The shores of the contact zone of the Subarctic and moderately cold seas

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Abstract. Longitude sectorality and latitudinal zonality of morpholithogenesis on the coast of Sakhalin is the result of the unique geographical position of the island, which is a zone of mutual influences and interactions of neighboring geosystems of the subarctic Sea of Okhotsk and the moderately cold northern part of the Sea of Japan – a contact geographical structure. Based on the digitizing of maps of morphogenetic types of shores, modern morpholithodynamic settings and lithological complexes of the coast, geomorphological and morphodynamic differences of the shores of Sakhalin Island are shown, the eastern shores of which have a subarctic appearance, and the western shores are washed by the temperate sea.

1. Introduction

The geosystems boundaries are relatively mobile zones of mutual influences and interactions of neighboring geosystems – contact geographical structures [1, 2, 3]. At the same time, most of the geomorphological boundaries can be considered as a kind of contact zones distinguished in physical geography, and the vast majority of terrestrial processes and phenomena are confined to them [4, 5]. Earlier we noted that the morphoclimatic position (geospatial parameters and related differences in morpholithodynamic parameters) of Sakhalin Island and the island-arc systems of the Northern Pacific allow us to consider them as contact zones of different types of seas, as well as seas and oceans [6].

The Sakhalin shores of the moderately cold northern part of the Sea of Japan and the subarctic Sea of Okhotsk are located 30–140 km from each other, and the ocean and sea shores of large islands in island-arc systems are separated by only a few kilometers. Thus, the morpholithodynamic characteristics of the shores of the contact zones, along with the peculiarities of hydrodynamics and thermal regime of the separated water areas, also determine the morphoclimatic parameters of the contact zone itself.

2. Methods and results

The presented work implements the methodology of morpholithodynamic studies based on both traditional and modern methods of obtaining and analyzing geospatial and geological-geomorphological information. Analysis of maps of morphogenetic types of the shores of the Northern Pacific, modern morpholithodynamic settings and lithological complexes of the coast of O. Sakhalin Island was carried out in the Quantum GIS geographic information system, the contours correspond to the accuracy of the original maps [7, 8]. To obtain the length of the coastline of each type, the Add
Geometry Attributes tool with the Ellipse Calculation option was used. Calculations were performed on the ellipse WGS84 EPSG:7030.

The main features of morpholithogenesis specificity from the marine and oceanic side of the contact zones were established by analyzing maps of morphogenetic types of the shores of the Northern Pacific (figure 1).

![Kuril Islands](image1)

![Sakhalin Island](image2)

**Figure 1.** Distribution of morphogenetic types of coasts of the island-arc systems of the North Pacific: 1 – with glacial-tectonic dissection (fjord), tectonically determined, 2 – abrasion-denudation; 3 – abrasion (aligned and coiled); 4 – abrasion dead; 5 – thermoabrasion and ice; 6 – abrasion-accumulative (leveled and coiled); 7 – created by wave processes, beach; 8 – created by wave processes, lagoon.

As expected in accordance with the previous field studies, in percentage terms, the seashores of the 1st and 2nd types prevail over the ocean shores of these types, both the Aleutian Islands and the Kuril...
Islands [6]. Abrasive shores in the Aleutians predominate on the sea side, and on the Kuril Islands, on the contrary, on the ocean side. The extent of the abrasive-accumulative shores is higher on the ocean side of the island-arc systems. The length of accumulative shores is also greater from the ocean side both in the Kuriles and in the Aleutians. The revealed features of morphogenetic types of sea and ocean shores indicate the predominant contribution of hydrodynamic and thermal regimes of the separated water areas to this distribution. Morphoclimatic parameters of the actual contact zone (island arc), unlike those on Sakhalin Island, do not affect this distribution. The morphotectonic and structural-formational conditionality of the development of the shores of island arcs is undoubtedly significant and requires further research. The obtained distributions of coast types from the sea and ocean sides of island-arc systems served as a starting point for updating the problem of the peculiarities of the development of the shores of linear contact zones separating marine basins, as well as seas and oceans.

Using the example of Iturup Island (Kuril Island Arc) and Chugunidak Island (Aleutian Island Arc), the features of the modern coastal morpholithogenesis of the contact zone and Aeolian accumulation, the so-called short-range transport, which refers to specific coastal relief-forming processes summing impacts in the Paleogeographic Middle-Late Holocene time scale were considered [9]. The most significant differences in the modern morpholithodynamics of the shores were established when analyzing the morphometric parameters of the megafestons of the beach on the island of Iturup. It turned out that on opposite sections of the Vetrovoy Isthmus, the size of ocean megafestons is more than twice the size of Okhotsk megafestons.

