Quaternary Science Reviews 109 (2015) 111–125

Contents lists available at ScienceDirect

Quaternary Science Reviews

journal homepage: www.elsevier.com/locate/quascirev

Arctic Holocene glacier fluctuations reconstructed from lake sediments at Mitrahalvøya, Spitsbergen

Torgeir O. Røthe [a, c, *], Jostein Bakke [a, c], Kristian Vasskog [b, c], Marthe Gjerde [a, c], William J. D'Andrea [d], Raymond S. Bradley [e]

[a] Department of Earth Science, University of Bergen, Allégaten 41, 5007 Bergen, Norway
[b] Uni Climate, Uni Research, Allégaten 55, 5007 Bergen, Norway
[c] Bjerknes Centre for Climate Research, Allégaten 55, 5007 Bergen, Norway
[d] Lamont-Doherty Earth Observatory of Columbia University, Palisades, NY 10964, USA
[e] Department of Geosciences, University of Massachusetts, Amherst, MA 01003, USA

ARTICLE INFO

Article history:
Received 6 August 2014
Received in revised form
20 November 2014
Accepted 27 November 2014
Available online 31 December 2014

Keywords:
Glaciers
Svalbard
Lake sediments
ELA
Ice-cored moraine
Palaeoclimate

ABSTRACT

The Arctic region has experienced a significantly larger warming during the last decades compared to the rest of the world, and model simulations indicate a continued amplification of future global warming in the Polar Regions. A better understanding of natural climate variability in the Arctic is much needed to provide a better context for the observed warming trend. By utilising proxy data it is possible to obtain palaeoclimatic records beyond the range of instrumental observations, which increase our understanding of long-term Arctic climate change. Here, a continuous record of past changes in Equilibrium-Line Altitude (ELA) has been reconstructed for the alpine glacier Karlbreen, located on the northwest coast of Spitsbergen (79° N), based on sediment analyses from a distal glacier-fed lake. A multivariate statistical analysis suggests that the concentration of geochemical elements Ti, Si and K in the lake sediments, together with the physical parameter dry-bulk-density (DBD), reflect changes in the amount of inorganic detrital input to Kløsa, which is closely linked to the size and ELA of the upstream glacier Karlbreen. A linear regression model based on historically documented glacier extents was used to calculate continuous ELA changes back to ~3500 cal. yr. BP. From about 9200 to 3500 cal. yr. BP, the sedimentary record indicates that Karlbreen was very small or had completely melted away. Karlbreen was probably close to its maximum Holocene extent several times during the Neoglacial, first around 1700 cal. yr. BP, then later at ~225 and ~135 cal. yr. BP. An ice-cored moraine system in front of Karlbreen extends well into the main basin of Kløsa, and it is difficult to explain how this moraine could have formed without disturbing the sedimentary record in the lake (e.g. through slumping events). The sedimentary record in Kløsa is continuous and undisturbed over the past 6700 years, suggesting that the outermost moraine formed prior to this time and that it most likely survived the Holocene Thermal Maximum on Svalbard.

© 2014 Elsevier Ltd. All rights reserved.

1. Introduction

In recent decades the Arctic region has warmed approximately twice as fast as the global mean, and this "polar amplification" of global temperature rise is expected to continue into the future (Masson-Delmotte et al., 2013). Instrumental climate records are generally sparse in the Arctic and rarely span more than 100 years into the past (AMAP, 2011). Proxy reconstructions are therefore needed in order to study long-term natural climate variability in this region, but few high-resolution terrestrial palaeoclimatic records are currently available. Filling this knowledge gap will enhance our understanding of natural Arctic climate variability, which may in turn shed light on the climate sensitivity of the Arctic.

