Human-induced relief and permafrost dynamics at Yamal Coast of Baydaratskaya Bay, Kara Sea

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Coastal dynamics monitoring took place at the West Yamal, near the place where 'Yamal-Europe' gas pipeline network crosses Baydaratskaya Bay, 20 years before the beginning of construction (since 1988). Lithological, geomorphological and geological structures of the 20 kilometer section around the proposed pipeline alignment were studied simultaneously. Monitoring of landscape dynamics in this area continued during the construction period. A considerable amount of data was accumulated both before and during pipeline contstruction. This can be used to assess the sensitivity of the coastal landscape to anthropogenic influences. In addition, climate changes which practically coincided with the beginning of the construction, has become an important factor affecting coastal dynamics in the last decade. These changes expressed in air temperature increase, ice coverage reduction, prolongation of dynamically active period and storm activity growth. As a result the trigger mechanism was launched leading to irreversible changes of coastal landscapes which require urgent intervention to protect the newly constructed facilities of oil and gas infrastructure.

The coast in the study area is represented by the Late Pleistocene-Holocene lake-alluvial poorly dissected plain with altitudes up to 20 m a.s.l. In some places the plain is significantly lowered by aeolian and thermokarst processes (up to 4-10 m a.s.l.). Merging thermokarst basins of different generations are numerous within the plain; ice wedge polygons are forming on their humid bottoms. An extensive section of laida separated from the sea by modern barrier beach is situated directly within the pipeline landfall. This section is presented by a low (up to 3 m) wetland with lots of lakes, being under the influence of tides and storm surges. In areas where high surfaces meet the coastline the coast is abrasional with pronounced coastal bluff composed mostly by frozen sands with low or medium ice content. Retreat rate of such coasts does not usually exceed 0.4-0.6 m [Kamalov et al., 2006]. The barrier beach is located in the center of study area; it separates lagoon and laida from the sea. It represents a typical full profile beach – a very stable accumulative form ideal for wave energy dissipation. It was chosen for the exit site of the underwater pipeline crossing construction through Baydaratskaya Bay. The geological structure of the coast is studied by drilling, including drilling from fast ice in the shallow waters (Fig. 1).

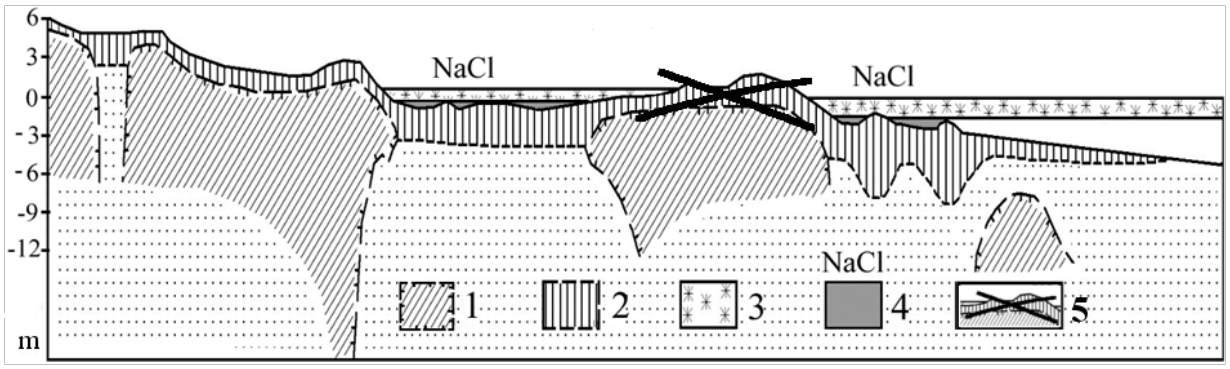

Figure 1: Geocryological crossection of Yamal coast of Baydaratskaya Bay, Kara Sea: 1 – permafrost; 2 – seasonally frozen (thawed) sediments; 3 – sea ice, 4 – cryopeg, 5 – seasonally thawed layer removal.

Permafrost is developed under the slope of high surfaces and under the barrier beach, while the sediments between them (under the lagoon and laida) are in unfrozen state, with permafrost cap both from the side of high surface and barrier beach. Relict permafrost block was found in shallow waters at a depth of about 2 m. In winter the cap of seasonally frozen sediments is formed within the underwater slope and lagoon up to the depth of about 3 m. The maximum seasonal freezing in shallow waters is marked under the longshore bars, as here sea ice in winter reaches the bottom. During the same period when the water exchange with the open sea is deteriorating in the depressions between the longshore bars and in the lagoon an increase of salt concentration as a result of ice formation takes place. It creates the conditions for the formation of saline soils and cryopegs. During summer and autumn the active layer becomes thawed; within the barrier beach its depth is 1.5 m.

Construction of the gas pipeline system began in 2007 and has significantly changed the appearance of the coastal zone. Sandy material composing the seasonally thawing layer on the surface of the barrier beach was almost completely removed for construction purposes. Barrier beach was formerly a natural and reliable protection from high storm surges. In the first year of construction the workers' settlement located on the laida right behind the barrier beach has been flooded as a result of storm surge 1.5 meter height typical (non-extreme) for October. Based on the altitude of the driftwood line within the laida the height of extreme surges here is at least 2.5-3.0 m a.s.l. Dredging in the river estuary south of the barrier beach led to a shortage of sediments in the estuary and partial interception of sediment flow coming from the south. As a result, abrasion accelerated on the adjacent parts of the coast and on the underwater slope, including the area of the pipelines alignment. Pipeline constructors were forced to proceed with the coast protection.

The surface of the barrier beach was artificially lowered and frozen sediments under the barrier beach were subjected to thawing. The dam made of coarse material with concrete block revetment was built directly on the barrier beach surface. As planned by the constructors, the dam was to protect the construction area from storm surges and coastal erosion. However, due to the removal of sandy material from the barrier beach the seasonally thawed layer shifted down the section, leading in permafrost thawing. As a result, coast protection construction simply 'failed' into the thawed permafrost. It should be noted that a similar technology was previously used on the Shishmaref settlement in Alaska, where it has proved to be completely unsuitable for the permafrost zone conditions [Mason et al., 2012].

Coastal processes activation on the Yamal Peninsula was caused by the construction of the pipeline excluding the existing norms and rules of work in the permafrost zone. It once again reminds us of the need for competent, evidence-based approach to environmental management in the Arctic at all stages of design, construction and operation of oil and gas facilities.

Acknowledgements

The work was supported by RFBR projects No 14-05-00408-a and 16-36-60099-mol_a_dk.

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