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An Icelandic terrestrial record of North Atlantic cooling c. 8800–8100 cal. yr BP

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1. Introduction

Iceland‘s location in the North Atlantic makes the terrestrial environment of the island sensitive to changes in atmospheric and oceanic systems in the region. The terrestrial ecosystem is particularly responsive to changes in ocean currents since the island is located at the junction of the relatively warm Irminger Current and the colder East Greenland Current (e.g. Stefánsson, 1962; Hansen and Østerhus, 2000). Palaeoenvironmental reconstructions from Icelandic lake sediments have revealed centennial and millennial scale environmental responses to climate change during the Holocene (Hallsdóttir, 1995; Rundgren, 1998; Hallsdóttir and Caseldine, 2005; Geirsdóttir et al., 2009, 2013; Larsen et al., 2011, 2012; Striberger et al., 2012; Blair et al., 2015; Eddudóttir et al., 2015, 2016; Schomacker et al., 2016). A prominent anomaly in some Icelandic palaeoenvironmental reconstructions is a cold period between c. 8700–7900 cal. yr BP, interrupting a trend of warming climate during the early Holocene (Geirsdóttir et al., 2009, 2013; Larsen et al., 2012; Eddudóttir et al., 2015). The cooling during this period is evident from proxies sensitive to changes in spring and summer temperatures and is reflected in changes in both terrestrial vegetation (Eddudóttir et al., 2015) and lake productivity (Larsen et al., 2012). The cooling observed in Iceland falls within the period c. 9000–8000 cal. yr BP, which is characterised by cold conditions in the Northern Hemisphere (Mayewski et al., 2004), and coincides with a cold anomaly beginning c. 8600 cal. yr BP recorded around the North Atlantic (cf. Rohling and Pälike, 2005). This longer cold period is distinct from the cold anomalies related to the 8.2 ka cold event (e.g. Alley et al., 1997; Baldini et al., 2002; Alley and Ágústsdóttir, 2005; Rohling and Pälike, 2005; Bamberg et al., 2010), which has been linked to the flux of meltwater at the final drainage of the glacial lakes Agassiz and Ojibway into the North Atlantic c. 8430 ± 300 cal. yr BP (Barber et al., 1999).

The timing and nature of terrestrial ecosystem changes in Iceland can highlight the nature of centennial scale climate fluctuations in the North Atlantic and provide information to complement marine records. The aim of this study was to create a detailed record of environmental changes in northwestern Iceland in response to early Holocene climate change. Here we present a palynological reconstruction of the period c. 10,100–7000 cal. yr BP. To establish whether changes in environmental stability occurred during this period the multi-decadal resolution palynological dataset is supplemented by plant macrofossils and measurements of organic and physical properties of the sediment, including organic matter (OM), total carbon (TC), total nitrogen (TN), carbon-to-nitrogen ratio (C/N), stable isotope ratios of carbon ($\delta^{13}C$) and nitrogen ($\delta^{15}N$), magnetic susceptibility (MS) and dry bulk density (DBD).

2. Regional setting

The site chosen for this study is Kagaðarhóll palaeolake (KAGA; 65°35′ 16″ N, 20°07′ 58″ W, 114 m a.s.l.) located in northwest Iceland, about 10 km south of the town of Blönduós (Fig. 1). The palaeolake is today a fen and is about 0.45 km^2 in area, with a drainage basin of about 0.6 km^2. The vegetation is dominated by sedges (Cyperaceae spp.), especially *Eriophorum angustifolium* (common cotton grass), the dwarf shrubs *Betula nana* (dwarf birch), *Salix phylicifolia* (tea-leaved willow) and *Salix lanata* (woolly

