Polar Science xxx (2017) 1–5

Contents lists available at ScienceDirect

Polar Science

journal homepage: https://www.evise.com/profile/#/JRNL_POLAR/login

Large thermo-erosional tunnel for a river in northeast Greenland

Catherine L. Docherty [a, b, *], David M. Hannah [a], Tenna Riis [c], Simon Rosenhøj Leth [c], Alexander M. Milner [a, d]

[a] School of Geography, Earth and Environmental Science, University of Birmingham, Birmingham, United Kingdom
[b] Department of Atmospheric Environment and Aquatic Ecosystem, Institute of Mountain Science, Shinshu University, Japan
[c] Department of Bioscience, Aarhus University, Aarhus, Denmark
[d] Institute of Arctic Biology, University of Alaska, Fairbanks, AK, USA

ARTICLE INFO

Article history:
Received 20 February 2017
Received in revised form
12 August 2017
Available online xxx

Keywords:
Permafrost
Stream
Climate change
Snowmelt runoff
Arctic

ABSTRACT

Thermo-erosional river bank undercutting is caused by the combined action of thermal and mechanical erosion of the permafrost by Arctic rivers whilst the overlying sediment withstands collapse temporarily. Here, we report the discovery of a large thermo-erosional tunnel that formed in the banks of a meltwater-fed stream in northeast Greenland in summer 2015. The tunnel was observed over eight days (14–22 July), during which period the tunnel remained open but bank-side slumping increased. Stream solute load increased immediately downstream and remained high 800 m from the tunnel. Whilst this field observation was opportunistic and information somewhat limited, our study provides a rare insight into an extreme event impacting permafrost, local geomorphology and stream habitat. With accelerated climate change in Arctic regions, increased permafrost degradation and warmer stream water temperature are predicted thereby enhancing potential for thermo-erosional niche development and associated stream bank slumping. This change could have significant implications for stream physicochemical habitat and, in turn, stream benthic communities, through changes in aquatic habitat conditions.

1. Introduction

Thermo-erosional niches are river bank undercutting resulting from the combined action of thermal and mechanical erosion (Walker et al., 1987): running water infiltrates cavities in the frozen active layer, forming underground tunnels, from where fast water current and warmer water temperatures, relative to the frozen ground, simultaneously thaw and erode the permafrost (Walker and Arnborg, 1966; Perreault et al., 2016). Whilst water temperature has been identified as the principal factor influencing thermo-erosional niche development, ice, sand and silt content in the permafrost are also important considerations (Dupeyrat et al., 2011). Thermal erosion is most prevalent in the High Arctic landscape due to (1) higher river flows during summer peak snowmelt and (2) the presence of permafrost which strengthens the river banks but permits larger amounts of bank undercutting, and large slump blocks when the banks finally collapse (Scott, 1978). Whilst the most common type of thermo-erosional niche occurs along stream banks or coastal areas where the above sediment collapses eventually, they can also be created without the sediment above the niche collapsing, forming tunnels. However, due to their tendency to occur in these remote environments, large tunnel forming thermo-erosional niches have rarely been reported. Most reports of large-scale thermo-erosional niches have been from Alaska and Canada and have been formed through ice wedge thaw (eg. Fortier et al., 2007; Godin and Fortier, 2012; Veillete et al., 2015 Kanevskiy et al., 2016). Limited information is available from other areas of the Arctic. To increase our knowledge on this phenomenon and create a pan-Arctic record, here we report and describe a large thermo-erosional tunnel over a stream in northeast Greenland.

2. Methods and data

2.1. Site description

The snowmelt-fed stream Aucellaelv is in close proximity to the Zackenberg research station at 74°28′ N, 20°34′ W in the Northeast Greenland National Park (Fig. 1). The mean annual air temperature is −9.1 °C and the warmest month is July with a mean temperature of 5.8 °C. The mean precipitation is 261 mm and falls mainly as

* Corresponding author.
E-mail address: catherine.l.docherty@gmail.com (C.L. Docherty).

http://dx.doi.org/10.1016/j.polar.2017.08.001
1873-9652/

Please cite this article in press as: Docherty, C.L., et al., Large thermo-erosional tunnel for a river in northeast Greenland, Polar Science (2017), http://dx.doi.org/10.1016/j.polar.2017.08.001

