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SHORT COMMUNICATIONS

The Application of Cluster Analysis to the Structural Studies of the Sedimentary Layer in the Northeast of the Barents Sea Shelf

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Abstract—During the recent decade, new data were obtained on the structure of the sedimentary layer in the northeast of the Barents Sea shelf. Spatial modeling is one of the promising methods for studying spatial, structural, and tectonic features. The spatial structural–tectonic model of the sedimentary layer of the Barents Sea shelf was interpreted using cluster analysis based on the obtained information on the morphometric characteristics of seismo-stratigraphic complexes.

Keywords: sedimentary basin, volumetric model, structural and tectonic floor, cluster analysis.

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INTRODUCTION

The studied area is located in the northeast of the Arctic shelf of the Barents Sea between the Novaya Zemlya and Franz Josef Land archipelagoes (Fig. 1). In terms of tectonics, the considered region belongs to the Barents (Svalbard) shelf (or marginal continental) plate, which is characterized by a heterogeneous structure.

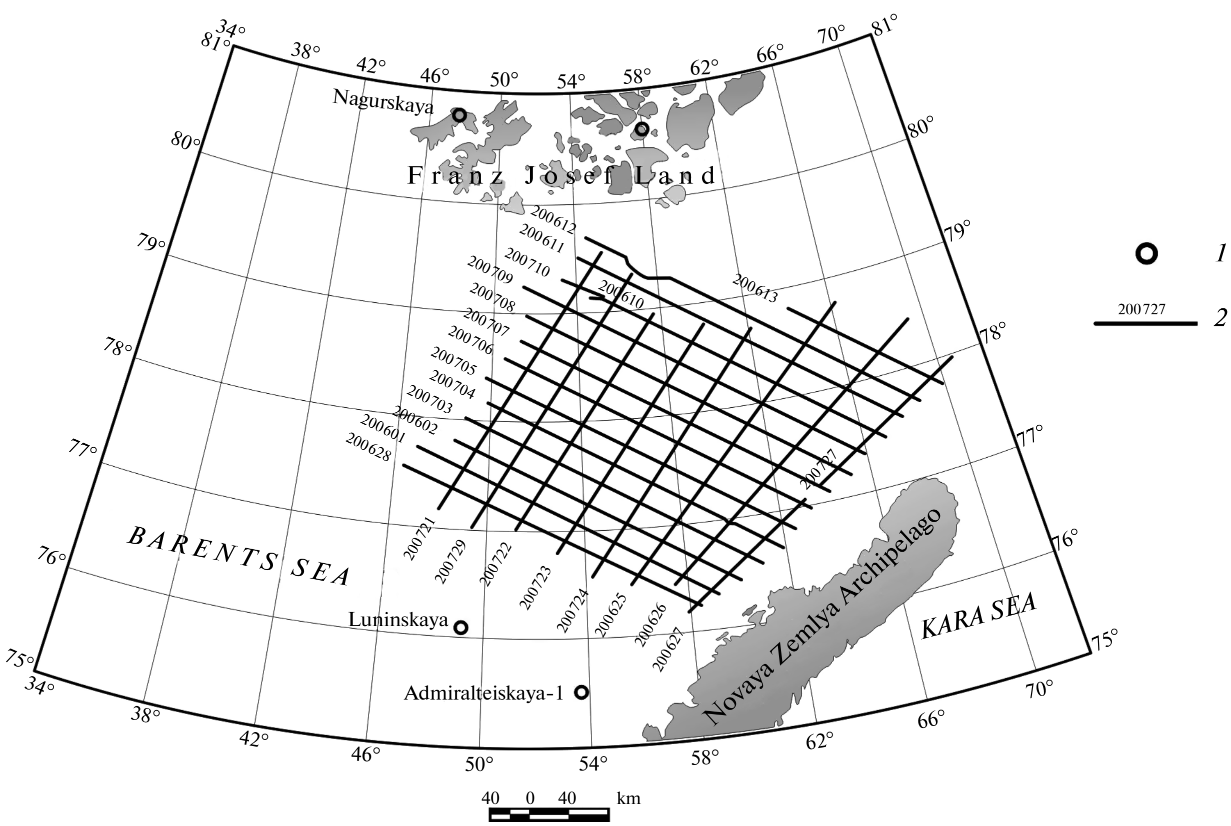

Fig. 1. A general chart of the northern part of the Barents Sea shelf and of the location of the network of integrated geophysical profiles: *1*, deep boreholes; *2*, survey profiles, 2007–2009.