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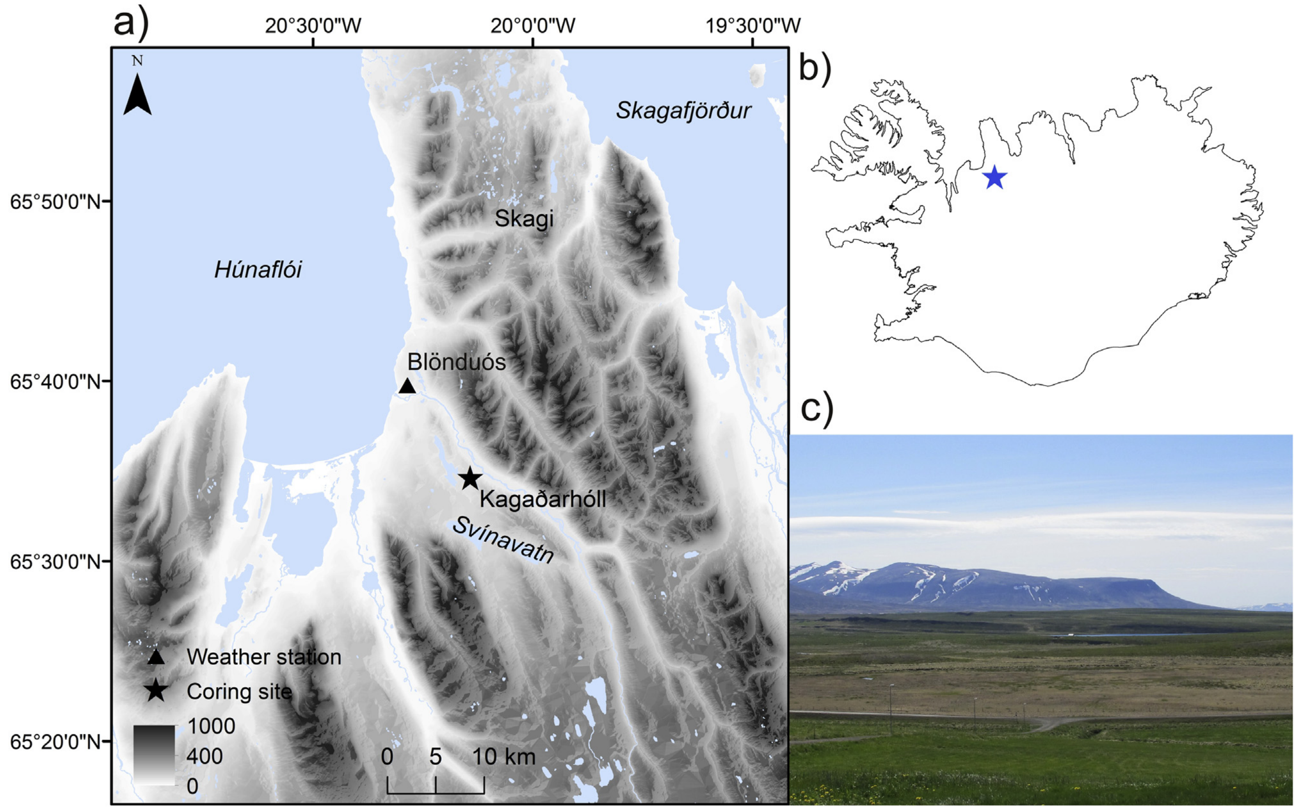

Fig. 1. The Kagaðarhóll study site. a) Map showing the location of the coring site in northwest Iceland, b) map of Iceland showing the location of Kagaðarhóll and, c) overview of the palaeolake.

willow), and the herb *Cardamine nymanii* (lady's smock). The overgrown lake is surrounded by *Betula nana*-dominated dwarf-shrub heath, hayfields and eroded, gravelly hills. The closest weather station is Blönduós (Table 1), which is located by the coast and may therefore represent a more maritime climate than Kagaðarhóll. For more detailed site information see (Eddudóttir et al., 2015, 2017).

3. Material and methods

Sediment cores were retrieved from the centre of the palaeolake using a Livingstone piston corer and a Bolivia adaptor fitted with 75 mm diameter polycarbonate tubes. A series of overlapping cores was used to construct a continuous Holocene sequence with 0 cm at the top of the core (see Eddudóttir et al., 2015). The period c. 10,100–7000 cal. yr BP is covered by three overlapping core segments connected by changes in magnetic susceptibility (MS) and tephra geochemistry (Fig. S1). A description of sediment characteristics according to the Troels-Smith system (Aaby and Berglund, 1986) is presented in Table S1.

The pollen dataset consists of 46 samples, covering the period c. 10,100–7000 cal. yr BP, comprising 31 samples previously analysed as part of a dataset published in Eddudóttir et al. (2015) and 15 new samples. Subsamples for pollen analysis (2 cm^3) were collected at 2–8 cm intervals. Pollen samples were prepared using 10% HCl, 10% NaOH, acetolysis (Faegri et al., 1989; Moore et al., 1991) and dense-media separation (Björck et al., 1978; Nakagawa et al., 1998) using LST Fastfloat (a sodium heteropolytungstate solution, density 1.9 $g\,cm^{-3}$). A tablet containing spores of *Lycopodium clavatum* (Stockmarr, 1971; batch no. 177745) was added to each sample to calculate pollen accumulation rates (PARs; grains cm^{-2} $year^{-1}$). Samples were mounted on glass microscope slides in silicone oil of 12,500 cSt viscosity. A minimum of 300 indigenous terrestrial pollen grains were counted for each sample. Identification of pollen grains and spores was based on Moore et al. (1991) and a pollen type slide collection at the University of Iceland. Pollen sums and categories followed Hallsdóttir (1987) and Caseldine et al. (2006). Pollen and spore taxonomy followed Bennett (2016) and amendments specific to the Icelandic flora by Erlendsson (2007). The sediments were analysed for plant macrofossils at contiguous 5 cm intervals and sample volume varied between 35 and 50 mL (for further detail see Eddudóttir et al. (2015)). Pollen and macrofossil diagrams were constructed using TILIA version 1.7.16 (Grimm, 2011).

Table 1
Observations from the weather station Blönduós. Unpublished data from the Icelandic Met Office.

Elevation	8 m a.s.l.
Period	1961–1990
Mean July temperature	9.4 °C
Mean January temperature	−2.5 °C
Mean tritherm temperature (mean June, July, August temperature)	8.7 °C
Mean annual precipitation	458 mm