When analyzing the Aeolian morpholithogenesis associated with the wave processing of mainly pumice-pyroclastic material during explosive eruptions in the Holocene, Neopleistocene, it was found that the dunes on the sea side of the Vetrovoy Isthmus of Iturup Island were formed as a result of the destruction of high coastal ledges composed of pumice-pyroclastic material of the Neopleistocene, during the period of increased erosion with sea level rise about 1.5 thousand years ago. The formation of younger dunes of the ocean coast is largely due to the processing of pyroclastic material that entered the coastal zone about 1000 years ago directly during the eruption [10]. A significant proportion of ash material in pyroclastics also caused a very rapid formation of pelitic sediments in a lagoon-type basin on the ocean side of Vetrovoy Isthmus of Iturup Island.

Sakhalin Island, whose unique geographical position allows us to consider it as a kind of contact zone of the border strip of the subarctic and temperate zones, characterized by a consistent change of natural conditions and temperature regime from north to south, has become a key area for detailed studies of the features of morpholithogenesis of the shores of linear contact zones separating marine basins, as well as seas and oceans.

The northern and eastern shores of Sakhalin Island are affected by the physical and geographical conditions of the subarctic zone. The formation and development of the shores is determined by the cold Sea of Okhotsk, which belongs to the category of subarctic freezing seas. The shores of eastern Sakhalin are characterized by the presence of permafrost rocks on the coast, including at the base of lagoon embankments, the development of thermal abrasion and the existence, up to mid-July, of coastal ice.

The western and southern shores of Sakhalin Island are more affected by the physical and geographical conditions of the temperate zone. The moderately cold conditions of the northern sector of the Sea of Japan provide a relatively frequent temperature transition through zero, the absence or short-term formation of ice and soldered ice.

Detailed zoning of morpholithodynamic conditions of the Sakhalin coast generally confirms the results of the analysis of the map of morphogenetic types of the shores of the Northern Pacific (figure 2).

There are about 2 times more abrasive shores from the Sea of Okhotsk than from the Japanese side. There are 2.5 times more dead abrasive ledges on the shores of the Sea of Japan, there are significantly more abrasive-accumulative and terraced shores. Interestingly, in general, the length of the shores with a dead abrasive ledge is higher in percentage terms on the Sea of Okhotsk than on the Sea of Japan. Such a distribution of coast types, along with the structural and geological features of the structure of the coasts, is probably due to a change in the intensity of destruction of the shores of the Okhotsk and
Japan Seas, during the warm periods of the Holocene, characterized with a longer period of "open sea" at negative air temperatures [11].

![Figure 2](image1.png)

**Figure 2.** Distribution of morpholithodynamic conditions along the shores of Sakhalin Island. 1 – active cliff in bedrock, 2 – active coastal ledge in weakly consolidated and loose formations, 3 – dead cliff in bedrock, 4 – dead cliff with a low terrace, 5 – dead coastal ledge in weakly consolidated and loose formations, 6 – accumulative Holocene coastal forms.

It should be noted that the Sakhalin shores of the Japanese and Okhotsk Seas practically do not differ in terms of resistance to destruction (figure 3).

![Figure 3](image2.png)

**Figure 3.** Distribution of lithological complexes of the coast of Sakhalin Island (using [8]). Rock groups: 1 – loose; 2 – weakly lithified (Maruyam Formation); 3 – weakly lithified (Okobykai Formation); 4 – strongly lithified (Kholm Formation); 5 – strongly lithified (Pila Formation); 6 – strongly lithified (Arakai Formation); 7 – strongly lithified (Ostrin Formation); 8 – strongly lithified (Langer Formation); 9 - strongly lithified intrusive rocks form promontories protruding into the sea.
3. Conclusion
For the first time, a quantitative characteristic of the results of the main relief-forming processes was obtained and the originality of the modern morpholithodynamics of the shores of the Northern Pacific was clearly demonstrated. An equally important result of the analysis is the actualization of the problem of the development peculiarities of the shores of the linear contact zones of the Northern Pacific, separating the sea basins, as well as the seas and oceans. Complex geological and geomorphological studies confirm the morpholithodynamic and geomorphological specifics of the shores of the contact zones.

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