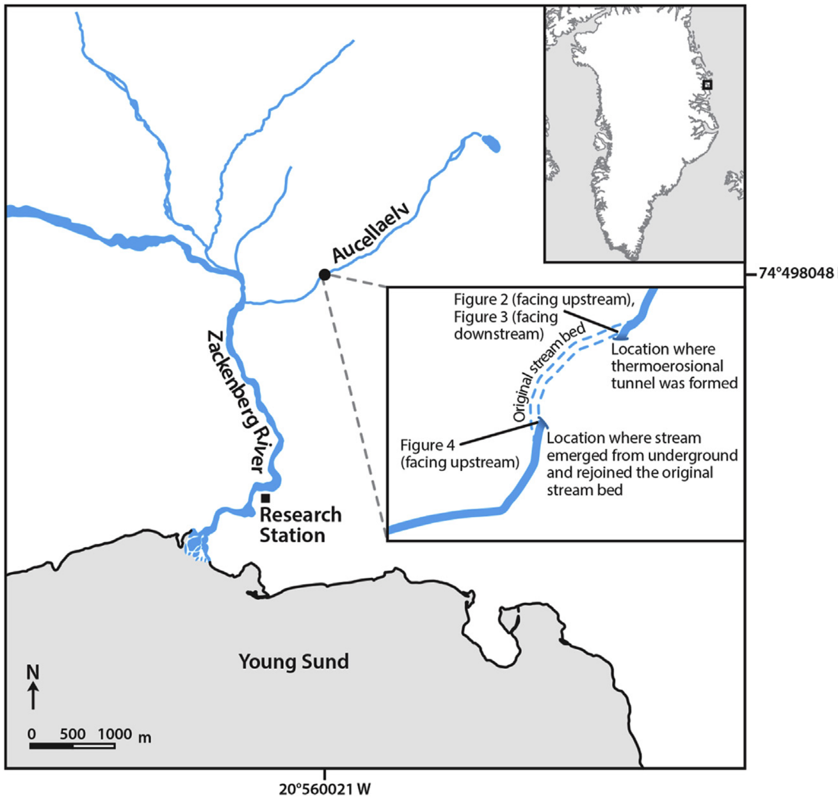

Fig. 1. Study area showing location of the thermoerosional tunnel and points from which Figs. 2–4 were taken.

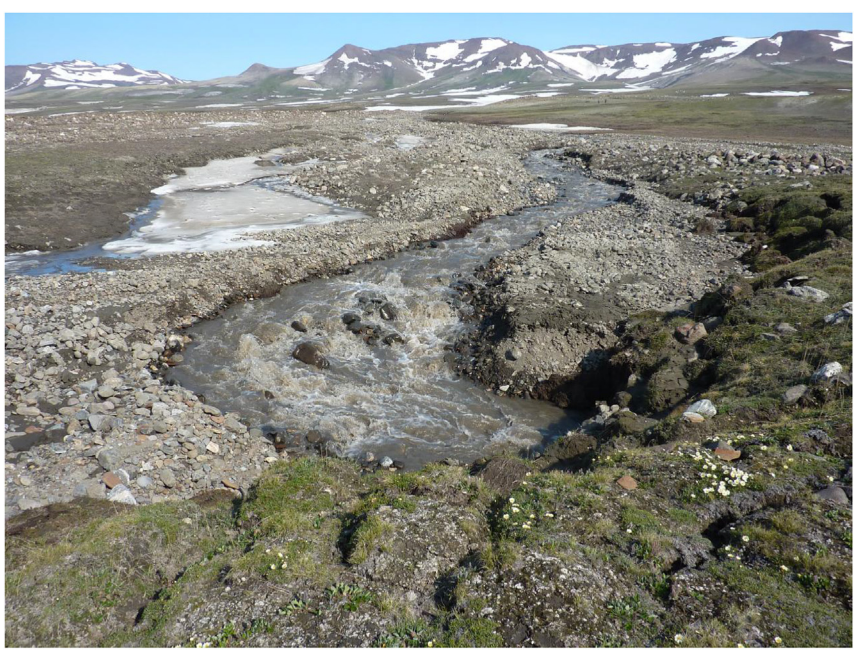

Fig. 2. Aucellaelv looking upstream at the point of the thermo-erosional niche. At the bottom of the photograph, the stream can be observed to go underground. Photo: Catherine L. Docherty.

snow (Hansen et al., 2008). The site was located on lower mountain slopes within a wide horizontal valley formed by glacial erosion approximately 10,000 years before present (Mernild et al., 2007; Bennike et al., 2008). Zackenberg is an area of continuous permafrost, with depth modelled to be 200–300 m deep and varying active layer thickness between 0.3 and 0.65 m (Christiansen et al., 2008). The region is composed of Cretaceous and Tertiary sandstones with loose sediment of weak compaction that is susceptible to erosion (Hasholt and Hagedorn, 2000) and is held together largely due to its frozen nature. Ice wedge polygons occur within