THE MECHANISM OF THE SEA COAST DESTRUCTION IN MARRE-SALE, WESTERN YAMAL

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The key site Marre-Sale is located in Western Yamal on the coast of the Kara Sea. The observations of coastal dynamics have been carried out since 1978. The 4.2 km study site is related to the second and the third marine terraces. The geological section is composed of marine clay with layers of sands, quite often folded (probably by glaciers). The top part of the section is represented mainly by continental deposits (alluvial, lacustrine, eolian etc) of sands, peat near the surface, and rarely sandy-loams and loams. At the study site we can allocate three basic lithological types of coastal sediments: 1) mainly sandy; 2) mainly clay; and 3) sandy-clay (marine clay with layers of sands and loams usually underlying the strata of continental sands). The last type is widespread in the study area.

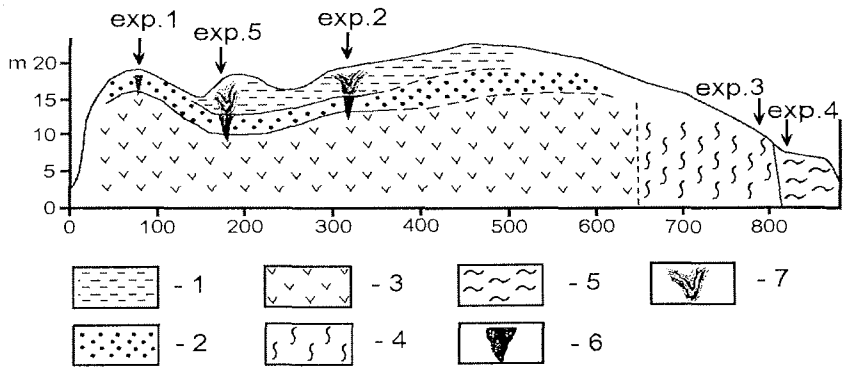

Figure 1. The section of the Quaternary sediments, Marre-Sale key site, northern part. 1 – syncryogenic continental sediments, which had thawed and then froze again epigenically (sand, sandy-loam with ice-wedge casts); 2 – syncryogenic ice-rich continental sediments (sand, sandy-loam with ice wedges); 3 – epicryogenic marine sediments (homogeneous clay with rare sand layers); 4 – folded epicryogenic marine and littoral sediments, frozen before the beginning of fold formation (interstratification of clay and sand); 5 – folded epicryogenic marine and littoral sediments, which had thawed after the fold formation had completed and then froze again epigenically (interstratification of clay and sand); 6 – ice wedges; 7 – ice-wedge casts, filled with sandy-loam and peat.

The cryogenic structure of coastal sediments is complicated. Depending on the cryogenic origin we can recognise four types of permafrost stratigraphic sections: 1) syngenetically frozen ice-rich continental sediments (thickness up to 5-7 m), and bedded by marine and littoral epigenically frozen sediments; 2) syngenetic continental sediments (thickness up to 7-10 m) withthe upper part (thickness up to 4-6 m) that had thawed and then frozed again epigenically; 3) marine and littoral epicryogenic sediments froze before the beginning of fold formation; and 4) marine and littoral epicryogenic sediments that thawed after the fold formation had completed and then frozed epigenically. Usually the sediments of the first and second type are bedded by the sediments of the third or the fourth type. In a number of sections the thickness of syngenetically frozen sediments is reduced, and epicryogenic marine

sediments lie practically below the active layer. Figure. 1 shows the section of the Quaternary sediments with various types of cryogenic structure.

The gravimetric moisture content of the sediments (without taking into account polygonal-wedge and massive ground ice) consists of 20-30% for sand (maximum up to 45% in syncryogenic sediments), 30-50% for clays and loams (maximum up to 100-120% in the layers of epigenetic clays). The ice wedges (width up to 3 m) were found at different depths. In syncryogenic sediments of the first type the ice wedges lie close to surface (at 10-20 cm under the active layer), the size of polygons changes between 15 and 30 m. In the sediments of the second type, ice wedges lie below 4-6 m, quite often penetrating into the underlying marine sediments. In the marine sediments (both in sands and clays) small massive ground ice bodies are found.

In September 2002, observation of the coast was carried out following the long heavy storm. The observations allowed us to recognise different segments of the coast, distinguished by the different mechanism of destruction. The mechanism can vary during the further degradation of the cliff, but the observation executed immediately after the heavy storm allows us to reveal "starting mechanism" of destruction.

