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Regional atmospheric circulation change in the North Pacific during the Holocene inferred from lacustrine carbonate oxygen isotopes, Yukon Territory, Canada

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Abstract

Analyses of sediment cores from Jellybean Lake, a small, evaporation-insensitive groundwater-fed lake, provide a record of changes in North Pacific atmospheric circulation for the last ~7500 yr at 5- to 30-yr resolution. Isotope hydrology data from the southern Yukon indicate that the oxygen isotope composition of water from Jellybean Lake reflects the composition of mean-annual precipitation, $\delta^{18}O_p$. Recent changes in the $\delta^{18}O$ of Jellybean sedimentary calcite ($\delta^{18}O_{ca}$) correspond to changes in the North Pacific Index (NPI), a measure of the intensity and position of the Aleutian Low (AL) pressure system. This suggests that $\delta^{18}O_p$ variability was related to the degree of fractionation during moisture transport from the Gulf of Alaska across the St. Elias Mountains and that Holocene shifts were controlled by the intensity and position of the AL. Following this model, between ~7500 and 4500 cal yr B.P., long-term trends suggest a predominantly weaker and/or westward AL. Between ~4500 and 3000 cal yr B.P. the AL shifted eastward or intensified before shifting westward or weakening between ~3000 and 2000 cal yr B.P. Rapid shifts eastward and/or intensification occurred ~1200 and 300 cal yr B.P. Holocene changes in North Pacific atmospheric circulation inferred from Jellybean Lake oxygen isotopes correspond with late Holocene glacial advances in the St. Elias Mountains, changes in North Pacific salmon abundance, and shifts in atmospheric circulation over the Beaufort Sea.

Keywords: Jellybean Lake; Holocene; Isotope

Introduction

The intensity and position of the Aleutian Low (AL), the semi-permanent low pressure located over the Gulf of Alaska, has emerged as an important control on Northwest Pacific Holocene climate (e.g., Edwards et al., 2001; Heusser et al., 1985; Latif and Barnett, 1994; Mann et al., 1998). Decadal scale variability of the AL have been recognized from analyses of instrumental data and is described by climate indices such as the North Pacific index (NPI) (Trenbirth and Hurrell, 1994) and the Pacific Decadal Oscillation (PDO) (Mantua et al., 1997). These indices are correlated with tree-ring and salmon abundance data (e.g., Biondi et al., 2001; Mantua et al., 1997) and snow accumulation, a proxy for moisture delivery (Bitz and Battisti, 1999; Moore et al., 2002a,b; Rupper et al., 2004). The AL is the main synoptic climate feature related to moisture delivery to the St. Elias Mountains of Alaska and the interior of the southern Yukon (Mock et al., 1998; Wahl et al., 1987). The St. Elias Mountains have a dramatic effect on the oxygen-isotope values of precipitation on both the coastal and interior sides of the mountains. Relatively ^{18}O-

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enriched precipitation falls on the coastal side compared to strongly ^{18}O-depleted precipitation just 200 km inland. This large fractionation between coastal and interior precipitation suggests that changes in air mass trajectories and moisture transport history from the Gulf of Alaska either over or around the St. Elias Mountains are a principle influence on precipitation-δ^{18}O at Jellybean Lake, located ~250 km inland in the southwest interior Yukon (Fig. 1).

Few studies have documented long-term high-resolution climatic variability beyond the last millennia from high latitudes in northwestern North America (e.g., Anderson et al., 2001; Heusser et al., 1985; Hu et al., 2001; Pienitz et al., 2000). Although recent climatic and environmental changes around the Gulf of Alaska have been documented by tree-ring and ice core studies (D'Arrigo et al., 1999; Davi et al., 2003; Holdsworth et al., 1992; Mann et al., 1998; Wake et al., 2002; Wiles et al., 1998, 1999), these records generally extend from <100 to a maximum of ~1000 cal yr B.P. Comparatively little is known about high-resolution climatic variability during the Holocene in the nearby interior regions of the Yukon Territory (Pienitz et al., 2000). Holocene climate changes at century to millennial time scales in the interior Yukon Territory were inferred by geomorphological evidence of late Holocene glacial advances (Calkin et al., 2001; Denton and Karlen, 1977), pollen records (Cwynar, 1988; Cwynar and Spear, 1995; Heusser et al., 1985; Keenan and Cwynar, 1992; Lacourse and Gajewski, 2000; Spear and Cwynar, 1997; Wang and Geurts, 1991), and multi-proxy paleolimnological investigations (Pienitz et al., 2000).

