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Holocene multi-proxy environmental reconstruction from lake Hakluytvatnet, Amsterdamøya Island, Svalbard (79.5°N)

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A B S T R A C T

High resolution proxy records of past climate are sparse in the Arctic due to low organic production that restricts the use of radiocarbon dating and challenging logistics that make data collection difficult. Here, we present a new lake record from lake Hakluytvatnet at Amsterdamøya island (79.5°N), the northwesternmost island on Svalbard. Multi-proxy analyses of lake sediments in combination with geomorphological mapping reveal large environmental shifts that have taken place at Amsterdamøya during the Holocene. A robust chronology has been established for the lake sediment core through 28 AMS radiocarbon ages, and this gives an exceptionally well-constrained age control for a lake at this latitude. The Holocene was a period with large changes in the Hakluytvatnet catchment, and the onset of the Neoglacial (ca. 5 ka) marks the start of modern-day conditions in the catchment. The Neoglacial is characterized by fluctuations in the minerogenic input to the lake as well as internal productivity, and we suggest that these fluctuations are driven by atmospherically forced precipitation changes as well as sea ice extent modulating the amount of moisture that can reach Hakluytvatnet.

1. Introduction

Palaeoclimatic reconstructions offer the possibility to extend earth system observations beyond the instrumental time period. Such reconstructions are especially important in the Arctic because the rate of on-going change is unprecedented within Common Era observations (Kaufman et al., 2009; Nordli, 2010; Nordli et al., 2014). However, our knowledge of the natural climate variability in the Arctic is limited due to the scarcity of data and the relatively short period of observation. Future anthropogenic climate changes will be superimposed on these natural variations, which might result in fundamental changes to internal climate feedback mechanisms, influencing the timing and amplitude of future climate. This leads to a critical emerging question in the scientific community: how will the effects of global warming be manifested in the Arctic? To make meaningful climate projections at the regional scale and to evaluate model simulations of future climate, we need a longer time perspective than the short instrumental period provides. Annual precipitation in the Arctic is projected to increase by 20% by the end of the twenty-first century (ACIA, 2004), among the highest globally, and this is a consistent feature among state-of-the-art global climate models (Kattsov et al., 2007). The anticipated climate changes, and especially those related to hydrology, will have a large impact on sources and sinks of greenhouse gases related to the Arctic tundra (Jørgensen et al., 2015), on local societies in the Arctic, and will likely impact lower latitudes through

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climatic teleconnections (Førland et al., 2009). However, to better anticipate future changes in the Arctic, a significant improvement in our documentation and understanding of the longer-term natural climate variability in this region is required. Due to low biological production and logistical constraints, the region north of 70°N is heavily under-sampled with respect to Holocene paleoclimate reconstructions (Sundqvist et al., 2014).

The High Arctic Svalbard archipelago (74-81°N, 10-35°E) is situated in a climatically sensitive site in the northern North Atlantic and is well-positioned to record past changes in atmospheric and oceanic circulation patterns of the North Atlantic Arctic. Lake sediments are excellent archives for recording regional climate change, because lakes trap detrital and organic material from the catchment, as well as organic material produced within the lake. The type of material entering the lake depends on the catchment area surrounding the lake basin (Rubensdotter and Rosqvist, 2009), and this in turn depends on a number of geological, geomorphological and climatic factors. Sedimentary fingerprinting of the various sources contributing to lake sedimentation and their past variations allows for detailed palaeoenvironmental reconstructions.

Here we present new palaeoclimatic data from one of the northernmost lakes in Europe, on Amsterdamøya island, NW Svalbard. We demonstrate that the potential for producing robust chronologies exists even in these remote polar regions, and that by careful selection of sites high-resolution palaeoclimatic reconstruction can be achieved. Here we present: 1) a high precision radiocarbon dated sedimentary lake sequence; 2) reconstructed detrital sedimentation processes from the Late Glacial until the present; and 3) a multi-proxy reconstruction of Neoglacial climate fluctuations at Amsterdamøya based on the runoff and productivity signal recorded in the lake sediments.

