Depositional environments of the Northwestern Black Sea inner and middle shelf during the Late Pleistocene and Holocene

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Introduction

The Black Sea level rise of up to 90 m during the past 25 ky led to a progressive shift from terrestrial and nearshore depositional environments to marine shelf settings. This work is aimed at reconstructing the depositional environments on the northwestern Black Sea shelf during the Late Pleistocene and Holocene.

Materials and methods

Reconstruction of depositional environments was based on detailed surveys of the northwestern Black Sea shelf, conducted at 1:200,000 and 1:50,000 scale by the Prichernomorskoe State Regional Geological Survey (e.g., Avrametz et al., 2007; Ivanov, 1987; Podoplelov et al., 1973-1975; Sibirchenko et al., 1983). Lithology, mineralogy, and thickness of sediments 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 to reconstruct the marine and coastal environments. Using a GIS framework, we were able to correlate the paleo-relief surfaces with the corresponding shoreline positions, taking into account uncertainties resulting from an insufficient number of radiometric dates. In doing so, we assume that the main features observed in modern seafloor relief of the northwestern Black Sea shelf correspond to erosional denudation surfaces formed in the aftermath of the Post-Karangat 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, Kadurin, 2006).

Results and Discussion

The Neoeuxinian Phase

By 25 ky B.P., the erosional denudation plain encompassed the entire area of the modern land surface and a vast region to the south of Tendra Spit and Odessa Bank, which was defined by a wide elbow-shaped Dnieper River valley. The plain occupies a Miocene-Pliocene peneplain formed by deltaic plains of the paleo-Prut, paleo-Dniester, and paleo-Bug Rivers. Its surface dips to the south from 180 to 80 m and consists of loess deposits incised by numerous rivers. To the south, the Late Pleistocene alluvial terrace valley occupied the main part of the modern shelf and is characterized by erosional and depositional processes. Here, the Dnieper, Dniester, and Danube valleys widened substantially and formed a single alluvial plain separated by local drainage divides. The upper reaches of the valley were dominated by marshy floodplains with oxbow lakes. A low deltaic plain occupied the present-day outer shelf, in some areas close to the shelf edge. It occupied a wide region of the nearshore zone. Its surface represented an actively forming alluvial plain with braided rivers confined by channel-margin bars. Vast lowlands formed between the bars contained numerous lakes and probably inaccessible swamps. Sandy ridges and spits separated this region from the sea. The depositional

environments of neritic offshore, avantdeltas, and very narrow neritic outer shelf were replaced by bathyal upper part of the continental slope (Larchenkov, Kakaranza, 2007).