During the observations, the coordinates of borders between the segments with various mechanism of destruction and various complexes of destructive processes were determined. These coordinates, like were coordinates for the top and base of the cliffs at the key site, were determined with the help of electronic tachymeter (DTM-350) and differential satellite method (DGPS) with the use of the equipment GeoExplorer3. The precision of fixing the top edge of the cliff reaches 0.1-0.2 m, and with the help of DGPS - 0.5-1 m.

More than 20 segments with the various mechanism of destruction were recognized during the observation of the coast. It was found that the major factors influencing the destruction mechanism are the composition, cryogenic structure and ice content of the sediments, as well as the wave activity. Thus, the presence of the ice-rich clays determines the high activity of thermodenudation, thermoersion, slumping processes, mudflows etc. These processes can be considered as a consequence of coastal erosion, because the basic reason of their activation is the breach of the equilibrium profile of the slope owing to erosion at the cliff base.

In total during the observation four major types of destruction were recognized:

1. Coastal erosion and thermoerosion processes. These processes accompanied by formation of wave niches and breakage of the basal part of the cliff (Fig.2). Such mechanism develops mainly at the sites where the ice-rich clay sediments lie at the basis of cross-section and at the sites with high wave activity.

2. Talus mechanism of destruction. This mechanism develops mainly at the sites of the coast composed by ice-poor sands. Quite often it is accompanied by deflation of sands and slope erosion.

3. Slumping mechanism of destruction. This mechanism is developing within the total height of the coastal slope. It is characteristic for the sites with ice-rich clay. Frequently at these sites thermoersion, thermodenudation and mud flows develop as well.

4. Thermodenudation processes. These processes are characteristic for sites where polygonal-wedge ice and massive ground ice occur. As a result of thermodenudation and slope erosion thermocirques and thermoerosion ravines are formed within the limits of the coastal slope. At some sites, the slopes are complicated with ground mounds ("baidjarakhs").

Frequently the combined type of destruction (1+2, 2+3 etc.) is recognized. The talus processes at the top part of the section and landslides at the base of the slope form in widespread combination. At the same time, erosive cliffs and wave niches were found quite often in the base of such slopes. This combined mechanism is characteristic of sites where ice-rich clay sediments lie in the base of the cliff and ice-poor sandy sediments lie in the upper part of the section.

Figure 2. The wave niche at the base part of the cliff, formed by the ice-rich folded marine and littoral sediments, Marre-Sale key site.

Table 1 shows a portion of the table reflecting the results of coastal observation at Marre-Sale area in September 2002, (numbers of sites increase from south to north). The received data indicates that morphology and gradients of the cliff are determined by various mechanisms of destruction connected to features of geological and cryogenic structure of sediments. The digital database concerning the dynamics of sea coast in Marre-Sale area was enlarged on the basis of these coastal observations.

Table 1. Results of the observation over the sea coastal dynamics at the key site Marre-Sale, total extent 4.2 km fragment (September 2002).

Segment	Extent of the segment	Major type of destruction	Structure of the section	Description of the cliff and its morphometric parameters	Major factors of coastal destruction
1	200	2	Mainly ice-poor sands, in the upper part with peat	Relatively stable slope with the gradient 30-35^0, almost plain, with height 10 m, locally - erosive cliff with the height up to 0.7 m.	Talus processes, locally coastal and slope erosion
2	160	2	Mainly ice-poor sands, in the base of the section with clay layers	Relatively stable slope with the gradient 30-35^0, almost plain, with height 14 m, with erosive cliff (height up to 2.5-3 m)	Talus processes, locally coastal and slope erosion, slumping processes
3	220	1+2	Mainly ice-poor sands; earlier at this site ground massive ice bodies had been found	The slope with the gradient 40-45^0, almost plain, with height 24 m, erosive niche with the height up to 0.5m and depth up to 1 m.	Coastal erosion, talus processes
4	180	2+3	Ice-poor sands, bedded by clays	The slope with the gradient 40-45^0, almost plain, with height 22 m, the beach locally is blocked by landslides	Talus at the top part of the slope, slumping processes at the base part
...	...	...	...	...	...
23	300	1+2	Ice-rich sands and sandy-loams with ice wedges (thickness of sands 4-5 m), bedded by ice-poor clays	The slope with the gradient 50-60^0, with height 22 m, erosive niche with the height up to 2 m and depth up to 3.5 m.	Coastal erosion, talus processes at the top part of the slope, crumbling of huge ground blocks at the base part locally - slumping processes

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