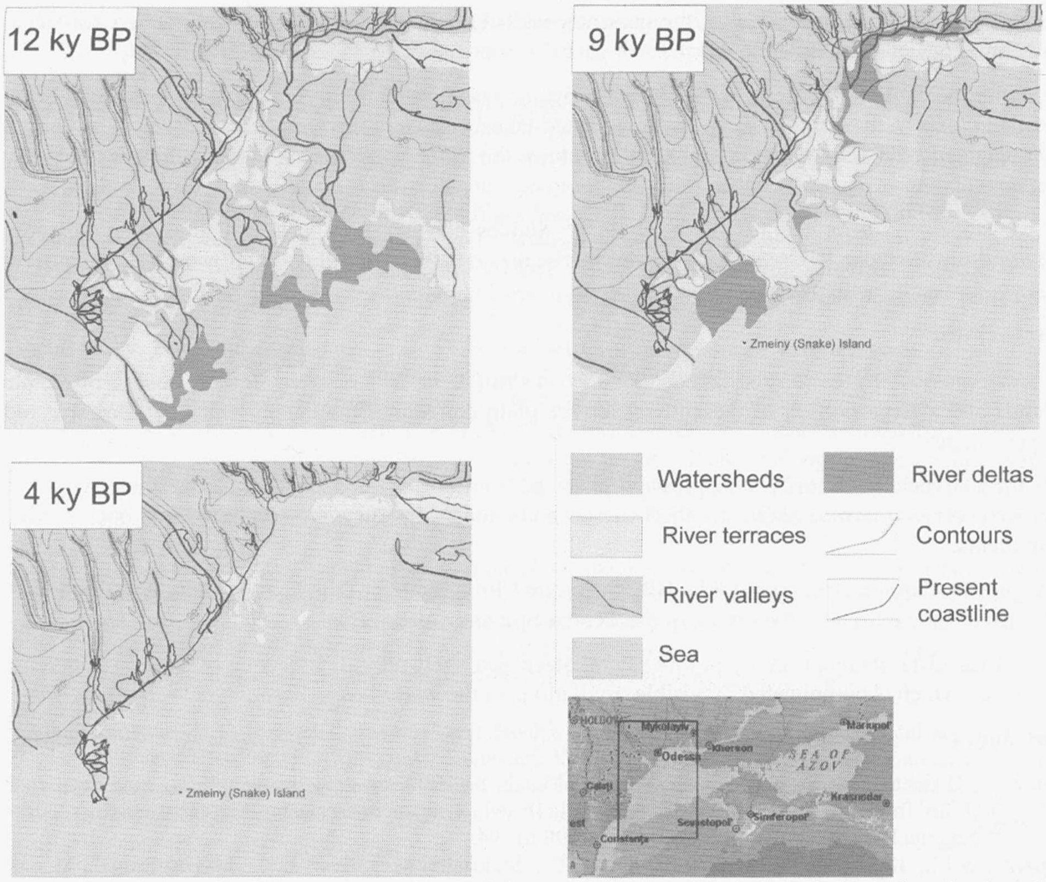

Figure 1. Paleogeographic reconstructions of the northwestern Black Sea shelf during the last 12 ka.

It is common to divide the Neoeuxinian and Chernomorian (Black Sea) periods of transgression during last 30–25 thousand years. Each period is further divided into several transgressive-regressive stages.

The landscape of 25 ka BP corresponding to the Early Neoeuxinian basin, when sea level was 89 m below present, was formed by three geomorphic elements, in general, spread from northwest to southeast: I – the denudation plain incised by numerous rivers; II – the Late Pleistocene alluvial terrace plain formed by the valleys of the Dnieper, Dniester, and Danube rivers; III – the lowland coastal delta plain (Larchenkov and Kadurin, 2007).

During the Neoeuxinian transgressive period, the subsequent sea-level rise to –55 m (15 ka BP) and –45 m (12 ka BP) led to submergence of the whole area of the deltaic lowlands and a large part of the alluvial terrace plain, during which time the paleo-Dniester and paleo-Dnieper limans became deeply embayed. The estuary that formed in the flooded Danube valley bordered this plain on the southwest.

The re-connection with the Mediterranean Sea at 9 ka BP led to stratification of the marine waters due to differences in salinity (Fedorov, 1983; Ivanov and Kakaranza, 2006). As a result of the Drevnechernomorian transgressive stage at 9 ka BP, almost the entire Late Pleistocene alluvial terrace plain was flooded by the sea, and the Dniester and Dnieper limans were converted to open marine embayments. The shelf was characterized by active hydrodynamic conditions, which precluded accumulation of sediment transported to the shelf edge and deep-sea trough. Sapropel mud and, less commonly, clay accumulated under neritic conditions on the outer shelf.

During the Kalamitian stage (until 4 ka BP), sea level rose to –7 m, and the coastline was quite close to its current position. The sea covered the entire present-day Chilia lobe of the Danube delta, with possible islands and promontories still existing in the area of the modern Dniester Bank. A large exposed region around the Tendra Spit and present-day Odessa Bank isolated a wide, latitudinally oriented embayment of the lower Dnieper valley. Most of the presently well- known geomorphic elements were established by this time.

Later, after the Dzhemitinian stage, the current coastline was formed. Many limans were established, and all of them, except the Dnieper-Bug, became closed lakes. Seawater covered Odessa Bank. The coastal zone contained both accumulation and abrasion areas, the latter being places where landslides are very active.

One can consider that, since 12 ka, the drainage divides consisting of loess still preserved subaerial steppe and forest-steppe landscapes. However, landscapes on alluvial sand and mud were formed in river valleys where active sedimentation was ongoing.

Conclusions

The sea-level rise of the Neoeuxinian sea-lake to –45 m (12 ka BP) resulted in the flooding of deltaic lowlands and a large portion of the alluvial terrace plain containing the deeply embayed Dniester and Dnieper limans.

After the Drevnechernomorian transgressive phase of 9 ka BP, the sea flooded almost the entire Late Pleistocene alluvial terrace plain, and the Dniester and Dnieper limans were converted into open marine embayments.

Throughout Kalamitian time (until 4 ka BP), the entire Chilia section of the Danube delta was flooded. A large tract of land existed in the region of the Tendra Spit and Odessa Bank.

The geologic data obtained on the northwestern Black Sea shelf provide evidence of a gradual increase in sea level, which is complicated by visible oscillations in the water level.

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