THE INFLUENCE OF PERMAFROST DEGRADATION IN NORTH RIVER BASINS ON MARINE AND ESTUARY COASTAL DYNAMICS IN THE MIDDLE SIBERIAN NORTH

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Introduction

Global climate fluctuations and local technogenic impacts influence cryolithozone state. Coastal dynamics of the Arctic seas and huge rivers of the Eurasian North are especially sensitive. Massive ice complexes, widespread in northern river valleys, melt due to thermal and chemical impacts; this leads to river flow enlargement, changes in the salinity of estuaries and offshore sea waters, and triggers landslide development on terrace slopes. This leads both to infrastructure destruction at northern ports and to increased runoff of sediments and salts. A larger sediment runoff may alter the depth of a sea. The coastal dynamics of northern river estuaries and mouths can be used to indicate regional climate change and local technogenic impacts.

Results

Multiple field investigations have demonstrated the fact that permafrost degrades in areas experiencing climate warming and in areas where industrial activity disrupts the cryolithozone. There are four main geocryological risks associated with permafrost degradation [Grebenets, Kraev, 2003]:

1. World ocean transgression [in part] due to ground ice and glaciers melting;
2. the activation of dangerous cryogenic processes (thermokarst, thermoerosion etc.);
3. the release of millions of tons of pollutants (frozen at the moment) to river systems and then to the world oceans as well as to the atmosphere;
4. the destruction of northern towns and tribal settlements.

In 1999-2002 field investigations of the modern coastlines of rivers, seas, lakes, and reservoirs were conducted in middle northern Siberian region. Sediments with high ice contents showed the fastest reaction to environmental changes and it was revealed that the action of water has the most destructive influence. For example, observation of several thermodenudation cirques on the Noril'skaya River (Pyasino lake basin) east coast revealed mean diameter growth from 60 to 80 m. Noril'sk meteorological data analysis did not show any tendency to climate warming. Instead, increasing thermodenudation along the river coasts is associated [Grebenets, 2003] with the local technogenic impact of large, metal producing factories of the Noril'sk industrial region. The mechanism by which

Fig. 1. Thermodenudation cirque is on Norilskaya river shore. July, 2002

industrial emissions can induce a ground-thermal response is outlined below.

First, modification to the forest tundra landscapes occurs, leading to an increase in the thickness of the seasonally thawed layer. This allows an increase in ground runoff to the river after an overflow event. The near shore area comes under mechanical and thermal influence of the river. Hydrological data for 1938-78 from the Noril'skaya River [Hydrological data..., 1978] indicate that mean water level reaches approximately 3.2 m during a debacle and 3.7 m during an overflow. These levels both reach the base of massive ice sheets. Physical impact due to floating ice causes mechanical destruction of shore ice massifs; thermial destruction is caused by relatively warm river waters. As a result of a single hydrological year the additional river runoff, formed by melting ice, enters the stream. The shore slope angle is reduced in cirques due to the thermal effect of the melt water, and the shore slopes between the cirques are destroyed mainly by mechanical action until the massive ice is exposed. Additional runoff increases the base water level in the river. The exposed shores undergo rapid melt due to solar radiation and warm summer temperatures.

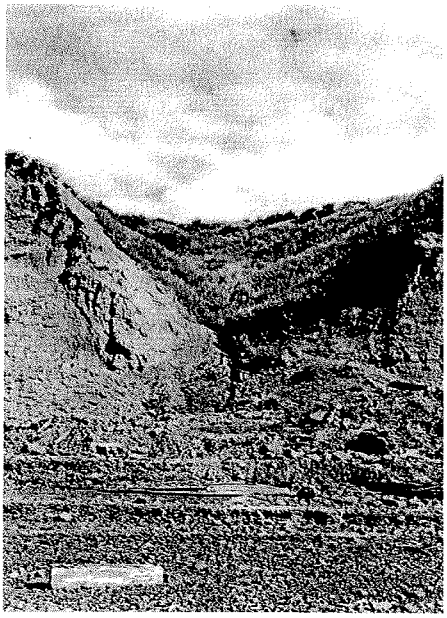

Fig. 2. Interblock depression reasoned by ice-wedges thawing. Micro terrace relief formed of slimy sediments. Mouth of Yenisei, July 2003

Second, accompanying emission of gasses by the Noril'sk industrial region (for example, sulfur dioxide emissions reach up to 2 M tons a year) causes acid rain, increasing the salinity of seasonally thawing layer waters. They transport dissolved chemicals both to the permafrost table and the top of massive ground ice sheets. The chemicals undergo various reactions both with mineral and organic components of the ground (also with other chemicals) or deposit when the bottom of the active layer is reached. The chemical reactions may be classified as exothermic and endothermic; both types of reactions have associated effects. Exothermic reactions introduce the heat to the permafrost table. Endothermic reactions increase ground salinity, which increases frozen ground strength thus resistance to slope cryogenic processes and destruction by river ice. The salinization of runoff waters (along with contamination by heavy metals) also results.