Glaciers are highly sensitive to perturbations in climate, which makes them excellent indicators of climate change (Oerlemans, 2005), although one should be aware that individual glaciers may respond differently to large-scale climate change due to a range of local factors. In many regions of the world, the largest Holocene

* Corresponding author. Department of Earth Science, University of Bergen, Allégaten 41, 5007 Bergen, Norway. Tel.: +47 55 58 81 05.
E-mail address: torgeir.rothe@geo.uib.no (T.O. Røthe).

http://dx.doi.org/10.1016/j.quascirev.2014.11.017
0277-3791/© 2014 Elsevier Ltd. All rights reserved.

glacier extent occurred within the last few hundred years, during the so-called "Little Ice Age" (LIA) (Davis et al., 2009), thereby effectively erasing terrestrial moraine evidence of earlier glacier fluctuations (Bakke and Paasche, 2011). However, lacustrine sediments deposited in distal glacier-fed lakes may be used to reconstruct continuous Holocene glacier fluctuations. Following its introduction by Karlèn (1976), this method has become well-established throughout Scandinavia (Nesje et al., 1991; Dahl and Nesje, 1992; Nesje et al., 2000; Dahl et al., 2003; Lie et al., 2004; Bakke et al., 2005, 2009, 2010; Vasskog et al., 2012). The method links downstream lake sediments to past glacier activity using measurements of physical properties (grain size, density, organic content, water content), geochemical properties (elements analysed at high resolution with XRF scanner), X-ray and magnetic properties (e.g. magnetic susceptibility, ARM, SIRM) along with multiple dating techniques, including radiocarbon dating and ^{210}Pb dating. Through calibration of the dated sedimentary records with independently dated moraine chronologies or historically documented glacier front positions, it is possible to develop continuous reconstructions of fluctuations in ELA (e.g. Bakke et al., 2010). However, reconstructing glacier fluctuations from distal glacier-fed lakes is particularly challenging in the Arctic due to the logistical difficulties of recovering sedimentary records and because the low amount of organic matter found in Arctic lake sediments makes it difficult to establish robust chronologies using radiocarbon dating (Snyder et al., 1994). Due to these limitations only a few continuous records of past glacier activity based on lake sediments exist from Svalbard (Mangerud and Svendsen, 1990; Svendsen and Mangerud, 1997; Snyder et al., 2000; Mäusbucher et al., 2002).

Here, the first high-resolution and continuous Holocene glacier reconstruction from the northwest coast of the Svalbard Archipelago is presented. Based on a multi-proxy study of sediments recovered from a distal glacier-fed lake the time intervals during which the upstream glacier Karlbreen has been present within the last 9200 years have been determined, and fluctuations in the ELA during the local Neoglacial interval (i.e. the last ~3800 years) have been inferred. The findings indicate that the most distal ice-cored moraine found in front of Karlbreen predates the LIA period and it most likely survived the Holocene Thermal Maximum (HTM) on Svalbard. The results from the sediment analyses together with data from the ground-penetrating-radar (GPR) also allow us to estimate the total erosion rate for a subpolar glacier in the Arctic. The glacier fluctuations correspond to the regional climatic pattern in and around the North Atlantic, as the declining summer insolation seems to be the main driving factor of the past 6000 years.

2. Regional setting

2.1. Holocene climate- and glaciation history on Svalbard

Following the deglaciation of the area after the Last Glacial Maximum, the glacier coverage was similar or even less compared to the present glacier coverage by 10 100 cal. yr. BP and marks the onset of the HTM on Svalbard (Jessen et al., 2010; Hormes et al., 2013). Several studies have identified a warmer-than-present early Holocene climate on Svalbard, for example as suggested by the presence of blue mussels (*Mytilus edulis*) along the northern coast, which suggests a summer sea-surface temperature (SST) 1–2 °C warmer than today's (Salvigsen et al., 1992; Salvigsen, 2002). Jessen et al. (2010) report of low concentration of ice-rafted debris from marine sediment cores between 10 000 and 7600 cal. yr. BP at the western coast of Svalbard and suggests few icebergs to be released during this period. A study of macrofossil assemblages in a lake core from Skardtjørna, a lake situated close to Isfjord Radio on the west coast of Svalbard, similarly implies that summer temperatures were 1–2 °C warmer from ~7000 to ~3000 cal. yr. BP.

