The Pechora Sea: Past, Recent, and Future

Shirshov Institute of Oceanology, Russian Academy of Sciences, Moscow, Russia
Geographic faculty, Lomonosov Moscow State University, Moscow, Russia
Murmansk Marine Biological Institute, Murmansk, Russia

Abstract—The main stages in the development of the Pechora Sea are discussed. It is established that, during the high sea level stand corresponding to the warmest epoch of the Mikulino Interglacial, the Pechora Sea represented a more spacious, as compared with its present-day size, basin owing to the flooded valleys of river lower reaches. No sea in its present-day configuration existed during the last (Valdai) glaciation. At that time, the sea could have occupied only a narrow area along the southern coast of Novaya Zemlya, where marine sedimentation was in progress during the Late Pleistocene and Holocene. During the glaciation and postglacial time, the dried bottom of the former Pechora Sea accumulated large volumes of sand that are now concentrated largely in the accretion structures along its southern coast. In the current century, changes will occur mainly in the coastal zone of the Russkii Zavorot Peninsula, Pesyakov Island, the Varandei Settlement area, and the Medynskii Zavorot Peninsula, where a shoreline retreat for a distance of 0.5 km is expected.

INTRODUCTION
Although the Pechora Sea represents an element of the larger Barents Sea, it is characterized by its own particular evolution history, bottom topography, and structure of the sedimentary sequence and differs from the latter in its hydrological and ice regimes.

The Resolution of the Central Executive Committee of the USSR of November 28, 1935, determines the formal boundaries of the Pechora Sea, according to which it is bordered by the line extending from Kolguev Island to Cape Chernyi in the Mezhduharskii Strait of Novaya Zemlya in the northwest and the line from Kolguev Island to Cape Svyatoi Nos on the Timan coast of the Malozemel’skaya Tundra in the southwest.

Previously, it has been proposed to subdivide the shelf of the Arctic seas into glacial and periglacial parts depending on the fact whether they experienced glacial impacts or not [15]. The shelves of the Barents and Kara seas are referred to the glacial type, while the bottom of the Pechora Sea, during glacial periods, has been developing under periglacial conditions, despite the fact that it was surrounded by ice sheets at that time [4 and others].

The Pechora Sea basin is an element of the oil-and-gas-bearing region; therefore, its development trend in the 21st century is of importance.

The cartographic materials that characterize the main results of these studies and the data presented in a digital form suitable for GIS usage are also constituents of international projects dedicated to the studies of the Arctic region.

MATERIAL AND METHODS
In terms of morphogenesis, the data on the bottom topography form a basis for defining regularities in the morpholithogenesis, particularly in shallow shelf marine basins such as the Pechora Sea.

Previously, we proposed a morphogenetic classification of the morphological structures and relief types in the Arctic seas that takes into consideration the complex interrelationships of various natural factors that determine the origin and shapes of different morphological structures [25, 26]. The classification takes into account all the basic morphological features precisely of the Artic shelf, which developed during the Quaternary under conditions that absolutely differed from those in other areas of the World Ocean.

Although the earlier morphogenetic classification of the bottom relief of the World Ocean [5] served as a basis for the development of the classification proposed, it cannot adequately characterize all the diversity of structures and regional morphological features of the coastal zone and shelf of the Arctic seas. Taking into consideration the fact that the natural conditions and, consequently, morphogenesis on the shelves of the Arctic seas substantially changed during the Quaternary, we classify both the recent and relic exogenous morphological structures.

Materials of the long-term studies that were carried in the Pechora Sea by the scientists from the Institute of...
Oceanology of the RAS during cruises of the R/Vs Professor Shtokman (cruises 8 and 12) and Akademik Sergey Vavilov (cruises 11 and 13) during the 1980s–1990s and the data obtained by stationary observations of the Geographic Faculty of Moscow State University on its southern coast served as the basis for this work.

In the course of the studies performed in the frameworks of the Russian Foundation for Basic Research project, navigation maps (scale 1: 200000), drilling data, and geoaoustic profiling records were analyzed to compile digital models of the bottom topography, the distribution of different types of the surface sediments, and the thicknesses of the Pleistocene and Holocene sediments. To accomplish this task, an original method was elaborated. In line with this method, depth contours in navigation maps are drawn with account for geophysical, geological, and geomorphological data to reveal the morphological–structural and genetic features of the relief. The human processing of cartographic material represents the principal condition, since the computer processing of bathymetric data at the initial stage reveals no particular and, what is especially important, genetic features. The program ArcView was used for editing, the adjustment of sheets, the introduction of changes, and the geometric correction of digital models. The maps illustrating the distribution of sediment types and their thicknesses are correlated with bathymetric charts.

In addition to the original materials, we also used published data [1, 17, 21, and others] paying attention primarily to the drilling and geochronological data.

**BOTTOM TOPOGRAPHY OF THE PECHORA SEA**

The bottom topography of the Pechora Sea reflects the main stages in its development during the Late Pleistocene–Holocene. An important morphological element of the Pechora Sea bottom is represented by underwater terraces (Fig. 1). Until recently, the bottom relief of the Pechora Sea has been characterized as a flat plain slightly inclined toward the South Novaya Zemlya Trench (SNZT). The echo sounding revealed, however, that this plain hosts several terraces that extend through the entire sea approximately parallel to the depth contours [14]. The best developed terrace is located at a depth of 118 m near the rear suture and at 120 m near its edge. Two other terraces are recorded at sea depths of 110 and 105 m. In addition, there is a fill terrace that is traceable at a depth of 54 m and is characterized by a horizontal surface approximately 16 km wide with sandy ridges on the latter. A step 8 m high separates this terrace from the higher terrace located at a depth of about 40 m. Even higher, there is another terrace at depths of 25–33 m. The shallowest terrace is traceable along the slope of the Pakhtusov bank at a depth of approximately 17 m. All these terraces reflect successive sea level rise events relative to its minimal stand during the maximum of the last glaciation.

Characteristic elements of the bottom topography in the Pechora Sea are also elongated depressions that represent former river valleys. The Pechora River paleovalley extending toward the Karskie Vorota Strait is particularly well expressed and is confirmed by drilling data. It is feathered by closed depressions with flat bottoms resembling fluvial lakes, which are widespread in the present-day tundra. According to G.A. Tarasov (pri-