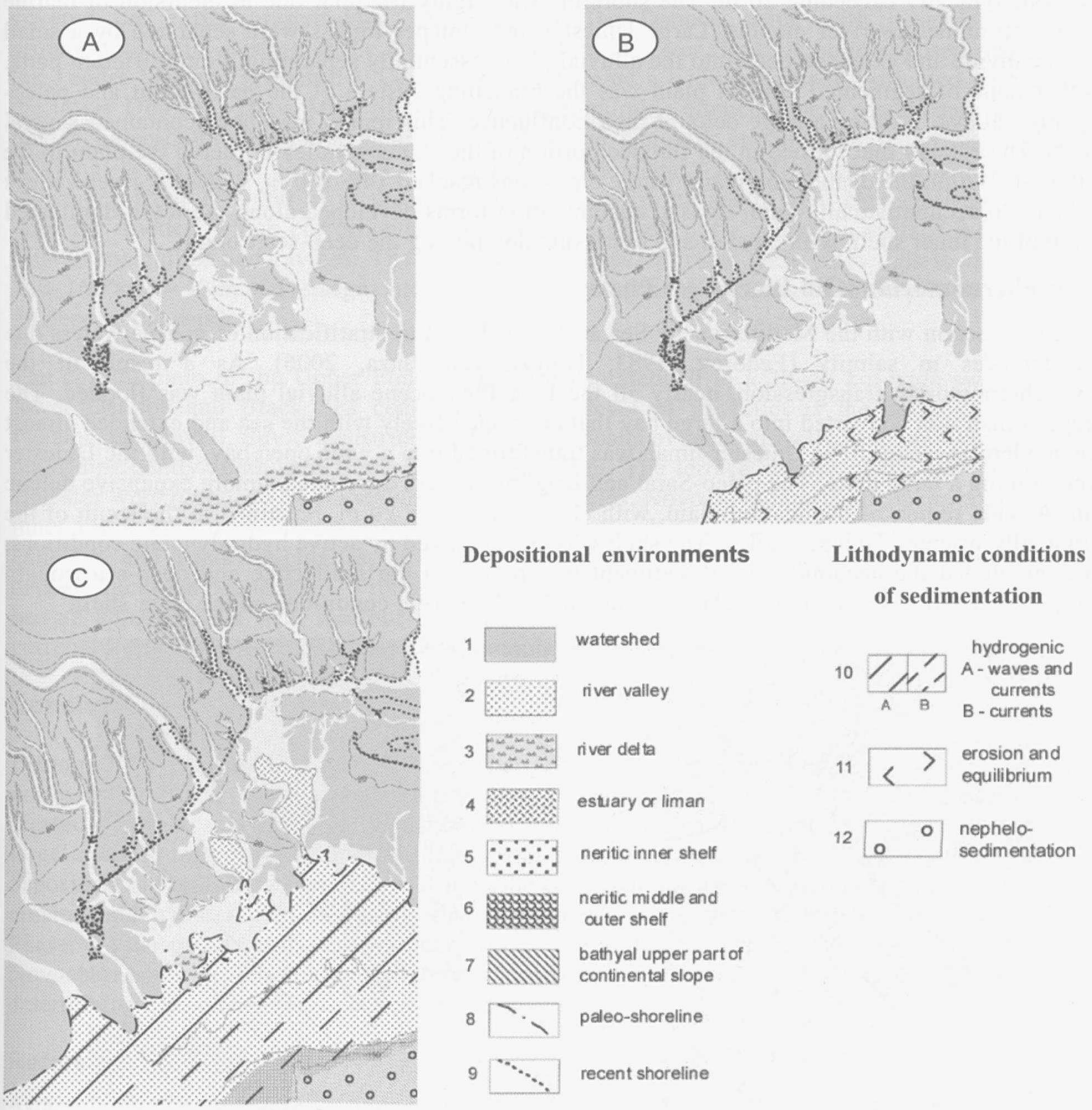

Figure 1. Depositional environments on the northwestern Black Sea shelf during Neoeuxinian time: A – early Neoeuxinian (25 ky B.P.); B – middle Neoeuxinian (18 ky B.P.); C – late Neoeuxinian (12 ky B.P.)

As a result of water-level rise in the Neoeuxinian sea-lake by 18 ky B.P., the shoreline attained the –55 m elevation. The Early Neoeuxinian coastal lowland was submerged, along with more than one third of the alluvial plain. This relatively wide and shallow sub-horizontal shelf setting had depths of 10–15 m. Due to the rise in erosion baseline, the denudation plain experienced widening of the valleys and fluvial deposition. The alluvial terrace plain, up to 40 m in elevation, was still occupied by the composite Dnieper-Dniester valley dominated by extensive marshy floodplains. Active deposition characterized the river valleys. The typical absence of deltas at the mouths of most rivers suggests a rather active hydrodynamic regime in the basin. The exception is the Dnieper River, which formed a large delta at its mouth. A wide distribution of *Stephanodiscus* diatoms in outer shelf sediments indicates fresh-to-brackish conditions.

At the end of the Neoeuxinian Phase (12 ky B.P.), sea level reached –37 m, and large parts of the alluvial terrace valley had been flooded. Dry land occupied less than a quarter of its former area, with elevations typically exceeding 20 m. The shoreline was highly irregular due to incursion of marine waters into numerous river mouths. Large Dniester and Dnieper limans were separated by a small drainage divide and extended deep into the alluvial plain, essentially separating it into different parts. Another zone of segmented alluvial plain was the branching system of the paleo-Sarat and paleo-Kogilnik valleys, forming a large delta at their confluence. This region may have contained several islands. The estuary that formed in the flooded portion of the Danube valley bordered the plain to the southwest. Within the denudation plain, where elevations reached 140–160 m, widening river valleys continued to accumulate alluvium. Coastal accumulation forms developed along the wave-dominated portion of the inner shelf, with erosion and bypassing dominating the deep-sea trough.

Drevnechernomorian (Old Black Sea) Phase

The re-connection with the Mediterranean Sea at 9 ky B.P. led to stratification of marine waters due to differences in salinity (Fedorov, 1983; Ivanov, Kakaranza, 2006). As a result of the Drevnechernomorian transgression, nearly all the Late Pleistocene alluvial plain was flooded. The Dnieper liman was converted into a large bay that connected freely with the sea and extended almost to its modern shoreline. The Dniester liman was transformed into a wide open bay, with the Dniester River forming a large delta. The paleo-Sarat and Kogilnik Rivers developed a more expansive deltaic plain. A wide region of denudation plain, with elevations above 20 m, remained to the south of the latitudinally-oriented Dnieper valley. The shelf was characterized by active hydrodynamic conditions, which precluded the 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.