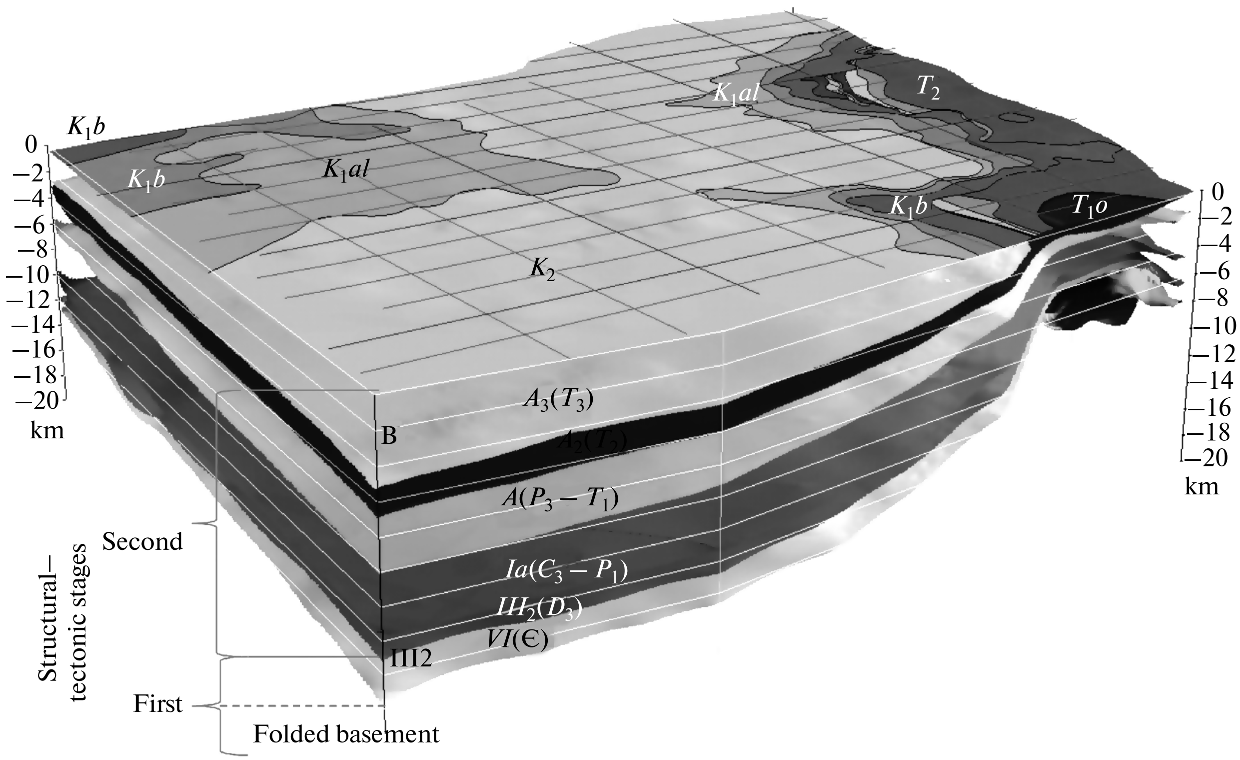

Fig. 2. The skeleton model of the sedimentary layer in the north of the Barents Sea shelf combined with the geological foundation on the basis of structural maps for 11 reflecting layers.

