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Climate changes, lead pollution and soil erosion in south Greenland over the past 700 years

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ABSTRACT

A peat core from southern Greenland provided a rare opportunity to investigate human-environment interactions, climate change and atmospheric pollution over the last ~700 years. X-ray fluorescence, gas chromatography-combustion, isotope ratio mass spectrometry, peat humification and fourier-transform infrared spectroscopy were applied and combined with palynological and archaeological evidence. Variations in peat mineral content seem to be related to soil erosion linked with human activity during the late Norse period (13^{th}–14^{th} centuries AD) and the modern era (20^{th} century). Cooler conditions during the Little Ice Age (LIA) are reflected by both slow rates of peat growth and carbon accumulation, and by low bromine (Br) concentrations. Spörer and Maunder minima in solar activity may be indicated by further declines in Br and enrichment in easily degradable compounds such as polysaccharides. Peat organic matter composition was also influenced by vegetation changes at the end of the LIA when the expansion of oceanic heath was associated with polysaccharide enrichment. Atmospheric lead pollution was recorded in the peat after ~AD 1845, and peak values occurred in the 1970s. There is indirect support for a predominantly North American lead source, but further Pb isotopic analysis would be needed to confirm this hypothesis.

Introduction

Ombrotrophic peatlands, receiving their inputs (precipitation and dusts) solely from the atmosphere, are widely recognised as important environmental archives. The stratified records of chemical elements and biological proxies contained within raised mires and blanket bogs can be used, for example, to provide information about changes in climate or land use, and levels of atmospheric pollution, during prehistory through to post-industrial times (e.g., Chambers et al., 2012; Meharg et al., 2012; Martínez Cortizas et al., 2013; Pontevedra-Pombal et al., 2013). Peat geochemical studies are available for locations across the major continental land masses and peripheries of North America and Western Europe, yet relatively few Holocene records exist from mid to high latitude North Atlantic islands. Evidence from Greenland, Iceland and the Faroes would enhance spatial data coverage for sites influenced by related atmospheric systems. The North Atlantic islands have relatively short and frequently interrupted histories of human occupation, with continuous recent (European) settlement dating back only to Norse colonisation (*landnám*) during the period ~AD 800–1000 (Fitzhugh and Ward, 2000). Where environmental archives of sufficient continuity and antiquity present themselves, these potentially offer opportunities to establish a geochemical baseline for 'pristine' North Atlantic environments during periods when people were absent from the landscape (cf. Dugmore et al., 2005).

Few peat geochemical investigations have been conducted in Greenland (Fig. 1A). Apart from cost and logistics, this is because peatlands are not extensive and raised bogs are absent (Feilberg, 1984). Some data are available from minerotrophic, groundwater-fed fens which demonstrate that such wetlands may preserve a record of atmospheric deposition, even though the identification of regional atmospheric signals can be complicated by mineral inputs from local sources (e.g. slopewash). Shotyk et al. (2003) used a fen developed between two small lakes near Tasiusaq (Fig. 1B), southern Greenland, to reconstruct fluxes of selected elements, notably mercury (Hg), lead (Pb) and arsenic (As), and related these to atmospheric deposition of anthropogenic origin after ~AD 1950. Their profile extended back ~2500 cal yr BP, but at reduced temporal resolution through the older part of the sequence. Schofield et al. (2010) presented a geochemical record from the nearby site of Qinngua (Fig. 1B), concentrating on the behaviour of lithogenic elements and halogens, and linking this to patterns