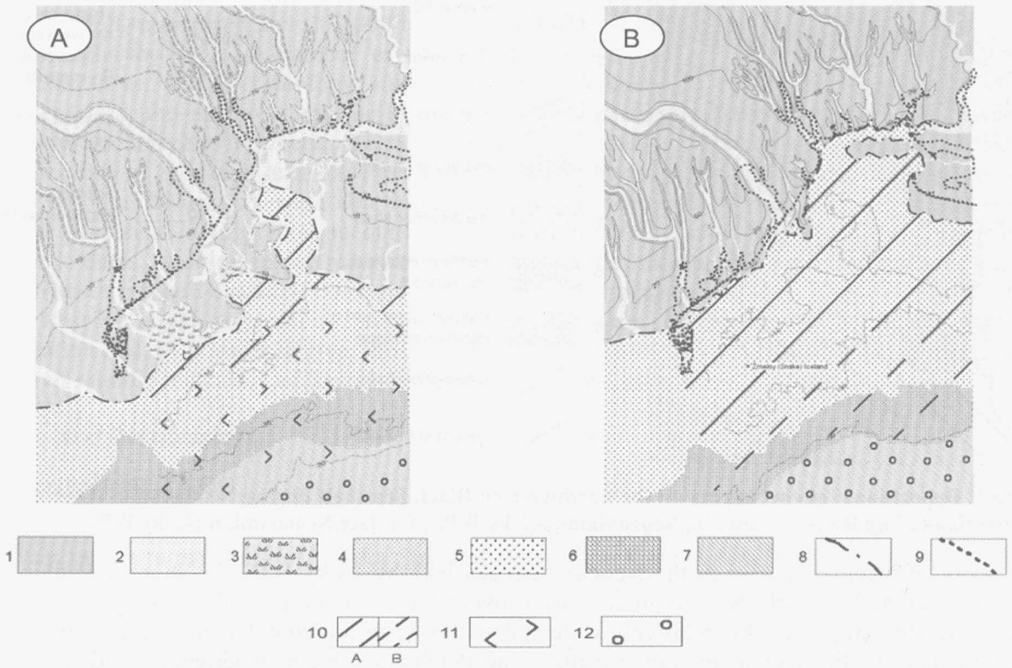

Figure 2. Depositional environments on the northwestern Black Sea shelf during the Holocene: A – Drevnechernomorian time (9 ky B.P.); B – Novochernomorian time (6 ky B.P.). Key: Depositional environments: 1 – watershed; 2 – river valley; 3 – river delta; 4 – estuary or liman; 5 – neritic inner shelf; 6 – neritic middle and outer shelf; 7 – bathyal upper part of continental slope, 8 – paleo-shoreline; 9 – recent shoreline. Lithodynamic conditions of sedimentation: 9 – hydrogenic (9a – waves and currents, 9b – currents), 11 – erosion and equilibrium, 12 - nephelosedimentation

Novochernomorian (New Black Sea) Phase:

During the Kalamitian stage (6 ky B.P.), the coastline approached its modern position, and 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 separated a wide latitudinally-oriented embayment of the lower Dnieper valley. Most of the familiar geomorphic elements were established: Balta sandy-muddy paleo-delta denudation plain, South Bug and Kogilnik erosion-denudation plains, Budzhak erosional-depositional plain, and the Black Sea lowland. The Dniester-Tiligul loess plain at elevations from 150–160 m in the north to 45–50 m in the south were characterized by vast flat drainage divides, which corresponded to segments of the Pontic peneplain surface incised by deep (40–80 m) gullies and ravines. The undulating Danube-Dniester loess plain dips to the south from 150–160 to 20–40 m and is segmented by a ravine-valley network from 80 m deep in the north to 30–40 deep in the south.

The coastal plain of the Upper Pleistocene terraces extended in a 30–40 km-wide swath along the lower Danube and Black Sea coast. The initial level of its relief is the surface of the Upper Pleistocene alluvial, fluvio-lacustrine, and liman deposits of sand, gravelly sand, and sandy mud. The plain dips gently southward from 60–65 to 45–50 m. The terrace valleys of the Danube and lower Dniester were produced by floodplain and terrace facies. Novochernomorian deposits cover the entire inner and middle shelf and are represented primarily by silt and clay oozes. Only within the Budzhak, Dniester, and Tendra highlands, as well as the Odessa Bank, do sandy sediments dominate, with deposit thickness becoming 3–5 times lower than in adjacent depressions. A vast field of shelly oozes has no apparent link with seafloor bathymetry. In the nearshore zone, wave action and longshore currents formed a variety of submerged accumulation forms, spits, and baymouth barriers.

