Polar Science 11 (2017) 83–95

Contents lists available at ScienceDirect

Polar Science

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

The morphology of peat bog surfaces on Hermansenøya, NW Svalbard

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ARTICLE INFO

Article history:
Received 20 July 2016
Received in revised form
28 November 2016
Accepted 29 November 2016
Available online 30 November 2016

Key words:
Svalbard
Peat bogs
Ice-wedge polygons
Thermokarst mounds
Polygonal peat plateau

ABSTRACT

This article analyses the surface morphology of the arctic peat bogs occurring on Hermansenøya, a small island in the Forlandsundet, NW Svalbard. Six small, shallow peat bogs on the island show different microrelief features formed by ice-segregation as well as thermokarst and thermo-erosion processes. On the peat bogs the following forms have been identified: aggradational, associated with the growth of different types of ground ice (frost peat mounds, peat plateaus, polygonal peat plateaus, networks of ice-wedge polygons); and degradational, associated with thermokarst (symmetrically developed residual peat mounds and the furrows in between) and thermo-erosion (channels of niveo-fluvial streams). Some importance can also be attributed to aeolian processes, i.e. snow drifting from the tops of convex relief features for aggradational forms. Lack of insulating snow cover significantly increases frost penetration depth, promoting cryosuction and/or ice growth at the base of a frozen core. The oldest preserved forms and structures, frost peat mounds with an ice-peat core and ice-wedge polygons, developed during climatic cooling at the turn of the Subboreal and Subatlantic (c. 3.0–2.5 ka BP). Thermokarst mounds are younger, associated with warmer periods after the Little Ice Age (the warmer 1920s). Channels of niveo-fluvial streams are being shaped today.

1. Introduction

Peat bogs are specific ecosystems, which produce organic material under natural conditions which undergo only slight mineralisation and accumulate in the form of peat deposits. Peat bogs in the High Arctic are characterized by a low accumulation rate of peat and microrelief features formed by periglacial processes (Åkerman, 1980; Żurek, 1984). Peat soils are susceptible to frost processes due to their physical properties (Kujala et al., 2008). Wet and frozen peat has a high thermal conductivity, affecting the development of a variety of types of cryogenic structures. On the other hand, dry peat has good insulating properties which hampers thaw penetration and preserves frozen structures during warm and dry summers. These peat properties often contribute to the formation of microrelief features such as frost peat mounds and peat plateaus. The height of microrelief is mainly constrained by the volume of its internal ice core. However, in the case of certain forms (e.g. residual peat mounds), their relative heights reflect depression by thermokarst and thermo-erosion processes.

The Hermansenøya area, a small island located in the central-eastern part of Forlandsundet, NW Svalbard (Fig. 1), is characterized by diverse small peat bogs. A variety of microrelief is distributed on the peat bogs making it possible to compare morphology, origin and age between different microrelief features under the same climatic zone.

This article aims to identify the morphology that forms the microrelief in arctic peat bogs and determine their origin and age on Hermansenøya. Attention was also paid to those processes which are primarily responsible for geomorphic change on the peat bogs.

2. Study area

Hermansenøya is an island located in the central-eastern part of Forlandsundet, NW Svalbard. It is 3.3 km long, 0.9 km wide at its widest point, and its area is c. 2.7 km^2. The island is separated from Spitsbergen, the main island of the Svalbard archipelago, by Farmsundet, which is 3.4 km wide. The coasts of Hermansenøya are mostly composed of rocky cliffs with heights from 2-3 m to 20–22 m. Well developed wide beaches with storm ridges, are distributed in confined places often cluttered with driftwood, as with the coasts of the neighbouring strandflats - Sarsøyra and Kaffiøyra (Niewiarowski and Myzyk, 1983; Węgrzyn et al., 2015).

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http://dx.doi.org/10.1016/j.polar.2016.11.006
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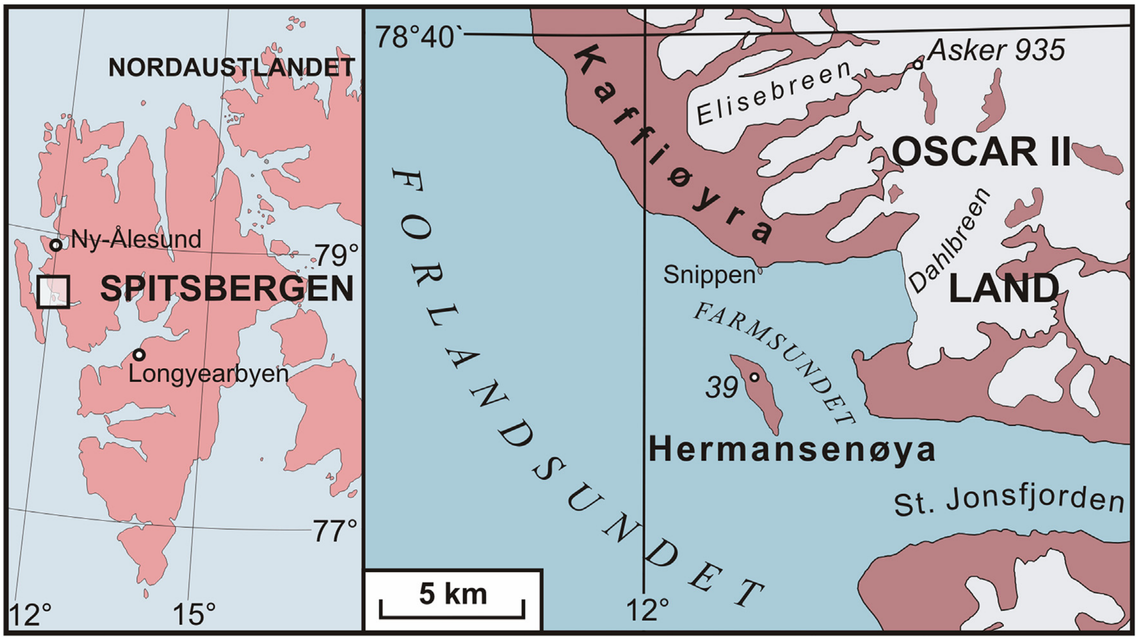

Fig. 1. Location of the study area.

