Quaternary Science Reviews 87 (2014) 1–11

Contents lists available at ScienceDirect

Quaternary Science Reviews

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

A deglacial and Holocene record of climate variability in south-central Alaska from stable oxygen isotopes and plant macrofossils in peat

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ARTICLE INFO

Article history:
Received 21 August 2013
Received in revised form
20 December 2013
Accepted 21 December 2013
Available online 21 January 2014

Keywords:
Holocene
Oxygen isotopes
Peat
Aleutian Low
Carbon

ABSTRACT

We used stable oxygen isotopes derived from bulk peat ($\delta^{18}O_{TOM}$), in conjunction with plant macrofossils and previously published carbon accumulation records, in a ~14,500 cal yr BP peat core (HT Fen) from the Kenai lowlands in south-central Alaska to reconstruct the climate history of the area. We find that patterns are broadly consistent with those from lacustrine records across the region, and agree with the interpretation that major shifts in $\delta^{18}O_{TOM}$ values indicate changes in strength and position of the Aleutian Low (AL), a semi-permanent low-pressure cell that delivers winter moisture to the region. We find decreased strength or a more westerly position of the AL (relatively higher $\delta^{18}O_{TOM}$ values) during the Bølling-Allerød, Holocene Thermal Maximum (HTM), and late Holocene, which also correspond to warmer climate regimes. These intervals coincide with greater peat preservation and enhanced carbon (C) accumulation rates at the HT Fen and with peatland expansion across Alaska. The HTM in particular may have experienced greater summer precipitation as a result of an enhanced Pacific subtropical high, a pattern consistent with modern $\delta^{18}O$ values for summer precipitation. The combined warm summer temperatures and greater summer precipitation helped promote the observed rapid peat accumulation. A strengthened AL (relatively lower $\delta^{18}O_{TOM}$ values) is most evident during the Younger Dryas, Neoglaciation, and the Little Ice Age, consistent with lower peat preservation and C accumulation at the HT Fen, suggesting less precipitation reaches the leeward side of the Kenai Mountains during periods of enhanced AL strength. The peatlands on the Kenai Peninsula thrive when the AL is weak and the contribution of summer precipitation is higher, highlighting the importance of precipitation seasonality in promoting peat accumulation. This study demonstrates that $\delta^{18}O_{TOM}$ values in peat can be applied toward understand large-scale shifts in atmospheric circulation over millennial timescales.

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1. Introduction

Numerous large-scale climate phenomena have been documented in Alaska during the deglacial and Holocene period. Evidence for a Younger Dryas (YD) cold reversal are well documented from Kodiak Island (Peteet and Mann, 1994) and Glacier Bay (Engstrom et al., 1990), and widespread warmth during the early Holocene has been linked to a peak in summer solar insolation (Kaufman et al., 2004). The enhanced seasonality associated with the early Holocene Thermal Maximum (HTM) is thought to have been instrumental in promoting rapid peatland expansion and accumulation, particularly on the North Slope of Alaska (Mann et al., 2002) and southern Alaska (Jones and Yu, 2010). Cooler temperatures persisted in the mid- to late-Holocene with the onset of Neoglacial cooling (Calkin et al., 2001; Barclay et al., 2009), and mounting evidence exists for a Little Ice Age (LIA) with cooler temperatures and/or wetter climate than today, as documented by the expansion of mountain glaciers across Alaska, including the Kenai Peninsula (Calkin et al., 2001; Barclay et al., 2009). Relatively few studies, however, provide nearly continuous information on the precipitation regime or moisture balance over the Lateglacial and Holocene, particularly for the early Holocene when peatlands were rapidly expanding.

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0277-3791/$ – see front matter Published by Elsevier Ltd.
http://dx.doi.org/10.1016/j.quascirev.2013.12.025

Several proxy records from Alaska and the Yukon Territory, Canada have demonstrated distinct changes in moisture over the Holocene, which are likely linked to large-scale changes in atmospheric circulation patterns (Fisher et al., 2004; Anderson et al., 2005; Yu et al., 2008; Abbott et al., 2010; Clegg and Hu, 2010; Chipman et al., 2012). However, none of these studies provides a detailed record of moisture and temperature change for the entire Holocene and deglacial interval. Despite the potential of peat cores to provide detailed, long-term records of paleoclimate and paleoenvironmental change, relatively few peat studies have employed stable oxygen isotope analyses to examine paleoenvironmental changes. Here, we use stable oxygen isotope analyses of total organic material (TOM), in addition to plant macrofossils and peat accumulation rates, from a peat core on the Kenai Peninsula, Alaska to examine deglacial and Holocene climate variability for south-central Alaska. We place our findings in the context of regional synoptic-scale climate patterns and their relation to peatland dynamics.

