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Extreme rates of riverbank erosion of the high bluff formed by the ice-rich syngenetic permafrost (yedoma), Itkillik River, Northern Alaska

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Riverbank erosion in areas underlain by ice-rich permafrost is strongly affected by the processes of thawing of ground ice, which include (1) thermal erosion, and (2) thermal denudation. Thermal erosion is a process of combined thermal and mechanical action of moving water, which results in simultaneous thawing of frozen soil and its removal by water. Thermal erosion can cause block collapse of eroded banks. Thermal denudation is a process of thawing of frozen soils exposed in the bluff due to solar energy and consequent removal of thawed soils by gravity. Studies of riverbank and coastal erosion revealed that the highest rates of erosion are typical of bluffs composed by yedoma (ice- and organic-rich syngenetically frozen silty deposits). Yedoma deposits can be up to 50 m thick, and they contain huge ice wedges up to 10 m wide. Since 2006, we have studied the process of riverbank erosion of the 35 m high exposure of yedoma along the Itkillik River in northern Alaska. Based on five measurements of the areas occupied by wedge ice in panoramic photographs taken in 2006, 2007, 2011, and 2012, the average wedge-ice volume makes 61% of the entire exposed bluff. The total volumetric ground ice content of the Itkillik yedoma, including wedge, segregated and pore ice, is 85%. We detect three main stages of the riverbank erosion for the study site and other similar sites in the areas of ice-rich permafrost: (1) thermal erosion combined with thermal denudation, (2) thermal denudation, and (3) slope stabilization. The first stage includes formation of thermoerosional niches; development of sub-vertical cracks and block-fall collapse of cornices; and thawing and disintegration of blocks of ground ice and frozen soil in the water. All these processes are accompanied by thermal denudation of the exposed bluff. On August 16, 2007, a big portion of the bluff fell down along the crack sub-parallel to the bluff. As a result, the vertical wall more than 65 m long entirely formed by the wedge ice was exposed. This block-fall affected the area of approximately 800 m2, and the volume of frozen soil and ice involved in the block-fall was about 15,000 m^3. The riverbank retreat due to thermal erosion and/or thermal denudation, measured from August 2007 to August 2011, varied from less than 10 to almost 100 m. An estimated retreat rate average for the whole 680 m long bluff was 11.4 m/year, but for the most actively eroded central part of the bluff (150 m long) it was 20.3 m/year, ranging from 16 to 24 m/year. During these 4 years, about 650,000 m^3 of ice and organic-rich frozen soil were transported to the river from the retreating bank (more than 160,000 m^3/year). Analysis of aerial photographs (1948-1979) and satellite images (1974-2013) showed that the riverbank was relatively stable till July 1995, when the Itkillik River changed its course and triggered extremely active thermal erosion. The total retreat of the riverbank in 1995-2010 varied from 180 to 280 m, which means that the average retreat rate for the most actively eroded part of the riverbank reached almost 19 m/year. Such a high rate of riverbank erosion over a long time period has not been reported before for any permafrost regions of Eurasia and North America.

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