MORPHOGENETIC CLASSIFICATION OF THE ARCTIC COASTAL SEABED

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Abstract

The Evolution of the arctic coastal zone is a result of the interaction of exogenic and endogenic processes. Previous classifications could not sufficiently characterize the variety of forms and regional features of the arctic seabed because the multitude of interactive processes have not been considered simultaneously. Based upon an a detailed analyses of morphology, origin, age, paleogeography, modern processes, geology and neotectonics, this paper presents a morphogenetic classification which divides the arctic relief into three large groups: structural, structural-sculptural and sculptural and their subtypes.

Introduction

A precise and standardized classification of the variety of relief forms of the Arctic shelf is essential for both scientific and applied purposes. The evolution of the arctic coastal zone, which is controlled by the interactions of modern wave and ice factors and the influence of numerous glaciations and large-scale sea level fluctuations, significantly differs from other coastal areas of the World Ocean. Glaciations have left coastal traces in the western part of the Russian Arctic whereas its eastern part was almost completely drained during glacial periods and the subaerial paleorelief is especially characterized by cryogenic forms: thermokarst, thermoabrasion, thermodenudation and cryodislocation.

Earlier classifications of the coastal seabed relief suggested by Ionin et al. (1990) for the World Ocean or by Shepard (1977) according to the peculiarity of geological structures or sedimentation processes could not characterize the variety of forms and regional features in the arctic zone. The classification presented in this paper is based upon scientifically evidenced information on morphology, origin and age as well as geological and neotectonic characteristics of the seabed relief. This kind of simultaneous analyses of a complex of interactive factors can be called "morphogenetic" approach.

The investigations are based on the results of long-term researches with the application of modern equipment including narrow-beam and multi-beam echo sounders, Parasound, side-looking radars, bathymetric maps and the analyses of numerous sediment samples. According to the Science and Implementation Plan of the Arctic Coastal Dynamics (ACD) project (IASC 2001) the classification will be designed for the integration into a circum-Arctic coastal Geo Information System (GIS).

Results and discussion

The seabed evolution is determined by both modern and paleogeographical processes such as vertical tectonic and glacio-isostatic movements. Among the exogenic and endogenic coastal processes it is possible to allocate active processes, which directly contribute to the formation of the shelf relief, and passive processes, which predetermine the display of the active processes and direct the course of their development. Active processes can be modern (hydrogenic, gravitational etc.), paleogeographical (glacial, erosional etc.), and in some cases

anthropogenic processes. Structural forms, with few exceptions, are related to passive morphogenetic factors. By such an approach it is possible to allocate three major categories of the seabed relief: structural, structural-sculptural and sculptural. This kind of subdivision is relative in many respects because the majority of relief forms is caused by both endogenic and exogenic factors and processes. It is necessary to determine the prevailing value of various factors of concrete seabed forms. A certain subjectivity in allocating structural and sculptural forms of a relief and in their morphogenetic division into active and passive factors cannot be avoided. The necessity to characterize the relief "layer by layer" arises inevitably when specialized geomorphological maps have to be produced and a database to be used in a GIS environment within in international network are has to be designed. As an example the following layers could be used: first layer - endogenic background; second layer - relief forms connected with the action of paleogeographic factors; third layer - modern relief forms caused by the action of endogenic processes.

Typical structural forms are large seabed forms predetermined by geological structures and created by endogenic processes, i.e. folded and/or fault-fracture tectonics, volcanism, vertical movements of the Earth's crust etc. Geological structures underlie all forms of the shelf relief and determine the position of large relief forms, such as synclinal underwater depressions, anticlinal and brachyanticlinal underwater raisings, monoclinal plains, flexure ledges etc. This large group can be further divided into two genetic types and some subtypes. (1) The *tectogenic type* includes plicated forms (anticlinal, brachyanticlinal, synclinal, brachysynclinal, monoclinal, uniclinal), disjunctive (fault and grabens, horsts, fracture-blocks) and non broken structural dislocations (subhorizontal and inclined plains). (2) The *volcanogenic type* includes magmatic and mud volcanic subtypes. Usually relief forms created by volcanic processes like lava domes and mud volcanic cones (Norwegian Sea) are located in water depths of more than 200 m.

In our morphogenetic classification structural-sculptural forms are referred to a category of transitive, often relict formations. These forms can be divided into the following subtypes: (1) *erosion-tectonic* (structural-erosive with fluvial or glacial relief, structural-erosive-gravity created by turbidity currents), (2) *glacial-tectonic* (structural depressions in internal basins of fjords and covered by glacial-marine deposits, structural swells with accumulative superstructure, structural forms with a surface of glacial ablation corresponding to fjords and adjacent underwater trough valleys, structural forms with glacial ablation and accumulative marginal troughs and anticlinal swells blocked by moraines).

Exogenic subaerial and subaquatic processes are the most active ones. The sculptural relief of the seabed is created by destructive and accumulative processes such as ablative and accumulative activity of Late Quaternary glaciers on the shelves of the marginal and internal seas of polar and subpolar climatic zones. Glacial forms are most typical among the relict exogenic sculptural relief forms within the limits of the glacial shelf in the Arctic. The sculptural relief forms can be divided into seven types and several subtypes: (1) *glaciogenic* (glacial-ablative, glacial-accumulative and glacial-dynamic), (2) *cryogenic* (thermokarst relict forms such as extended underwater depressions and hollows documented by echosounding and acoustic profiling in the Laptev, East Siberian and Pechora Seas; the origin of these negative relief forms is connected with the thermal destruction of ice lenses and wedges during the late glacial transgression, the size ranges from 2 to 10 m depth, 10-100 m width and extension of 3-4 km depending on the thickness of the lenses of repeatedly-cavern-load ice; in the Chukchi Sea the relict thermokarst relief forms are large depressions which are

covered by a 7-10 m thick Holocene sediment layer; cryodislocative relief forms represented by folds and frost mounds have a local distribution in the Arctic, for example Western Yamal Peninsula), (3) *hydrodynamic* (wave abrasion forming modern cliffs and benches and paleo underwater terraces, wave accumulation with ancient underwater accumulative forms and coastal barrier islands, spits, beaches, etc., abrasive-accumulative processes forming modern underwater coastal slopes, mainly subglacial accumulative and tidal forms such as sandy waves and ridges, tidal troughs, step tidal benches, etc.), (4) *torrentogenic* (accumulative and erosive as for example in the Bering Strait where due to strong quasistationary currents a subhorizontal plain lacking modern deposits is formed in the central zone while as a result of deposition underwater cones are generated in the adjoining southern Chuchi Sea), (5) *fluvial* (fluvio-glacial and potamogenic forms with ice-marginal valleys and channels of paleo-rivers, ancient and modern deltas, river mouth bars, etc.), (6) *gravitational* (rockfall-landslides, turbidity currents) and (7) modern *anthropogenic* (constructive forms connected with ground spoil, artificial islands, basements of port constructions, oil derricks etc., destructive forms with artificial cuts, port channels, waterways in gulfs and other near port constructions within shallow water).

Conclusions

The Arctic shelf can be described as a zone developed under long-term endogenic and exogenic interactions. The initial structure was created by the basement surface which was and is constantly reworked by a complex of paleogeographical and modern processes within various glacial and interglacial periods and sea level fluctuations. The classification suggested in the present article is based on scientifically evidenced data on morphology, origin and age and on the geological and neotectonic features of the seabed relief and considers the multitude of natural factors and their interactions and evolution in time. Three types of major relief forming processes were distinguished and further subdived: structural, structural-sculptural (transitive) and sculptural (formed by modern and paleogeographical exogenic processes).

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