2. Study site

Horse Trail (HT) fen (unofficial name; 60 24.9′ N, W150 54.1′ W) is located on the Kenai Peninsula to the west of the Kenai Mountains in the lowlands between Skilak Lake and Tustemena Lake (Fig. 1), Alaska. The Kenai Mountains are composed of Mesozoic bedrock, while the lowlands are composed of alluvial fan and uplifted continental shelf of Tertiary age with a flat to rolling surface formed by glacial events (Rymer and Sims, 1982). Most of the Kenai Peninsula was glaciated during the Last Glacial Maximum (Reger and Pinney, 1997) except for small ice-free refugia scattered throughout parts of the western lowlands (Reger et al., 2007). This area was proposed as a small, unglaciated portion of the Kenai during the Naptowne glaciation (maximum extent ~23,000 cal yr BP; Reger and Pinney, 1997; Reger et al., 2007). One of these proposed refugia exists between Skilak Lake and Tustemena Lake, but the HT Fen coring location appears to have been glaciated, as the peat record begins 14,500 cal yr BP and bottoms out in glacial till. The earliest part of the record reveals that the HT Fen site began as a shallow pro-glacial lake during the Bølling–Allerød warming (Jones, 2008). *Calamogrostis*, *Carex* spp., *Equisetum fluviatile*, *Rubus chamaemorous*, and *Potentilla palustris* comprise the low-lying areas of the fen today. The dominant moss species are *Sphagnum squarrosum* and *Sphagnum angustifolium* with *Aulacomnium palustre* comprising a minor component of moss cover. A narrow streambed cuts through the fen to the west of the coring site, and *Alnus* spp. border the stream. Higher areas of the fen contain *Picea mariana*, *Ledum palustre*, and *Vaccinium uliginosum*. The water table at the HT Fen site is near the surface of the peat.

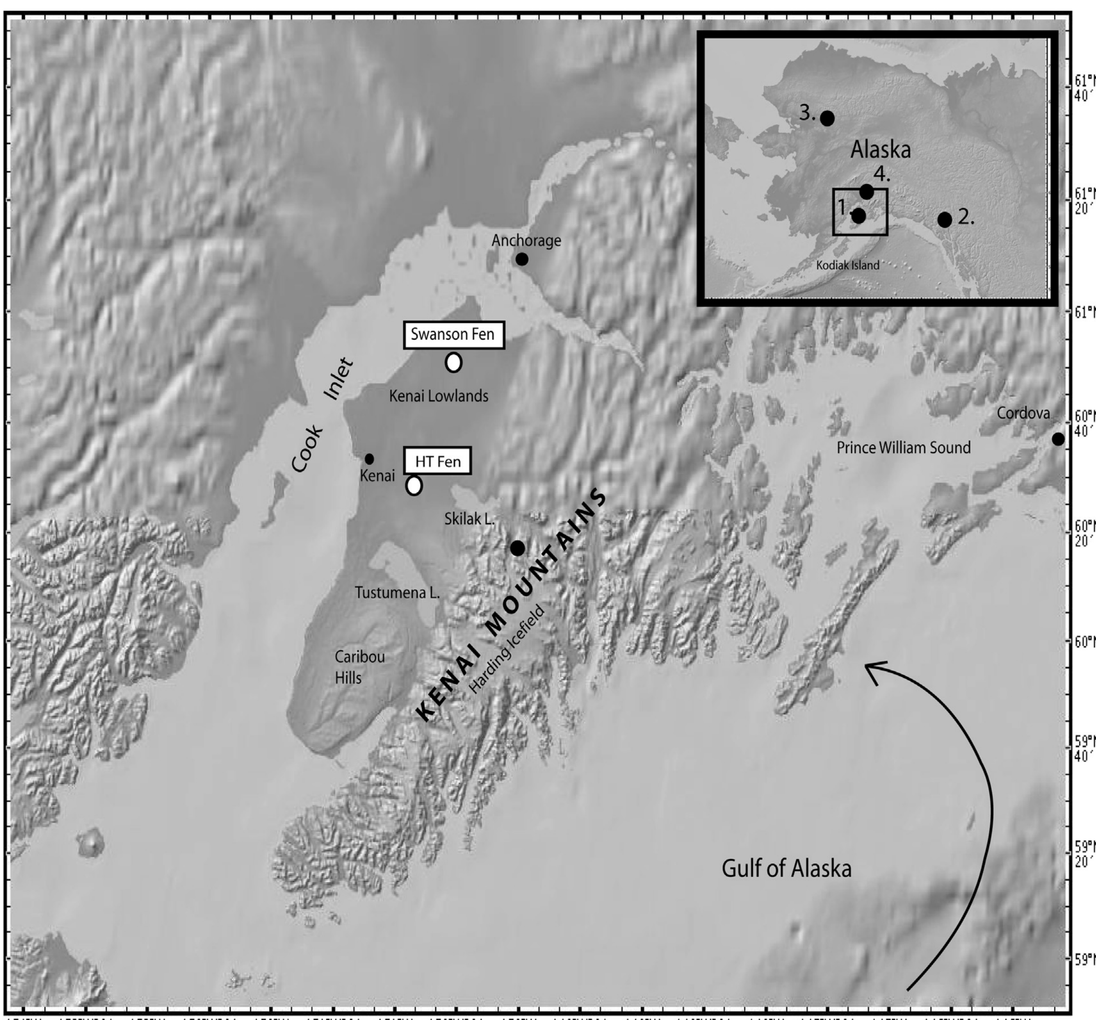

Fig. 1. Map of study region, showing 1. HT Fen, Swanson Fen (Jones et al., 2009) and the location of 2. Jellybean Lake (Anderson et al., 2005), 3. Takahula (Clegg and Hu, 2010), and 4. Hundred Mile Lake (Yu et al., 2008), where other oxygen isotope studies were published. The arrow shows the direction of Aleutian Low circulation.