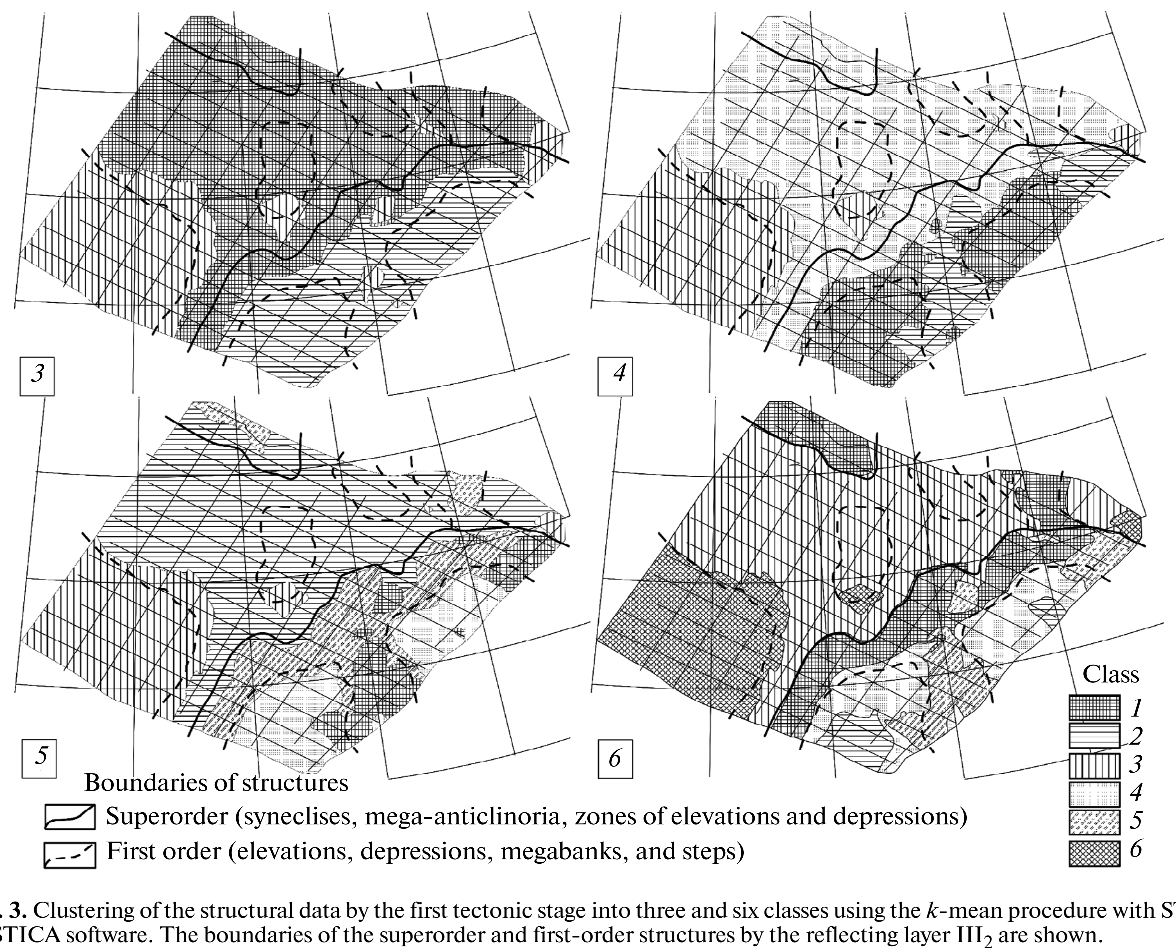

Fig. 3. Clustering of the structural data by the first tectonic stage into three and six classes using the *k*-mean procedure with STATISTICA software. The boundaries of the superorder and first-order structures by the reflecting layer III_2 are shown.

