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# Massive ground ice and corresponding relief in the Kara sea region

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The objective of the study is to assess the role of tabular (massive) ground ice in the mechanisms of relief formation in cryolithozone. Area under study represents Arctic plains. Key sites are chosen in the areas of wide tabular ground ice distribution in the Central Yamal Peninsula and coastal zone of the Yugorsky peninsula in the Kara sea region. Detailed long-term study at the key sites provides evidences of interrelation between tabular ground ice occurrence, activity of its degradation and specific landforms: thermocirques and landslide cirques, resulting from cryogenic processes. Major factor determining cryogenic processes connected to tabular ground ice, is the regional or local change of thaw depth and/or thickness of covering ice deposits. At early stages slope processes occur at a catastrophic speed due to ice melt. At this time the rate of slope destruction depends on the climatic parameters such as summer air temperature, precipitation, and sunshine. But the more active is destruction the more abundant are deposits, removed downslope to accumulate there, and to protect ice from further melting. Thus, the stages of "maturity" arise from the activeness of the destruction. Attenuation of the ice destruction may be temporary, connected with periodic reduction of seasonal thaw depth and insulation of tabular ground ice by landslide masses. Then at respective alterations of climatic conditions ice melt can renew with former speed. The final attenuation of active ice melting, and resulting slope processes, occurs actually only at complete exhaustion of an ice body up to the depth equal to the base level of thermodenudation. When this happens, then relief inheriting concavities left by the melted ice, turns to slow evolutionary development. If the sole of tabular ground ice body is above the base level of thermodenudation, slope processes, such as landslides, solifluction, slope wash, thermal erosion, occur. When the ice body sole is above the base level of thermodenudation, then thermokarst develops. Thus, relief development in the areas of tabular ground ice distribution dependent on

mechanisms and speed of destruction, and distinguished by the characteristic forms, proceed in two interchanging phases ? active and passive. The active phase is a period when short-term climatic conditions are favourable for ice melt. Passive phase on the contrary is characterized by unfavourable conditions such as cold and dry summer, possibly, thick snow cover. While phases are interchanging, relief passes longer-term stages of evolutionary trend. Subdivided are the following stages. 1. Initial lowering of the surface or deepening of the active layer resulting from erosion, deflation, nivation, biogenic and human activity (at the passive phase, only slope wash). 2. Embryonic thermocirque resulting from retrogressive thaw slumps and earth flows (at the passive stage, accumulation of slope deposits outbalances destruction). 3. Mature thermocirque which is developing due to slumps, slides, thermal erosion, mudflows, failures (passive phase is accumulation as at the stage 2, but faster). 4. Attenuating thermocirque with only residual thermoerosion and nivation, limited active-layer detachment slides (at the passive phase, recovering vegetative cover, mild sloping). 5a. (Ice body sole above the base level of thermodenudation). Landslide cirque developing through active-layer detachments (cryogenic landslides) and thermoerosion (passive phase is a period between the landslide events with attenuating thermal erosion). 5b. (Ice body sole below the base level of thermodenudation). Laydas (marsches) that appear as a result of thermokarst at the footslope over the residual ice body (at the passive phase, vegetation recovery and freezeback of the sediments accumulated over ice). Widespread ancient concave landforms (landslide cirques) at both Yamal and Yugorsky peninsulas are most likely remnants of Holocene optimum and are several thousand years old. At the same time, simultaneously, surfaces appear which are at different stages of development from embryonic thermocirques to landslide cirques and laydas. This means that the process of relief formation connected to tabular ground ice destruction, is in part an irregular process. An unexpected activation may occur anytime, when climate changes significantly, causing a local hazard.