The maximum altitude of Hermansenøya is 39 m asl, in the central part of the island.

Hermansenøya is built of Late Proterozoic rocks of the Hecla Hoek succession, folded during the Caledonian orogeny. From the west it borders the Late Cretaceous-Paleogene Forlandsundet Graben, which separates NW Spitsbergen from the isle of Prince Karls Forland (Hjelle, 1993; Michalski et al., 2014). Five marine terraces cut into metamorphic rocks have developed on the island, the heights of which are 4–6 m, 7–9 m, 10–12 m, 15–17 m and 21–24 m asl, respectively (Fig. 2). They were formed during the Late Weichselian and Early Holocene, i.e. c. 11–9 ka BP (Niewiarowski et al., 1993). Beach deposits, if any, are very thin on the terraces. According to Forman (1989), traces of beach deposits are also present at a height of c. 33 m asl, associated with the maximum of the Late Weichselian marine limit. Peat bogs have developed on the youngest raised beaches and lagoons composed of marine silts and sands. Characteristic microrelief features have been formed on the bogs by frost, thermokarst and thermo-erosion processes. A layer of silty-sand sediment is also recognized on the floors of periodic and episodic pools, positioned directly on the rocky substratum.

Hermansenøya lacks a permanent river system. During the short summer, small pools and short episodic niveo-fluvial streams appear in the vicinity of all peat bogs, discharging meltwater from the central part of the island. Their length varies from 50 to 250 m. These streams usually open into the pools and then disappear in the peat bogs developed in the lowest parts of the previous lagoons. On some peat bogs the excess water from the pools is discharged via channels directly into the sea.

Hermansenøya lies in the polar climate with intensive oceanic influence. Temperature and precipitation conditions in the Hermansenøya and Kaffiøyra region for the period from 1975 to 2014 are described based on data collected during Toruń Polar Expeditions to NW Svalbard in which meteorological measurements. The mean annual air temperature (MAAT) is c. −5.5 °C to −5.0 °C, the average air temperature of the warmest month (July) is c. +4.8 °C. Summer temperatures in this region in the studied period (1975–2014) have shown statistically significant strong upward trends (Przybylak and Araźny, 2016). The average temperature of the coldest month (March) is c. −13.0 °C to −12.5 °C. The average monthly air temperature below 0 °C lasts for at least 8 months. Annual precipitation averages 350–450 mm, with snowfall at about 80% (Przybylak and Araźny, 2012). These climatic conditions significantly affect the active layer thickness (ALT) of the permafrost. Between 1979 and 2014, measurements of the ALT were carried out using a metal rod every 2–3 days. The ALT on Hermansenøya reaches its maximum at the end of August (Araźny and Grześ, 2000). On the storm beach ridge, the average ALT was 118 cm, ranging from 88 cm in 1979 to 154 cm in 2007. The trend of maximum thickness of this layer was 0.75 cm a^{-1} in 1996–2014. In the tundra (marine terrace covered by a thin cover of pebbles, gravels and sands) the average ALT is c. 150 cm, while on a moraine - c. 200 cm. The tundra and moraine areas also revealed an increased ALT in this period (by 0.66 and 2.52 cm a^{-1}, respectively) (Araźny et al., 2016). The minimum ALT was recorded in the peat bogs (c. 35–40 cm) and in the frost peat mounds (c. 25–30 cm) (Jaworski and Niewiarowski, 2012). Therefore, during the polar summer, even when the temperature reaches 10 °C or more, under the thin layer of dry peat covering peat mounds they remain frozen. It is worth noting that MAAT on Hermansenøya corresponds to the transition zone between continuous and discontinuous permafrost; according to Jahn (1975) it is about −5 °C, while according to French (2007) it is between −6 °C and −8 °C. However, significant thickness of permafrost on Hermansenøya (just as on the neighbouring Kaffiøyra) is largely a remnant of the Late Weichselian Glaciation (Humlum, 2005).

Snow on the peaks of convex relief features is often blown away by strong winds at the end of winter, having a great effect on the formation of certain types of ground ice in cryogenic mounds. This phenomenon triggers cryosuction and/or ice growth at the base of a frozen core (incl. Seppälä, 1990, 2011).

Environmental conditions also affect the nature of the tundra vegetation. According to its regionalisation, Hermansenøya is located in the middle-arctic tundra region and is dominated by two plant communities: snow-bed tundra and fresh moss tundra (Gugnacka-Fiedor and Noryśkiewicz, 1982). Vegetation is correlated to soil cover, which on Hermansenøya is varied. According to Plichta (1993), Gelic Cambisols occupy the large part of the area which mainly overlies sand and gravel deposits on isostatically