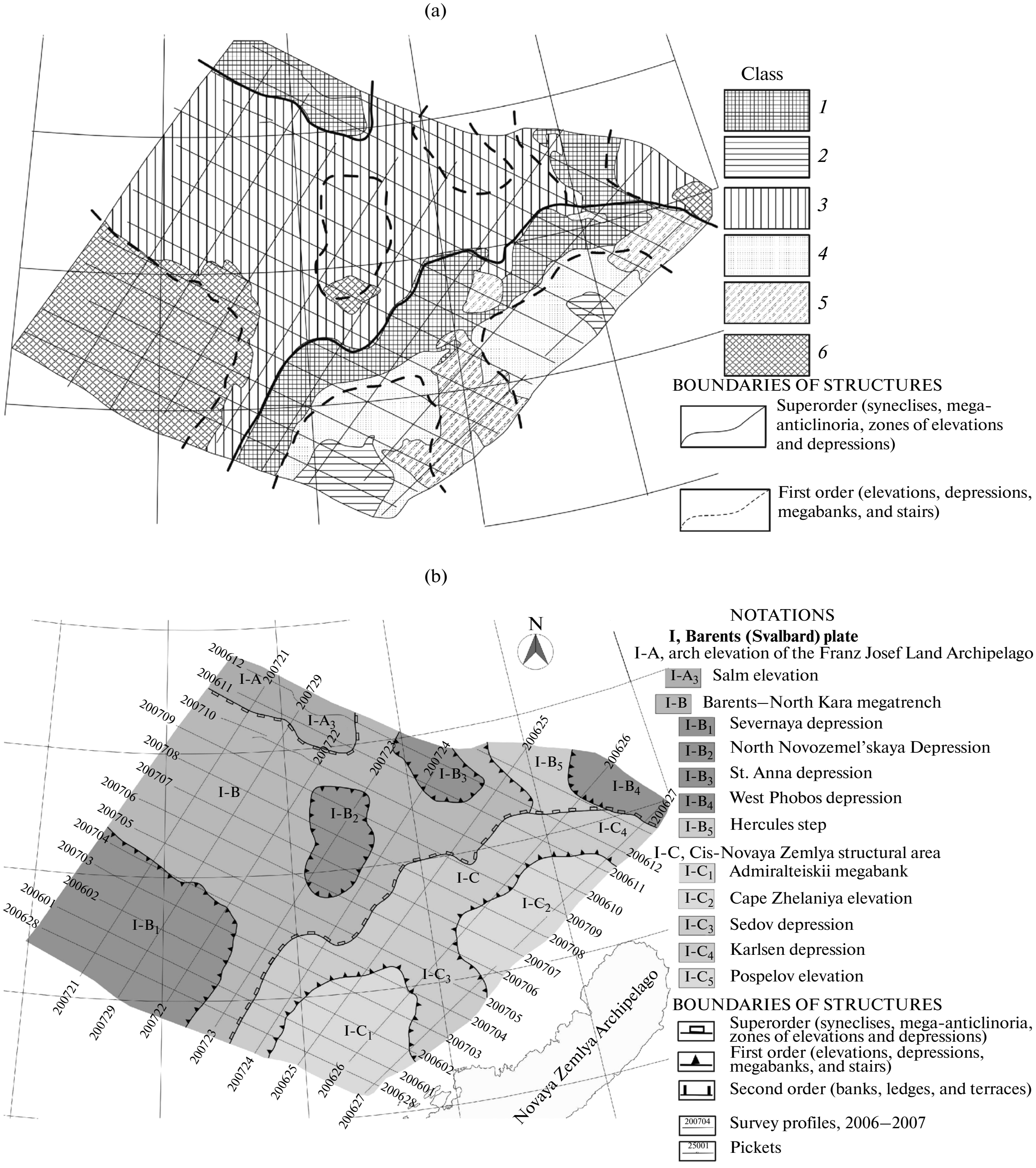

Fig. 4. The compression of the data clustering by the first tectonic stage into six classes (a) and the corresponding tectonic scheme (b).

The key phase of the crust consolidation is associated to the Late Riphean–Pre-Vendian time; however, the Baikal basement of the Barents–Kara superblock contains welded massifs of the Early Proterozoic continental crust. The rigid continental blocks of the basement are separated by riftogenic faults of polycyclic evolution. The current structure of the plate as a part of the platform was formed during Post Cimmerian time along with the ending of the formation of the Paikhoi–Novaya Zemlya orogen.