Conclusions

During the Neoeuxinian Phase, a large part of the present-day inner and middle shelf of the northwestern Black Sea represented a nearshore fluvial-deltaic plain. The fluctuating rise in sea level created favorable but unstable depositional conditions, which were not ideal for preservation over large areas. During submergence, the terrestrial sediments were subjected to erosion, transport, and deposition not only on the shelf, but also on the continental slope and in the deep-sea trough. It is the erosion and bypassing of sediments that dominated on the shelf during the Drevnechernomorian Phase. Widespread and stable depositional conditions were established only during the Novochernomorian Phase. Hydrodynamic conditions and seafloor relief were the key factors determining the content and thickness of sediments.

References

Avrametz, V.M., Kakaranza, S.D., Sibirchenko, M.G., Mokrjak I.M., Shvez L.K., Makovetskaja I.M., and Eremina L.Ju. (2007). Zvit z provedennja geologichnoi ziomky masshtabu 1:200,000 pivnichno-zakhidnoi chastyny shelfu Chornogo morja v mezhakh arkushiv L-36-XIII. –XIV, XV. [Report on geological survey 1:200,000 within map quadrates L-36-XIII. –XIV, XV]. Prychonomorske DRGP, Odessa, 399 pp. (in Ukrainian)

Fedorov, P.V. (1983). Sredizemnomorskie transgressii v geologicheskoj istorii Chernogo morja [Mediterranean transgressions in the geological history of the Black Sea]. *Bulleten' Moskovskogo obshchestva ispytatelej prirody. Otdel geologicheskij* [*Bulletin of the Moscow Investigators of Nature. Geological Section*] 58(6):120–126. (In Russian)

Ivanov, V.G , ed. (1987). Otchet o razrabotke stratigraficheskoj skhrmy I legendy chetvertichnykh otloz-henij dlja geologicheskikh kart masshtaba 1:50000-1:200000 po severnoj chasti shelfa Cher-nogo morja. [Report on the development of stratigraphic scheme and legend of Quaternary sediments for geological maps 1:50,000-1:200,000 for northern part of the Black Sea shelf]. Odessa, Prichernorskaja GRE, 157 pp. (in Russian)

Ivanov, V.G., and Kakaranza, S.D. (2006). Major stages of Late Pleistocene – Holocene evolution of the northwestern Black Sea. *Extended Abstracts of the Second Plenary Meeting and Field Trip of IGCP-521 Project "Black Sea - Mediterranean corridor during the last 30 ky: Sea level change and human adaptation"*, Yanko-Hombach V., Buynevich I., Chivas A., Gilbert A., Martin R., Mudie P. (eds). August 20-28, 2006, Odessa National University, Odessa, Ukraine, p. 75–80.

Larchenkov, E., and Kadurin, S. (2006). Reconstruction of north-western Black Sea coastline positions for the past 25 ky Extended Abstracts of the Second Plenary Meeting and Field Trip of IGCP-521 Project "Black Sea - Mediterranean corridor during the last 30 ky: Sea level change and human adaptation", Yanko-Hombach V., Buynevich I., Chivas A., Gilbert A., Martin R., Mudie P. (eds). August 20-28, 2006, Odessa National University, Odessa, Ukraine, p. 105.

Larchenkov, E., and Kakaranza, S.D. (2007). Depositional environments on the northwestern Black Sea outer shelf and continental slope during Late Pleistocene and Holocene. *Extended Abstracts of the Third Plenary Meeting and Field Trip of IGCP-521 Project "Black Sea - Mediterranean corridor during the last 30 ky: Sea level change and human adaptation" (September 8-17, 2007, Southern Branch of the Institute of Oceanology, Russian Academy of Sciences and Demetra Beneficent Foundation, Gelendzhik, Russia-Kerch, Ukraine)*, V. Yanko-Hombach, I. Buynevich, P. Dolukhanov, A. Gilbert, R. Martin, M. McGann, and P. Mudie, eds, pp. 99-101. Rosselkhozakademiya Printing House, Moscow.

Podoplelov, O.N., Karpov, V.A. Ivanov V.G., Mokrjak I.M,. and Zagorodnij G.G.. 1973-1975. Otchet o geologicheskoj s'emki shelfa severo-zapadnoj chasti Chernogo morja masshtaba 1:50,000 [Report on geological survey 1:50,000 of the northwestern part of the Black Sea]. Krymgeologiia, Odessa, 367 pp. (in Russian)

Sibirchenko, M.G., Karpov, V.A., Ivanov V.G., Mokriak I.M, V.G. Ziultsle V.V., and Tatarovskii V.V. 1983. Otchet po izucheniju litilogicheskogo sostava donnykh otlozhenij shelfa Chernogo morja s zeliju sostavlenija geologo-litologicheskoj karty masshtaba 1:200,000. [Report on lithological study of the Black Sea shelf for the preparation of geological-lithological map 1:200,000. Krymgeologiia, Odessa, 427 pp. (in Russian)