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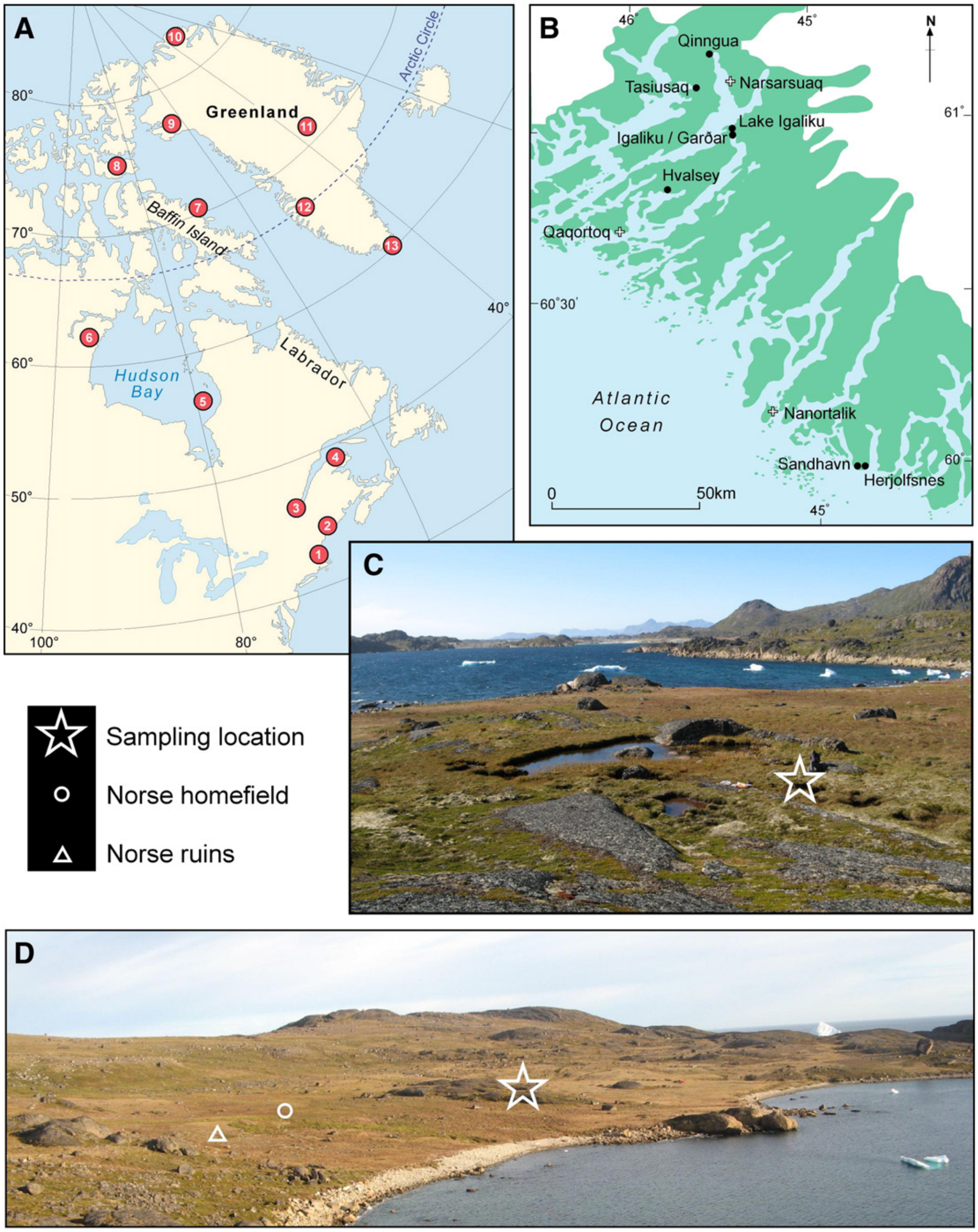

Figure 1. (A) Map of Greenland and northeast North America showing the locations of sites and places mentioned in the text. Key to numbering: (1) Plow Shop and Grove Ponds; (2) Big Heath and Sargent Mountain Pond; (3) Lake Tantaré; (4) Point d'Escuminac; (5) Imitavik Lake; (6) Far Lake; (7) Lake CF8; (8) Devon Island; (9) Camp Century; (10) Lake G07-01; (11) Summit; (12) Kangerlussuaq; (13) Sandhavn and Cape Farewell. (B) The area around Sandhavn, southern Greenland, showing sites and places mentioned in the text. (C) The sampling location at Sandhavn. The white star marks the position from which the peat monolith was taken. (D) The landscape around the sampling location at Sandhavn showing the position of the Norse ruins and former homefields (photographs by J.E.Schofield, August 2008).

of soil erosion and storminess over the last *ca* 1000 yr, albeit noting a significant hiatus in the profile (~AD 1380–1950).

An investigation by Golding et al. (2011) at the Norse farmstead of Sandhavn (Fig. 1B), near the southern tip of Greenland, revealed a small peat-filled depression set within a rock platform (Figs 1C and 1D). The basin appears isolated from the groundwater table and radiometric dating indicates that peat growth has apparently been continuous since the mid-13th century AD. This provided a rare opportunity to characterise the geochemical signal contained within a predominantly rain-fed peat from a Greenlandic setting. The main objectives of the research reported here are: (i) to search for geochemical signatures that are representative of changes in climate and of possible impacts arising from past human activity at the site (e.g. soil erosion); (ii) to study the relationship between climate, vegetation and peat decomposition in a subarctic environment; (iii) to establish high resolution records for atmospheric metal pollution and to discuss likely sources for these. Although the peat profile from Sandhavn spans a relatively short timeframe (~AD 1250–2000) and cannot provide baseline environmental information for the period before the arrival of Norse settlers, the research is important because: (a) it provides data encompassing a significant climatic perturbation – the Little Ice Age (LIA; Grove, 1988); (b) the basin is adjacent to the homefields (i.e. the hay-producing areas) of a Norse farmstead (Fig. 1D) that was in use from ~AD 1000–1400, and the sampling location was anticipated to be particularly sensitive to the