There is considerable spatial climatological variability in the southern Yukon Territory and adjacent Alaska due to complex topography and the influence of air masses originating in the Arctic, Gulf of Alaska, and Bering Sea (Streten, 1974; Wahl et al., 1987). Such regional climatic heterogeneity and absence of long-term high-resolution paleoclimatic data make it difficult to adequately describe sub-century scale regional paleoclimate and investigate forcing mechanisms that caused Holocene climatic change. Recent studies have explored the possibility of cyclic

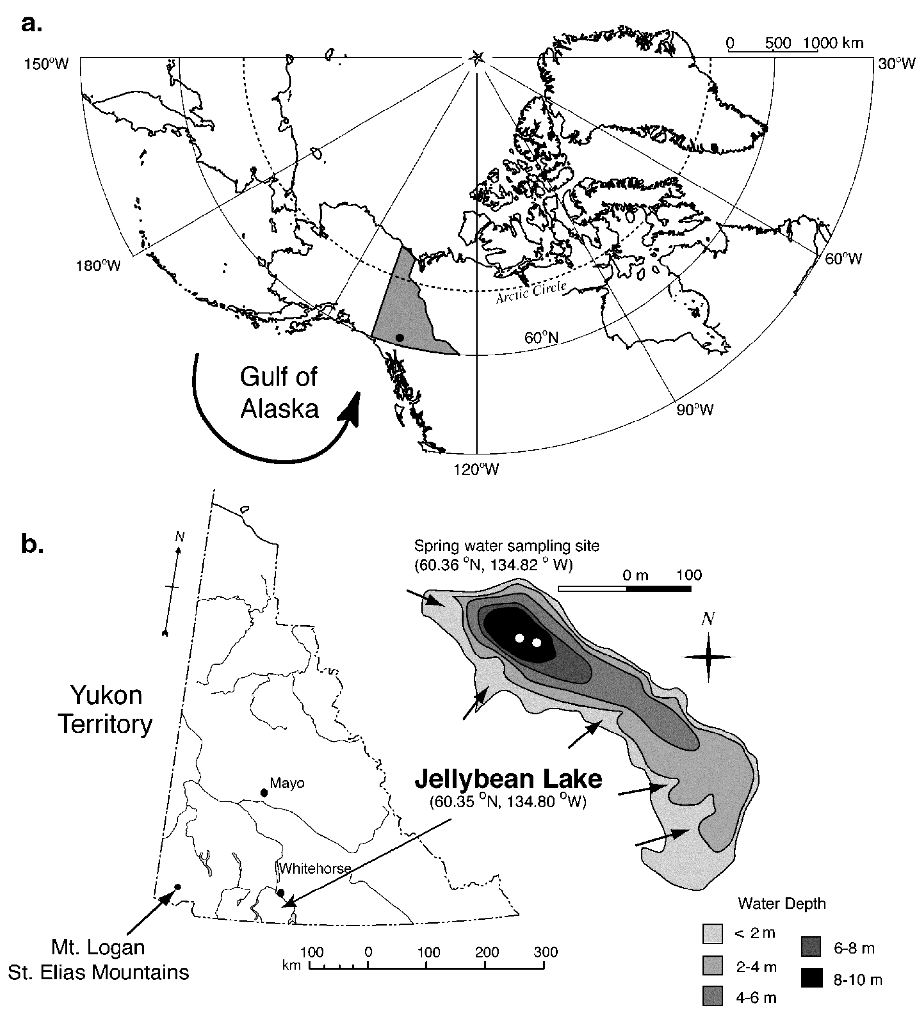

Figure 1. (a) Location map showing the Yukon Territory and sites referred to in the text. The general atmospheric circulation around the Aleutian Low in the Gulf of Alaska is indicated by the arrow, (b) bathymetry of Jellybean Lake where arrows indicate the locations of artesian springs and open circles the coring sites.