The data on the structure and composition of the earth's crust in the treated region are based on numerous surveys that were performed at the aquatic area and adjacent lands (Bro et al., 1982). The structure of

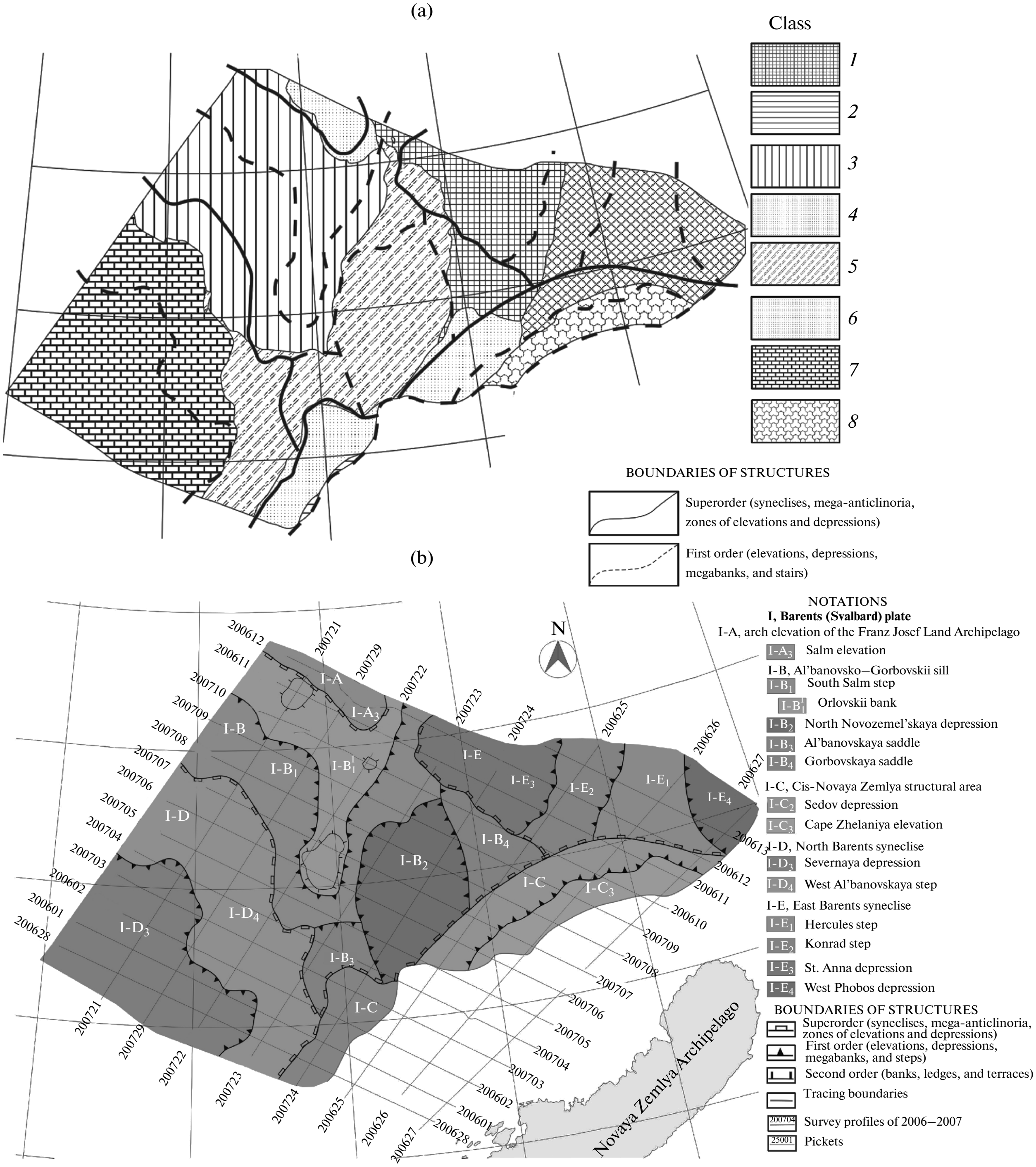

Fig. 5. The data clustering for the Upper-Paleozoic–Triassic part (pz3–t) of the sedimentary layer (a) and the scheme of the structural–tectonic zoning (b) over the top of the Triassic sediments (reflecting layer B).