About 4000 years ago a gradual cooling in summer temperatures has been inferred based on macrofossil analysis (Birks, 1991). This gradual cooling marks the onset of the Neoglacial period on Svalbard, when glaciers in Linnédalen (southwest Svalbard) showed their initial growth (Svendsen and Mangerud, 1997). Here, frequent glacier expansions have been reconstructed for the Neoglacial period, culminating in the LIA (Werner, 1993; Svendsen and Mangerud, 1997; Lubinski et al., 1999). The late Holocene fluctuations have later been confirmed by ^{10}Be dating of terminal moraines in front of the Linnébreen (Reusche et al., 2014). δ^{18}O measurements on ice cores from Lomonosovfonna and Holtedahlfonna have been used to reconstruct winter surface-air temperatures for the past 1000 years and indicate gradual winter cooling (approximately 0.9 °C per century) from AD 800 to AD 1800 (Divine et al., 2011). During the 20th century, mass balance measurements and glacier front variations show a general retreat of glaciers on Svalbard (Hagen and Liestøl, 1990; Hagen et al., 1993).

2.2. Study area

Mitrahalvøya ("halvøy" = peninsula) is located on the northwest coast of Svalbard (Fig. 1A). A mountain range stretches from south to north on the eastern part of Mitrahalvøya, with summits ranging from 600 to 700 m a.s.l. The study area is located on the northeastern part of Mitrahalvøya, where the alpine glacier Karlbreen ("breen" = Glacier) flows down from Chunfjellet (688 m a.s.l.) towards a series of down-valley lakes.

2.2.1. Catchment area

Meltwater from Karlbreen (79.2397°N, 11.5358°E) drains through a chain of lakes ("Inner Moraine Lake", Kløsa, and Erlingvatnet) before reaching the fjord in Signehamna (Fig. 1A). The sediment records presented here are retrieved from Kløsa (~0.25 km^2), a 12.5 m deep lake, located downstream from Karlbreen at 42 m a.s.l. Note that the late Weichselian marine limit on the southern tip of Mitrahalvøya is ~20 m a.s.l. (Forman, 1990). The total catchment area of Kløsa is ~3.5 km^2, including the "Inner Moraine Lake" (~0.06 km^2) and Karlbreen (~1 km^2). The relatively low relief of the landscape surrounding Kløsa limits the possibility of large avalanches or debris flows reaching the lake. The short response time needed for paraglacial readjustment in smaller catchments (Ballantyne and Benn, 1994) should also limit the influence of paraglacial processes on the sedimentary budget of Kløsa, particularly towards the middle-to late Holocene. The glacier-lake system studied here should therefore represent an optimal site for reconstructing past glacier fluctuations (Dahl et al., 2003).

Karlbreen has not been classified as a specific glacier type, although small alpine glaciers on Svalbard are usually classified as subpolar (Hagen et al., 1993). A subpolar glacier is characterised by cold-based margins and temperate basal conditions where it is thicker. This classification is based on thermal conditions and may therefore change both temporally and spatially. Glaciers in polar maritime climates may be warm-based in the accumulation zone, and cold-based in the near-surface area of the ablation zone due to winter chilling (Hagen et al., 1993). The occurrence of surging glaciers is widespread on Svalbard and the region have a high number of surge-type glaciers (Hagen et al., 2003; Sund et al., 2014). Smaller cirque glaciers are not typically found to be surging (Werner, 1993), and no surge-history of Karlbreen is reported. Neither is there any geomorphological evidence (e.g., abnormal margins, loop-shaped moraines, etc.) of surge-type behaviour found in relation to Karlbreen.

Download English Version:

https://daneshyari.com/en/article/4735943

Download Persian Version:

https://daneshyari.com/article/4735943

Daneshyari.com