2. Setting

The island of Amsterdamøya ('øya' = island) (N79°46′, E10°45′) is located at the northwesternmost corner of Svalbard in the North Atlantic Ocean, where the distance from Amsterdamøya to the shelf break is only 8 km, and border the Arctic Ocean and the Fram Strait. The West Spitsbergen Current (WSC) (Aagaard et al., 1987) is the northernmost limb of the Norwegian Atlantic Current (NwAC), bringing warmer Atlantic waters as an extension of the North Atlantic Current (NAC) to the NW coast of Svalbard (Fig. 1A). Due to this northward transport of warm water and its impact on air masses, the western side of the Svalbard archipelago is dominated by warmer temperatures, more precipitation and less sea ice than the east coast. On the coast of western Svalbard (Ny-Ålesund and Isfjord Radio) (Fig. 1A) average temperature (1961-1990) in summer (June, July, August) is 4 °C and range from −12 to −15 °C during the winter months (January, February, March; JFM). Winter (JFM) precipitation on Svalbard ranges from 190 to 440 mm/year (Førland et al., 2010). The alternating westerlies and the polar-front jet stream modulate the present climate on Svalbard and are influenced by the North Atlantic Oscillation (NAO) and the Arctic Oscillation (AO). During positive AO winters, cyclones reach the Barents Sea region thereby bringing more snow to Svalbard; conversely, a negative AO is associated with NE-E winds, cold temperatures, and lower winter precipitation (e.g Luks et al., 2011).

2.1. Lake, catchment, and geomorphological setting

Our study site, lake Hakluytvatnet (79°46′24″N, 10°44′21″E) (12 m a.s.l.) is a small lake with a surface area of ~0.1 km^2 (Fig. 1). The catchment area (~2.2 km^2) displays steep cliffs incised by two cirque valleys surrounding the flat valley floor. The northwest-facing valley fill framing the lake forms a terrace towards the sea (Fig. 1C), and the modern day beach fringing the terrace consists of well-rounded gravel-and-boulder type beach sediments. Maximum water depth of Hakluytvatnet ('vatnet' = lake) is ~5 m, and the lake is surrounded by 'northern arctic-tundra zone'-type vegetation (Birks et al., 2004). The lake has a pH of 5.9, conductivity values are low and filamentous algae are frequent in the lake and in the lake outflow with extensive submerged moss growth even at 5 m water depth (Birks et al., 2004). Hydrolab field measurements in September 2014 revealed that the lake water had a temperature of 4 °C, and that the water was well-mixed by wind and showed no stratification. The geometry of the lake basin is shallow, and it dips gently towards the deepest part where maximum sediment thickness is ~2.5 m (Fig. 1D). At present, there are no glaciers in the catchment; however, two perennial snow patches are present on the plateau in the southern part of the catchment serving as the main source area for the river feeding Hakluytvatnet (Fig. 1C).

The bedrock geology in the catchment around lake Hakluytvatnet consists of a metamorphosed basement comprised of migmatites, banded gneisses rich in biotite and late-tectonic granites of Caledonian age form the bedrock in the area. Small outcrops of amphibolite are present on the north side of the catchment, as well as small appearances of marble layers on the north and south side of the catchment area (Hjelle and Ohta, 1974; Ohta et al., 2007). Amsterdamøya island is characterized by gently sloping plateaus >300 m a.s.l. covered by autochthonous block fields. Steep cliffs towards the sea frame the plateaus (Hjelle and Ohta, 1974).

Surface exposure ages on glacial erratics from Amsterdamøya and the neighbouring Danskøya island (Fig. 1B) indicate that the summits in the area have remained ice-free since >80 ka BP, although the lower ground remained glaciated until 18–15,000 years ago (Landvik et al., 2003). These more recent ages are further supported by surface exposure ages from Hormes et al. (2013), indicating that the NW sector of Svalbard became deglaciated between 13,600 and 11,700 years ago after a local ice dome covering the NW Svalbard disintegrated. The marine limit (ML) at Amsterdamøya is not constrained, but is probably close to present day sea level (Boulton and Rhodes, 1974; Forman, 1990; Landvik et al., 1998; Salvigsen, 1979). There has been little postglacial emergence in the NW part of Svalbard, and neither Amsterdamøya nor Danskøya display any clear geomorphological evidence of uplift in relation to sea level since the ice cover disappeared (Boulton and Rhodes, 1974; Landvik et al., 1998; Salvigsen, 1977).

3. Methods

The environmental reconstruction in this study is based upon a combination of geomorphological mapping, field ground-truthing, lake coring, and multi-proxy laboratory analyses. A firm chronology has been established for the lake sediments from AMS radiocarbon dating.

3.1. Field mapping

The Quaternary landforms and deposits in the study area were mapped based on aerial photographs (orthophoto: Norwegian Polar Institute, series S2011_25160), and complementary field surveys during the summer seasons of 2012 and 2014. In field, we collected samples of various sediments and for positions we used a handheld GPS receiver (Garmin CSX60). The topographic maps of Amsterdamøya are not of a quality suited for detailed mapping and positioning, therefore we used the GPS for determining the location of different sites and sampling locations. The average error bars on the locations are in the order of 2–30 m.

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