Analysis of coastal dynamics and permafrost conditions of the Yamal Peninsula using GIS

Alisa Vladislavovna Baranskaya[1], Stanislav A. Ogorodov[1], Nataliya G. Belova[1], Alexey P. Vergun[1], Natalya N. Shabanova[1], Dmitriy E. Kuznetsov[1], Olivier Gosmant[2], Eric Cauquil[2], Annie Audibert-Hayet[2], Pascal Dauboin[2], & Jean-Baptiste Geldof[2]

[1] *Lomonosov Moscow State University, Moscow, Russian Federation*
[2] *Total E&P Recherche Develoment, Paris, France*

Determining the features of coastal dynamics and the rates of coastal processes can be a difficult task for any region of the world. In the Arctic, knowing the main trends of the development of coastal processes and their expression in the morphology of coastal landforms, is of vital importance. Most of the settlements, transport corridors and areas of industrial development in the Russian Arctic are situated within the coastal zone. Polar coastal regions are important for subsistence hunting and fishing as well as for mineral resource exploration. Therefore, knowledge about Arctic coastal dynamics is necessary for local, regional and state government land management, as well as local subsistence users and mining companies.

In the Arctic, the movements of coastlines result not only from the direct action of wave abrasion and accumulation, but are highly dependent on permafrost factors which are absent in the temperate and tropical regions. To better understand coastal dynamics, coastal morphology and evolution should be observed together. The state of permafrost should also be considered, including its properties, Quaternary history, sediment composition and ice content. The presence of permafrost results in very specific processes of thermal coastal erosion. Despite the short dynamically active period (ice-free period) when the waves can affect the coasts, morpholithodynamic processes in the coastal zone of the Arctic seas are characterized by significant rates, determined by low stability of coastal forms composed by permafrost. About half of the length of the Eurasian Arctic coast is affected by thermal abrasion and retreats with average rates from 1 to 5 m/year (Ogorodov, 2008).

One more specific feature of the Arctic coasts is the action of sea ice on the coasts and bottom of seas. The length of the ice-free period influences the rates of thermal abrasion, while the wave energy coming to the coasts depends on the distance of the wave fetch. Therefore, the Arctic coastal dynamics should be analysed with connection to sea ice features in the region as well. Another important component is the meteorological factor, as the Arctic coasts composed by permafrost are the most vulnerable to the quick ongoing climatic changes.

For the investigations of coastal dynamics on a local scale, a regional study was made for Yamal Peninsula, Russia, by MSU and Zubov State Oceanographic Institute in collaboration with Total oil and gas company. Yamal is the centre of the Russian Arctic and one of the key areas of the North. In the last years, due to active oil and gas exploration, the industrial infrastructure is moving further and further towards the north. The main objects are situated in the coastal zone, as it is the most accessible location (by water transport). Integrative analysis of coastal morphology and dynamics, types of coasts, in connection with permafrost and Quaternary geology, sea ice impact and climate change will be a basis for decision-making connected with, on the one hand, designing and building separate industrial objects, and, on the other hand, planning a long-term strategy of development for the region.

To perform such comprehensive analysis, an integrative GIS-system was created. It includes layers on permafrost properties: Quarternary geology, sediment composition, depth of permafrost, temperature of permafrost, ground ice, active layer properties, etc. Information on sea ice impact is presented for the south-western part of the Kara Sea, for the Gulf of Ob and Baydaratskaya Bay. Layers on coastal morphology and dynamics include maps of types of coasts for Yamal Penisula in the scale of 1:1000000, together with maps of coastal resistance to wave erosion (with all other conditions being equal). For key areas, detailed maps of coastal dynamics are provided, including geomorphological maps, and maps of coastal

retreat with the indication of coastal retreat rates derived from multitemporal satellite imagery analysis. The difference of the maps of types of coasts from the existing ones (in particular, the integrative global map of types of coasts created in the framework of the ACD project (Arctic Coastal Dynamics Project Team, 2008)) is that the present study focuses on the local scale, with Yamal Peninsula being the main object of investigations. A separate part of the GIS system is dedicated to sea bottom morphology and sediments including bathymetric, geomorphologic and other maps of the south-western part of the Kara Sea, Gulf of Ob and Baydaratskaya Bay. Meteorological data of the existing stations is also provided within the GIS.

The comprehensive analysis of such GIS system allows to determine the most dangerous areas of Yamal Peninsula which can be affected by the most intensive coastal erosion in the nearest future. Due to the integrative processing of permafrost, geomorphological, meteorological and other data, it can be suggested, which factors will be the most important for the development of a certain segment of the coastline.

References

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A comprehensive study of coastal dynamics has been made for Yamal Peninsula using GIS in the framework of a joint project between Total and Zubov State Oceanographic Institute. Data on geomorphology, dynamics and permafrost features of the coasts have been combined. As a result, we have been able to analse the distribution of the coastal sections which are the most vulnerable in the future. Such investigations can help with planning and design of coastal infrastructure, as well as for global regional decision-making