the northeast of the Arctic shelf of the Barents Sea includes two structural–tectonic stages, viz., upper and lower, which are separated with the surfaces of regional stratigraphic and angular discordances. The lower stage consists of the Pre-Paleozoic faulty basement (which is sometimes considered as a particular stage) and the Lower–Middle Paleozoic litho–stratigraphic complex (LSC). The upper stage includes the sediments from the Devonian to Quaternary times; within this stage five LSCs are distinguished, which consist of pronounced structural transformations in the sedimentary layer of the considered area.

The authors created a spatial model for the sedimentary layer of the Barents Sea shelf. Based on this model, a structural–tectonic analysis of the morphometric characteristics of the seismo-stratigraphic complexes was carried out.

Methods of the studies. The authors used cluster analysis (Mandel', 1988; Aldenderfer and Blashfield, 1989) to classify the structural data on the reflecting layers that belong to the same structural–tectonic stage.

A block of the regular block model is considered as the subject. Each of the blocks includes a point in its center that is characterized by two parameters, viz., thickness and coordinates. A group of subjects (here, the area of the sedimentary layer) that are characterized by the density parameter, i.e., by compact agglomeration of the parameters, is usually considered as a cluster.

To classify and identify the structural data on the reflecting layers, *k*-means clustering was performed using STATISTICA software, which was the best choice for the given case.

The structural parameters were used as the input data for the calculations, i.e., the absolute marks for the tops and bottoms, as well as the thicknesses of seismo-stratigraphic complexes, for each of the blocks of the regular model (presented in tables). The initial conditions, the number of clusters, and the limiting threshold of the classification were then specified.

The formation of the initial data massif for the cluster classification includes the compilation of spatially equidimensional matrices of all the parameters and the standardization of their values that are required for the application of the algorithm to calculate the distances (the equal dimensions of the parameters are necessary), as well as to input the tabulated data into the working software environment.

The treated area is constituted by the Pre-Paleozoic faulty basement, as well as by Lower–Middle Paleozoic and upper structural stages. The latter stage includes the sediments from the Upper Devonian to Quaternary times. The schemes of the tectonic zoning are available for the III_2 (D_3) and B (T–J) levels of the reflecting layer that correspond to the first and second structural stages (Fig. 2).

The goal of these studies was to subdivide the region into zones on the basis of the structural data by the noted reflecting layers.

The region was classified successfully into three, four, five, and six classes using cluster analysis (Fig. 3). Each of the classes was superimposed on the tectonic boundaries of the superorder and first-order structures in the tectonic scheme of zoning by the III_2 reflecting layer and by the top of the Upper Devonian sediments. Quite a good agreement is seen for the clusters and the results of geological mapping.

As shown in Fig. 3, the boundaries of most of the structures are well defined, resulting from the subdivision of the structural data into six classes, excluding local depressions in the central part (Fig. 4). The homogeneity of the classes related to the elevations in the area of the Cis-Novaya Zemlya structural area (the southeast of the region) requires special consideration.

The comparison of data clustering for the section fragment between the III_2 and B reflecting layers that belong to the second structural–tectonic stage results in a less pronounced coincidence of the boundaries (Fig. 5). In this case, 11 parameters were used, namely, the absolute marks according to six reflecting layers (III_2, I-A, A, A2, A3, and B), as well as five values of thickness. The tectonic zoning was carried out for the B reflecting layer. The feature set of initial data should probably be revised and limited.

CONCLUSIONS

The application of cluster analysis based on spatial modeling with the integrated analysis of a wide set of geophysical data showed a good convergence of the results of tectonic zoning of the aquatic area and the zoning based upon the common treatment of the drilling data, as well as of the seismic, gravitation, and magnetic profiling. However, we note that the cost of cluster analysis, including data interpretation, is much lower, even compared to the minimum quantity of the works on summarizing the geological and geophysical data.

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