Noril'skaya river flows into Pyasino lake where is situated the headwaters of the Pyasina River. Water runoff increase in the upper reaches of the watershed will cause an attendant increase in the lower reaches of the watershed. The Pyasina River crosses North-Siberian plain, which is characterized by various structures of perennially frozen ground, including multiple ice wedges, massive ground ice sheets and buried ice delfs [Popov, Tumel', 1989]. The Pyasina River basin is 10 times larger than the Noril'skaya River basin. The shores of the Pyasina River and its tributaries have been undergoing active mechanical and thermal erosion over the last several decades.

A phenomena noted in the estuary of the Yenisei River is almost the same. Research conducted in the Ust'-Port settlement and surrounding area have revealed intensive ice-wedge melting in the near shore zone for last 30 years. This has led to the generation of block relief (fig. 2). Thermoerosion also destroys massive grounds sheets of up to 6-8 m thickness,

widespread in this region, fig. 3. An onbserved increase of fine- fraction sediments in the runoff composition may be attributed to thermodenudation of sediments in the region of the Sanchugovskaya River (a Yenisei tributary). Yenisei pebble beaches are covered with fine-fraction sediments from the thermodenudation of cirques and tributary shores. This material flows to Kara Sea in suspension, especially during overflows and heavy storms. The Dudinka River (another Yenisei tributary) adds pollutants from the Noril'sk industrial region as dissolved salts and suspended sediments.

The increase in fresh water runoff in the Yenisei and Pyasina River basins will ultimately contribute to a reduction in Kara Sea salinity levels in offshore areas. The freezing point of water is increased towards 0° C as salinity drops [Zubov, 1944]. The net result will be a southward migration of the mean edge of the sea ice, at least in the eastern part of the Kara Sea. This border coincides with the climatologically axis of western summer cyclones moving into the eastern regions of the cryolithozone.

CONCLUSION

Accounting only last circumstance, with modern temps of global climate warming there is no risk of western cyclones move axis replacement from continental part of Eurasia. However, a more precise assessment of the potential impact posed by increasing runoff of the northern rivers due to cryolithozone ice melting caused by climate warming or local technogenic impact will only be obtained with additional research. The salinity decrease in shelf zone sea waters is balanced by thermal runoff of submeridional flowing huge rivers of cryolithozone. Dissolved salts and suspended sediments runoff from thawing pulp depositories are also compensating salinity reduce.

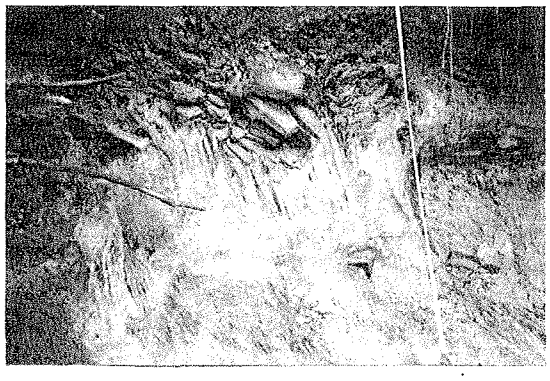

Fig. 3. Massive sheet ground ice in Yenisei valley. July, 2002

To determine coastal dynamics of seas, estuaries and mouths in order to further possible global climate warming it's necessary to monitor extra river sediments formed by shores destruction. It allows defining the temps of sedimentation in Arctic seas near mouth parts. Asian shelf beneath Arctic seas has a gentle slope in this area. Sea may shallow due to additional sedimentation in a short time. Both squares of landflow fields and shelf cryolithozone growth are expected. Sea coasts thermoabrasion temps decrease reasoned in marine waves speed drop on shallow areas.

REFERENCES

Grebenets V., Kraev G. Global ecological catastrophe caused by permafrost degradation due to climate fluctuations and technogenesis// Proc. of the Int. Conference "Arctic Alpine Ecosystems and People in a Changing Environment", Polar Environmental Centre, Tromso, Norway, 24 Feb.-1 March, 2003 – Norway, Tromso: Polar Environmental Centre, 2003 – P. 200

Grebenets V. Geocryological-geoecological problems of urbanised territories and basic methods of operation geosystems in industrial centres of the North Proc. of the 8th International Conference on Permafrost. Zurich, Switzerland, 21-25 July 2003 – Netherlands, Lisse: Swets & Zeitlinger B.V., 2003, Vol. 1. – P. 303-307

Hydrological data on the land surface water resources – Krasnoyarsk, 1980, Vol. 7, № 0, 1, 5-8. – 369 p.

A. Popov, N. Tumel' Taymyr region// Regional cryolithology – Moscow: MSU, 1989. – P. 88-101

Zubov N. Ice of Arctic. – Russia, Leningrad: Gidrometeoizdat, 1944. – 568 p.