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Comprehensive Model of Frost Boils and Earth Hummocks Formation.

Yuri Shur (ffys@uaf.edu), Chien-Lu Ping, and Donald (Skip) A. Walker  
University of Alaska Fairbanks, USA

Frost boils and earth hummocks widely occur in the permafrost region. Features of the first type generally occupy the northern part of the permafrost region; of the second type occupy its middle part. In some areas they occur simultaneously. Formations of frost boils and hummocks have been described in general terms of cryoturbations - a complex of seasonally interchanging processes of frost heave and thaw settlement. Most of properties of frost boils and earth hummocks such the bowl shape of boils, a continuous organic accumulation at the periphery of the active layer, and risen elevation of boils and hummocks above surrounding areas cannot be explained by seasonal reversible changes. Also frost boils and earth hummocks occur in the permafrost region; all existing hypotheses do not explain the role of permafrost in their formation.

Frost boils and inter-boil areas are integrated into one well-organized and long-term functioning system linked to dynamics of the upper permafrost zone. Formation of this system starts with occurrence of vegetation in inter-boil areas in shallow thermal cracks limited by the thickness of the active layer. Such cracks have been described on numerous occasions in Russian permafrost literature. Vegetation and products of its decomposition in the inter-boil area change the thermal properties of the active layer which depth steadily decreases. It triggers the intermediate layer formation with accumulation of aggradational ice and perennial frost heave beneath vegetated inter-boils and in some extent under boils. Perennial frost heave related to accumulation of aggradational ice forms bowl shape of frost boils and is responsible for the rising surface of frost boils. Inter-boil areas are a source of organic, which moves under boils along cracks of post-cryogenic structure due to formation and thawing of ice at the border with permafrost. Solid particles of organic accumulate at the bottom of the active layer. Dissolved organic moves upward to freezing front in winter or to drying boil surface in summer. With time in many cases, layer of organic covers completely the periphery of boils in others it is incomplete but always adjusts to its source - the vegetated inter-boils area.

Vegetation development on the boil surface and readjustment of the upper permafrost leads to the development of hummocks. A hummock is formed from a frost boil by cumulative perennial frost heave due to long-term accumulation of aggradational ice in the intermediate layer of permafrost which replaces the a part of the active layer in response to vegetation development on the boil surface. Loss of vegetation on the hummock surface leads thawing of the aggradational ice and to substantial thaw settlement. Differential accumulation of aggradational ice and formation of the intermediate layer of uneven thickness in upper permafrost play the important role in formation of different patterned grounds.