

# Modeling of heaving and ejection of soil in the permafrost zone of Yamal

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In the permafrost zone, dangerous natural phenomena occur – gas and soil blowouts with the formation of craters on the earth's surface with a depth and diameter of several tens of meters. The paper considers one of the factors that may be the cause of blowouts – the decomposition of gas hydrates. With the climatic warming of the environment, the decomposition of gas hydrates in soil is accompanied by the formation of gaseous methane with a pressure of about 2MPa. A model of the formation of a cavity filled with gas during the decomposition of gas hydrates has been developed. The model assumes the presence of a layer of gas hydrates located at some depth from the earth's surface. In this layer, it is assumed that there is an initial crack. When the ground temperature changes, free methane appears in the crack. When the gas pressure exceeds the rock pressure, the crack opens and develops parallel to the earth's surface along the gas hydrate layer as an open crack, fueled by the resulting methane.

In the calculations carried out, the regularities of changes in the stress state of the ice-ground layer as a circular horizontal crack grows at a depth of 30 m from the earth's surface are determined. When the crack radius reaches 15 m at its boundary cylindrical vertical crack of the same radius, may originate and develop in the direction of the earth's surface. It is shown that with the development of a closed cylindrical crack, the horizontal crack should stop growing. With the continued decomposition of gas hydrates, the gas cavity should increase due to the upward displacement of a part of the soil bounded by a cylindrical crack that can grow to the surface. With an increase in the height of the cavity, the gas pressure should decrease, but this activates the process of decomposition of gas hydrates. The interaction of the processes of gas pressure drop and decomposition of gas hydrates determines the slow process of moving the ice- ground cylinder up the cylindrical crack. On the earth's surface, this shift should manifest itself as a heaving of the soil.

Calculations show that the redistribution of stresses in the ground column leads to the appearance of areas of tensile stresses. This should contribute to the formation of induced cracks- pores. When filtering methane into cracks-pores, conditions are created for the subsequent destruction of gas-saturated material by the layer-by-layer separation mechanism. The quasi-static equilibrium of forces caused by the weight of the shifting ice-ground cylinder, the gas pressure in the cavity, and the forces of resistance to displacement on the banks of the crack can be disturbed by the beginning of the destruction of the cylinder as a whole by the mechanism of layer-by-layer separation. This layered destruction, along with the provoked dynamic ejection of the fractured cylinder by gas pressure from below, can be interpreted as the release of soil and gas with the formation of a cylindrical funnel.